HAL
open science

Quality assessment of mitigation translocation protocols for protected plants in France

Margaux Julien, Bruno Colas, Serge Muller, Bertrand Schatz

To cite this version:

Margaux Julien, Bruno Colas, Serge Muller, Bertrand Schatz. Quality assessment of mitigation translocation protocols for protected plants in France. Journal of Environmental Management, 2022, 302 (part B), pp.114064. 10.1016/j.jenvman.2021.114064 . hal-03496987

HAL Id: hal-03496987

https://hal.science/hal-03496987

Submitted on 23 Jan 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Journal of Environmental Management 302 (2022) 114064

Quality assessment of mitigation translocation protocols for protected plants in France

Margaux Julien [a, b,*], Bruno Colas [c], Serge Muller [d, 1], Bertrand Schatz [a, 1]

[a] CEFE, CNRS, Univ Montpellier, EPHE, IRD, Montpellier, France
[b] Ecotonia, 60 Rue Tourmaline, 13510, Eguilles, France
[c] Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Systématique et Evolution, 91405, Orsay, France
[d] Muséum National D'Histoire Naturelle, UMR 7205, MNHN-CNRS-UPMC-EPHE-UA, CP 39, 16 Rue Buffon, 75005, Paris, France

* Corresponding author. CEFE, CNRS, Univ Montpellier, EPHE, IRD, Montpellier, France.
E-mail address: margauX.julien@cefe.cnrs.fr (M. Julien).
1 Members of the CNPN.
https://doi.org/10.1016/j.jenvman.2021.114064
Received 22 June 2021; Received in revised form 22 October 2021; Accepted 2 November 2021
Available online 17 November 2021

ARTICLE INFO

Keywords:
Plant translocation
Mitigation translocation
Protocol quality
Mitigation hierarchy
Conservation
Environmental impact assessment

ABSTRACT

Mitigation translocations are increasingly used worldwide in response to land planning pressures. The quality of translocation protocols and their adjustment to the ecological traits of the translocated populations are crucial to optimise translocation success. We studied the quality of translocation protocols presented in derogation re- quests, a mandatory step in France to translocate a protected plant species. We analysed 103 translocation proposals for 93 different species in 92 files examined between 2018 and 2020. After tracing the history of the place of translocations in legal procedures in France, we assessed each translocation proposal according to an evaluation grid, which involved the quantity and quality of information on plant species and translocation sites in the files and the quality of translocation protocols. We have shown that the translocation protocols are of low quality, with a lot of missing information. The biology and ecology of the species suggested for translocation are not sufficiently known, nor are the ecological characteristics of the host sites. Derogation requests that received a favourable opinion from the assessment body are more likely to propose a protected host site and post- translocation monitoring. We believe that, to optimise their outcome, mitigation translocations need to be improved upstream, with more detailed protocols and better species knowledge. We highly recommend following the same guidelines for mitigation translocations as for conservation translocations.

1. Introduction

Plant translocation is the deliberate movement of plant material of a wild plant species from a natural population or *ex-situ* collection to a new natural or semi-natural site (Commander et al., 2018). Translocations can be a relevant tool for rare or endangered species when the design and implementation of this operation are optimal for its success (Maschinski and Albrecht, 2017). Translocations may be used in two broad categories of situations. First, mitigation translocations consist of relocating plant populations before destroying their habitat, including construction or other anthropogenic environmental transformations. They are often implemented in response to legislation to reduce the impacts of development projects on these plants (Germano et al., 2015; Bradley et al., 2020). Second, conservation translocations aim to achieve a tangible conservation benefit at the population, species, or ecosystem level (IUCN/SSC, 2010). They may consist of reinforcing an extant population, reintroducing a population in a site where the species pre- viously went extinct or introducing a species in a new site to maintain or increase the number of populations. They also may consist of community seeding with a habitat restoration goal.

Several authors have recently attempted to evaluate the outcome of plant translocations in terms of populations dynamics (Dalrymple et al., 2012; Fenu et al., 2019, 2020; Godefroid et al., 2011; Liu et al., 2015; Silcock et al., 2019). All mentioned both the difficulty of finding feed- back and the rare reports of failure. However, feedback on failures can provide valuable collaborative information on mistakes that could be avoided (Godefroid et al., 2011; Abeli and Dixon, 2016; Dalrymple et al., 2020). Silcock et al. (2019) reported that less than 11% of conservation and mitigation plant translocations in Australia were readily available in the peer-reviewed literature. We do not have data to calculate this percentage for European translocations, but a similar percentage seems entirely plausible from our discussions with many translocation stakeholders.

When dealing with protected or endangered species, the imple- mentation of a translocation project requires the selection of a host site and the preparation of an operational translocation protocol that is adapted to the biology and ecology of the plant species considered (Maschinski and Albrecht, 2017; Commander et al., 2018; Fenu et al., 2019; Silcock et al., 2019).

Some case studies have highlighted elements of translocation pro- tocols to improve chances of success for given species in given envi- ronmental settings. Examples include the use of barriers to reduce herbivory and human disturbance in *Dianthus morisianus* (Fenu et al., 2016), the selection of microsites with good microenvironmental con- ditions in the lichen *Flavocetraria nivalis* (Brooker et al., 2018), watering during dry periods in six translocated plant species in southwestern Australia (Dillon et al., 2018), or taking into account the genetic struc- ture of the populations (Maschinski and Albrecht, 2017; Commander et al., 2018; Van Rossum and Hardy, 2020). Long-term monitoring after translocation is also essential to determine the translocation success (IUCN/SSC, 2010; Maschinski and Albrecht, 2017; Commander et al., 2018) and provides feedback, sometimes unexpected, that contributes significantly to improving future translocation protocols (Albrecht et al., 2011; Jusaitis, 2012; Silcock et al., 2019). But all these studies focused mainly on conservation translocations; feedback on mitigation trans- locations is scarcer as already pointed out by Germano et al. (2015) and Bradley et al. (2020).

The IUCN/SSC (2010) states that mitigation translocations need a "rigorous analysis and great caution should be applied when assessing potential future conservation benefits and using them to mitigate or offset current development impacts". These

recommendations are poorly followed, and mitigation translocations are generally conducted with little scientific rigour, short-term or no monitoring, and often lead to failure (Germano et al., 2015; Bradley et al., 2020). Furthermore, this type of translocation is controversial: a translocation proposal can make a development project involving habitat destruction more acceptable to decision-makers, even if the outcome of the translocation is highly un- certain (Fahselt, 2007).

Mitigation translocations allow to mitigate the impacts on biodi- versity of construction or development works as part of a mitigation hierarchy. The mitigation hierarchy is an environmental policy used in many countries and is generally composed of four steps: Avoid, Mini- mise, Restore, Offset (BBOP, 2012). These steps should be applied in order: impacts on biodiversity should first be avoided as much as possible, then minimised, and, if there are residual impacts, they should be compensated through restoration and offsets (Gardner et al., 2013; Bull et al., 2016). These steps are implemented in Environmental Impact Assessments (EIA, see Morgan, 2012). The objective is to achieve no net loss of biodiversity, and this concept has emerged in legislation in many countries worldwide, alongside the notion of a mitigation hierarchy (Bull et al., 2016). In the United States, the mitigation hierarchy was first mentioned in 1970 by the US National Environmental Policy Act, while in France and Germany, a few years later in 1976 (Morgan, 2012; Regnery, 2017).

This study aims to assess the quality of plant translocation protocols in derogation requests in France to provide recommendations for improving their preparation and implementation. Although some miti- gation translocations have been used since 1976, no evaluation of their use in derogation requests is available to date.

We addressed the following questions:

1) What was the proportion of French derogation requests between 2018 and 2020 that included one or more suggested plant translocations?
2) Where and which plants were most often suggested for translocation? Did avoidance and minimisation measures significantly reduce the number of plants affected by development projects and if so, did this mitigate the need for translocation?
3) Were the ecological traits of translocated plants sufficiently detailed in the project and considered in the translocation protocol?
4) What was the overall quality of the translocation protocols assuming optimal consideration of all known ecological traits of translocated species?
5) What elements of the translocation protocol characterised a file that received a favourable opinion from the CNPN?

2. Materials and methods

2.1. Legal proceedings in France

In France, the mitigation hierarchy has only three steps, as the “Restore” step is included in the “Offset” step (Alligand et al., 2018). In case of residual impacts after avoidance and reduction steps, French legislation requires a derogation request. This file must include the main points of the EIA and present sufficient technical and scientific argu- ments to demonstrate that the project has 1) a major public interest, 2) the least environmental impact of several feasible alternatives, and 3) no global impact on the conservation status of each impacted protected species. Respect for each of these three conditions for granting a dero- gation, judged by the CNPN, is necessary to authorise the destruction of individuals of protected species. Therefore, mitigation translocations are frequently suggested in these derogation requests under the theoretical argument that they would limit or cancel out the impact of the destruction of individuals or their habitat on the conservation of the species concerned.

Translocations can be suggested as a reduction measure, within the hierarchy of mitigation measures ("Minimise" step), or as accompanying measures. Translocations may be suggested as a reduction measure when the source and host sites are in the same project area or when there is good feedback from previous similar operations with the same species that translocation is likely to be successful (Alligand et al., 2018). Otherwise, translocations are presented as accompanying measures. These measures are outside the mitigation hierarchy because their outcome is too uncertain but they complement and reinforce it.

We focused on plant translocations in the context of the derogation requests submitted to the French Ministry of the Environment, which the National Council for the Protection of Nature assesses (in French: "Conseil National de la Protection de la Nature", hereafter CNPN). This committee is responsible for ensuring compliance with the biodiversity law and technically and scientifically assessing the mitigation hierarchy measures enhanced for the land-use project (Regnery, 2017).

The opinions issued by the CNPN on the derogation request can be favourable (with or without unavoidable conditions), or unfavourable. Finally, the Prefect of the department (a French administrative unit) can grant or refuse the derogation and the development project, considering the different opinions on environmental and non-environmental grounds (Art. R. 411-8-1 of the French Environmental Code). These steps are summarised in Fig. 1.

2.2. Derogation requests as the subject of this study

We studied all derogation requests (n 92) examined by the CNPN between 2018 and 2020, from metropolitan France, including at least one protected plant species. These derogation requests corresponded to 103 proposals for the translocation of plant populations of 93 different species. These three years have benefited from legislative and administrative homogeneity. They came after the 2016 Biodiversity Law (Law n° 2016–1087), which gave new recommendations for the application of mitigation measures, and after a decree reforming the CNPN (Decree n° 2017–342). They came before the full application of a new decree (Decree n° 2019–1352), which tended to reduce the role of the CNPN in favour of regional scientific authorities.

2.3. Evaluation grid

We compiled the data from the derogation requests into an assess- ment grid, which we used for each protected plant population presented in each file. A line in the grid represented an impacted plant population, whether or not it was involved in a translocation measure. This meth- odology is commonly used in EIA studies (Bigard et al., 2017; Tinker et al., 2005). We studied every plant population presented in derogation requests: for non-translocated populations, only populations of pro- tected species are present. However, some unprotected species pop- ulations were present for translocated populations (see Additional Table 2). An additional document presents the analyses without the populations of non-protected species: this has minimal impact on the results.

=

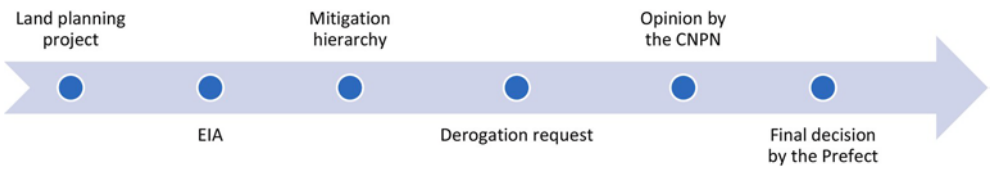

Fig. 1. Steps required to obtain authorisation to implement a land planning project towards protected species.

We collected information grouped into six categories for each plant population involved in a translocation proposal: generalities, the mitigation hierarchy, life-history traits, translocation protocol, host sites, and post-translocation monitoring (see Additional Table 1 for detailed information). We considered a translocation proposal to be a request to move one or more individuals or a viable part of individuals from one site to another or return them after the work to the location where they previously lived. Therefore, each population corresponded to individuals of the same species from the same study site. We called the plant populations used for translocation "translocated populations" and the plant populations for which no translocation was planned "non- translocated populations". We selected the different criteria presented in Additional Table 1 according to the standard recommendations of the scientific literature to perform a translocation (IUCN/SSC, 2010; Maschinski and Albrecht, 2017; Commander et al., 2018).

2.4. Historical data

We had access to a database centralising the number of derogation requests per year since 1996 and the CNPN opinion for each file (favourable/unfavourable). Between 2010 and 2015 and between 2018 and 2020, we had access to more information (full CNPN opinion). We counted the number of derogations requests each year from 1996 to 2020 and determined the proportion of files that received a favourable opinion from the CNPN. In addition, we determined the proportion of favourable opinions mentioning translocations and the number of pro- tected plant species by derogation for the years in which we have full opinion.

2.5. Data analyses

We realised all analysis using R 3.6.3 and R studio (R Core Team, 2020) and the package *tidyverse* (Wickham et al., 2019). Figures were modified with Inkscape 1.0.2.

2.5.1. Characterisation of translocated populations: which and where?

We calculated the proportion of derogation requests that included at least one translocation measure. On all population s mentioned in the derogation requests, we calculated the proportion of translocated populations and, for these populations, the proportion of species with national, regional, and departmental protection. In addition, we counted the number of times each family and species were used to translocation among all the plant species cited in the derogation requests. Similarly, we determined the number of species for each habitat according to the EUNIS classification (Davies et al., 2004). We chose to use the first level of this classification (*e.g.*, A for marine habitats), except for grasslands, for which we used level 2. Indeed, many plant populations are present in the grasslands, which allowed for enough species at level 2 of the clas- sification. We did the same for habitats according to the EU Habitats Directive because this classification is commonly used in Europe.

We counted the number of derogation

requests from each department and determined the mean number of translocated populations per file (hereafter: translocation rate). Maps were done with the R library *maps* (Becker et al., 2013). We classified each plant population accord- ing to the project type (see Additional Table 1), and we determined the proportion of translocated and non-translocated populations for each type.

2.5.1. *Mitigation hierarchy*

We collected information on the location (inside or outside the project range) for each translocated population and whether feedback on the suggested translocation protocol from previous translocations was mentioned in the derogation request. This allowed us to determine whether translocation measures were correctly classified as reduction or accompanying measures. We collected the number of individuals in each project-impacted population before the application of the mitigation hierarchy and the expected number of individuals after. We compared these numbers (before vs. after) using a generalised model using a quasi- Poisson distribution due to the overdispersion of the data. The effects tested to explain the differences were translocation status and project evaluation year.

2.5.2. *Life-history traits*

We calculated the proportion of derogation requests that included at least one translocation measure. On all populations mentioned in the derogation requests, we calculated the proportion of translocated pop- ulations and, for these populations, the proportion of species with na- tional, regional, and departmental protection. In addition, we counted

To test whether the information on biological and ecological traits was more complete for translocated populations than for non-translocated populations, we counted the presence of this information for each life-history trait for each plant population. The proportions of missing data for each criterion for the translocated and non-translocated population were compared with Chi^2 tests (or Fisher exact tests when the Chi^2 conditions were not met). Finally, we performed a Wilcoxon test on all traits studied to determine if there was a difference in traits between translocated and non-translocated populations. To determine if the flowering period was well considered, we determined the flowering period of each translocated population and the recommended trans- location periods for the same species. Then, we plotted the curves over a year for the flowering period of all species suggested for translocation, as well as the planned translocation periods for these same species.

2.5.3. *Translocation protocol*

The same procedure as for biological and ecological traits was applied to the translocated populations for some of the protocol criteria, the host site, and the post-translocation monitoring. In addition, these criteria were used as proxies to determine if the protocols were described with enough details. We identified 15 questions from guide- lines (IUCN/SSC, 2010; Maschinski and Albrecht, 2017; Commander et al., 2018) to determine the quality of translocation protocols. Each indicator was scored 1 or 0 as a positive or negative response, respec- tively. A quality index (adapted from the biodiversity index in Atkinson

et al., 2000; Bigard et al., 2020) was then calculated by dividing the number of positive responses divided by the number of questions for each translocated population.

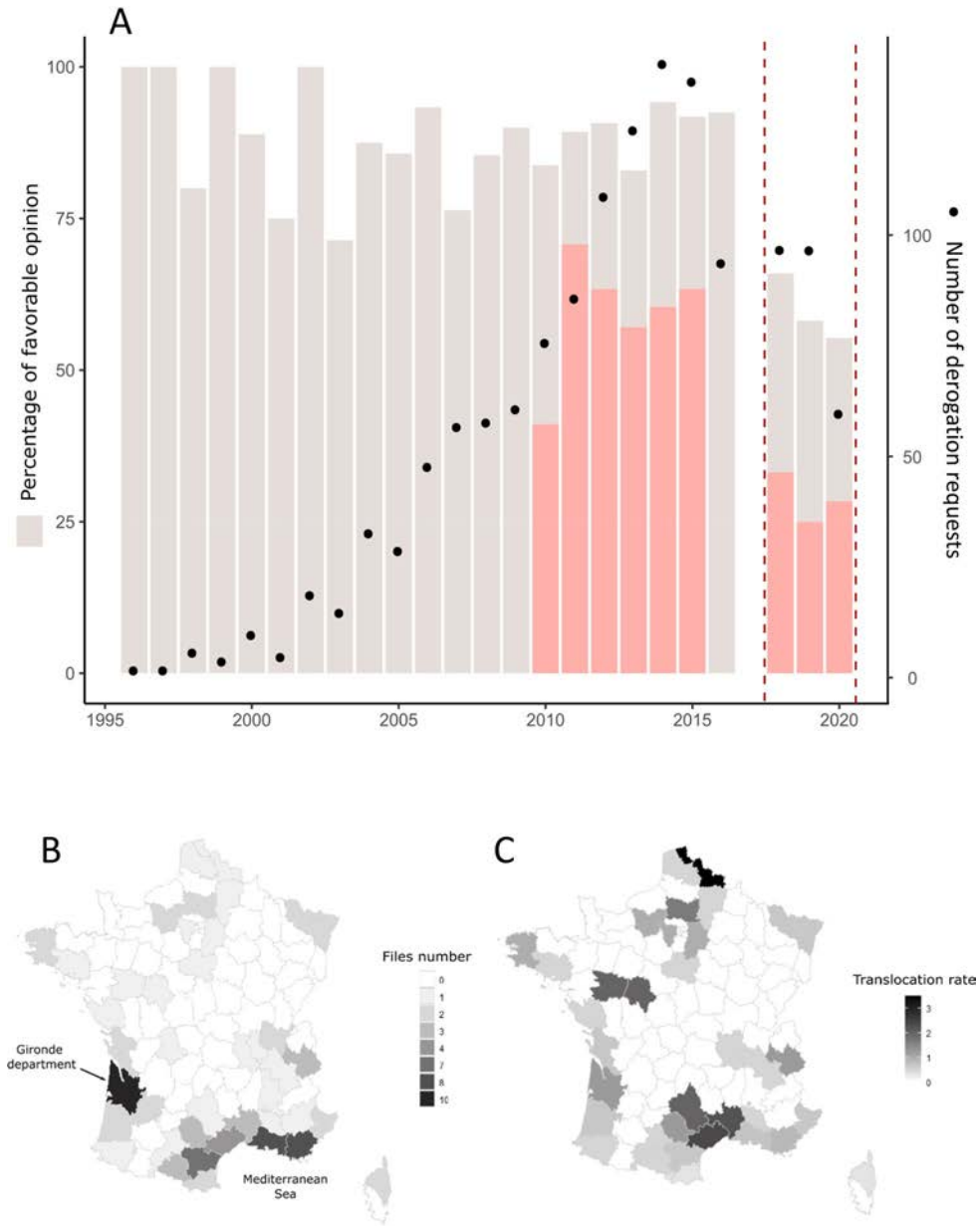

Fig. 2. A. Number of derogation requests per year (black dots) and the percentage of favourable opinions (grey bars). The red portion corresponds to the files with a favourable opinion that contains a trans- location. Dotted lines frame the period studied in this paper. No information is available for the year 2017, due to a change in the CNPN. B. Number of derogation re- quests analysed by department. C. Mean number of translocations for one file by department. (For interpretation of the refer- ences to colour in this figure legend, the reader is referred to the Web version of this article.)

The questions were:

1) Were mycorrhizae considered?
2) Were pollinators considered?
3) Was genetic diversity considered?
4) Was a specialist organisation/person consulted?
5) Was the vegetation of the host site similar to the source site?
6) Was the soil at the host site similar to the source site?
7) Was post-translocation management planned?
8) Was post-translocation monitoring planned?
9) Was the host site protected?
10) Was a control population monitored?
11) Was the host site safe for the translocated population?
12) Was the translocation period appropriate?
13) Was the translocation method appropriate?
14) Was the number of years of monitoring appropriate?
15) Was the host site suitable?

Indicators from 1 to 10 were positively rated when mentioned in the file, even if the indicator was not detailed. For indicator 11, risks were rarely documented in the files. We, therefore, determined whether there were any potential risks based on the location of the site. The risks encountered were pollution, trampling, erosion, and the presence of herbivores. For indicators 12 to 15, the conditions to be met were not very restrictive to allow easy comparison between all species. For indi- cator 12, we measured the translocation period to be suitable when it did not cover the flowering period of the species. For indicator 13, we only assumed that an annual plant should be translocated by seed harvest. For indicator 14, we reflected the number of monitoring years to be inappropriate when less than five years of monitoring were planned. For indicator 15, we concluded the host site to be unsuitable when the habitat was different from the source site (according to EUNIS classifi- cation; Davies et al., 2004) or when no indication of the host site was given. Finally, we resolved that the criteria were not met when no in- formation was available.

2.5.4. *The opinion of the CNPN on the file*

The CNPN gave a favourable with unavoidable conditions or unfavourable opinion to each derogation request (favourable opinion without unavoidable conditions are rare and absent from our sample). We explored certain criteria according to the opinion of the committee to determine which elements of the translocation proposals were most often found in derogation requests receiving a favourable opinion. We used a binary logistic regression on the CNPN opinion to test for the effect of the same criteria as for the quality index. To these criteria, we added the number of translocated individuals. The criteria that did not affect the CNPN opinion were no longer presented in the final model to simplify it. Missing values were included in the model as a separate modality for potential risks of the host site, as it was impossible to tell whether the site was risk-free or not. The same applied to the choice of the translocation period. Missing values were considered NO modality for protecting the host site and the presence of the species. The POSSIBLE modality of the presence of the species was grouped with the YES modality. We presented the result of the binary regression with the odds ratio of each criterion. This allowed us to quantify the effect of the criteria. We used the *forestmodel* library and the function *forest_model* (Kennedy, 2020).

3. Results

3.1. *Historical data*

The number of derogation requests increased until 2016 (Fig. 2A), the year of the biodiversity law, which reformed EIA. After that, the number of derogation requests per year was lower. In 2020, a further loss was observed due to a new

decree occurring at the end of the year. Favourable opinions were more frequent before 2017 (~80%) than during the period studied here (~60%).

Translocations were often used: between 2010 and 2015, 71% of files with a favourable opinion contained at least one translocation request. The proportion of derogations with translocation measures increased between 2010 and 2014, from about 50% of the CNPN opinions mentioning translocation in 2010 to about 75% between 2011 and 2015.

3.2. Characterisation of translocated populations: which and where?

During 2018–2020, 69.1% of derogation requests (n = 92) contained at least one translocation measure proposal. These files had 282 plant populations, of which 36.5% were suggested for translocation (103 plant populations). On average, there were 3.0 plant species per file; 2.2 plant species per file had residual impacts; and 1.1 plant species per file had a translocation measure (average over 92 derogation requests). Compared to historical data, between 2010 and 2014, there were 1.8 plant species with residual impacts per derogation request (average on 544 deroga- tion requests).

The distribution of the sites concerned by the derogation requests analysed here showed a significant difference between departments. They were therefore not evenly distributed in France, and particularly frequent in the Gironde department and in the Mediterranean area (Fig. 2B). However, the translocation rate, *i.e.,* the average number of translocations per derogation request (Fig. 2C), showed a different dis- tribution. Some departments with a few files available for analysis contributed by their large number of translocations per file. There was a lack in several regions, such as in the centre of France in both maps; most projects and translocations are concentrated by the sea, near the bor- ders, and near Paris.

Among these 103 plant populations, the most frequent species were *Aristolochia rotunda* (n=4) and *Lotus hispidus* (n=3). The most frequent species in the non-translocated populations were *Serapias neglecta* (n=6), *Serapias parviflora* (n=6), and *Ranunculus ophioglossifolius* (n=5). It can be noted that *S. neglecta* and *R. ophioglossifolius* were never suggested for translocation among all the files studied (recommended 3 times for *S. parviflora*). On the contrary, *A. rotunda* was always suggested for translocation (translocation not advised for *L. hispidus* once). *A. rotunda* is not protected, but it hosts as a mandatory host a protected butterfly (*Zerynthia polyxena*, Lepidoptera) and is translocated to protect the butterfly. Among the 103 populations concerned by a translocation measure, 2.9% came from species under departmental protection, 44.7% from species under regional protection, 33.0% from species under national protection, and 19.4% from species without any legal protection in France. All species concerned by a translocation proposal were listed LC, DD, or NA on the IUCN World List of Protected Species, and 7.7% of translocated populations were from threatened species listed on the IUCN French red list (NT, VU, or EN).

We observed significant variations between plant families in the ratio of translocated/non-translocated populations requests (Fig. 3A), with substantial differences of about 8.2 times between the most translocated Apiaceae (66% of cases) and the least translocated Cyper- aceae (8% of cases). Cyperaceae, Liliaceae, Ranunculaceae, and Orchidaceae were the least suggested for translocation, contrary to Apiaceae and Asteraceae, which was the most recommended for translocation.

We observed significant variations in the ratio of translocated/non- translocated populations depending on the type of project (Fig. 3B), with a difference of more than 4.1 times between the most translocated species in urbanisation projects (53%) and the least translocated

species in cable burial projects (13%). Projects related to urbanisation, tourism facilities, and protection/safety projects often included translocation measures, which was less the case for cable burial, industrial and photovoltaic projects.

Populations living in certain habitat types were translocated more often than others (Fig. 3C), with a difference of more than 3.4 times between the most translocated species in agricultural habitats (62% of cases for this habitat) and the least translocated species in bogs and fens habitats (18% of cases for this habitat). Populations living in agricultural habitats, woodland edges and clearings, and coastal habitats were often suggested for translocation. In contrast, forests, heaths, and peatlands were rare in projects that include translocations. The results of the Habitats Directive classification (Fig. 3D) are much the same, with very few translocations in peat bogs compared to grasslands and dunes.

3.3. Mitigation hierarchy

In the files studied, translocations were mentioned as an accompa- nying measure in 28.9% of cases, as a reduction measure in 45.0%, and an offset measure in 21.6% (it was not mentioned as a measure in 4.5% of cases). However, 59.2% of plant populations were translocated *in situ*, and 27.2% mentioned feedback from previous similar operations (but there is no certainty about the feedback quality). According to the definition in Alligand et al. (2018), a translocation is a reduction mea- sure if it is planned on the project area or if there is sufficient feedback. In total, 69.9% of the translocations met the definition of reduction measure, considering that feedback was sufficient; and 30.1% of the translocations met the definition of accompanying measure. According to these considerations, translocation measures were correctly classified for only 55.3% of the populations.

We then examined the differences between gross and residual impacts. A generalised model showed a significant difference in the range of impacts between the translocated and non-translocated populations (YES modality: Estimate = 1.116; p-value = 0.0395). Thus, the miti- gation effort was significantly lower when populations were suggested for translocation than non-translocated populations. There was also a significant difference between years: in 2018, the mitigation effort was greater than in 2019 and 2020 (2018: Estimate = 6.87; 2019: Estimate = 1.82 and p-value = 0.0025; 2020: Estimate = 1.28 and p-value = 0.0051).

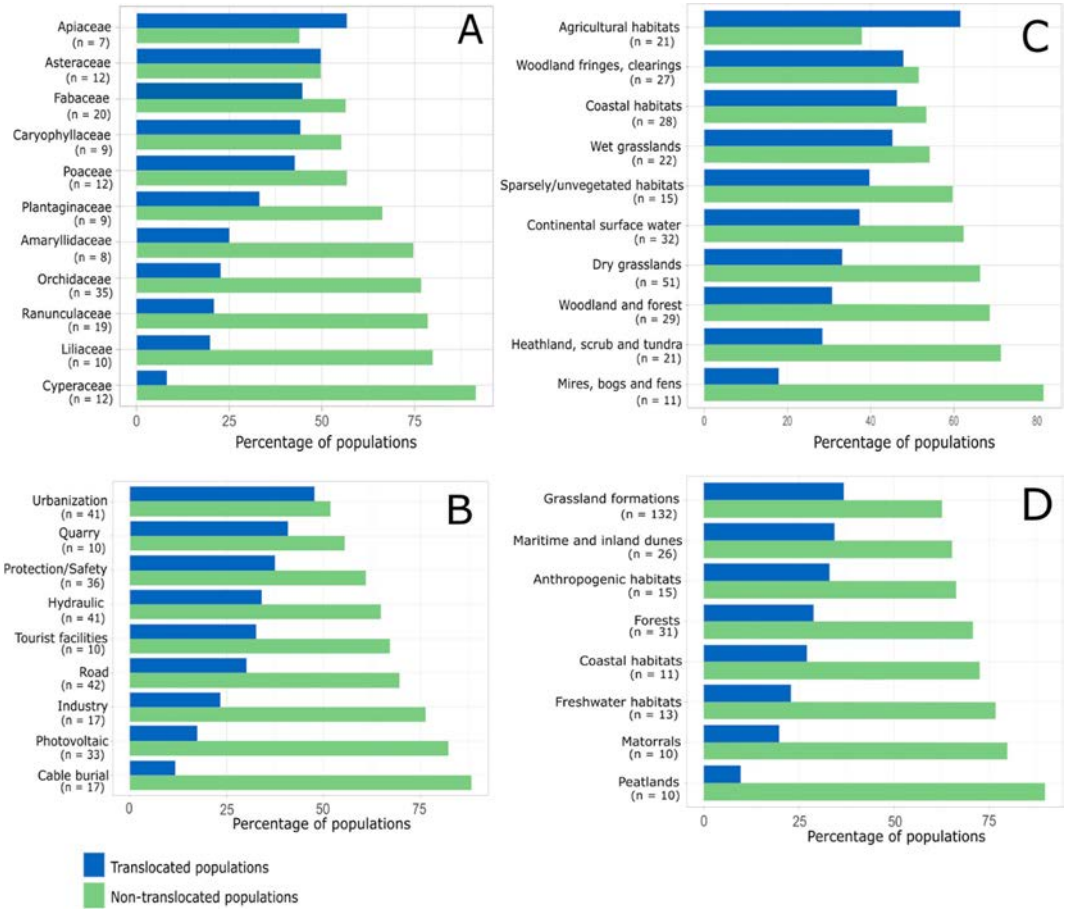

Fig. 3. A. Proportion of translocated and non-translocated populations per plant family. Families with at least nine plant populations were represented. B. Proportion of translocated and non-translocated populations by project type. Types with at least ten plant populations were represented. C. Proportion of translocated and non-translocated populations by EUNIS habitat. D. Proportion of translocated and non-translocated populations by habitat of the European Habitat Directive. Habitats with at least ten plant populations were represented.

3.4. *Life-history traits*

A more significant effort to provide information was made for translocated populations to include the life cycle type, the flowering period, the dispersal mode, and vegetation preferences in the derogation file (Fig. 4A). However, some criteria were rarely met and indicated a

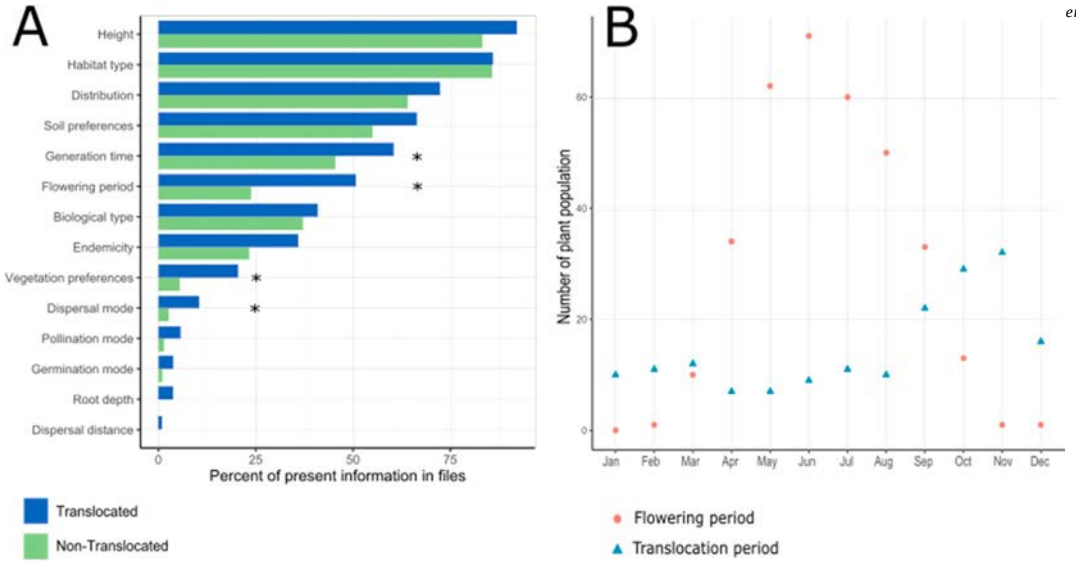

Fig. 4. A. Proportion of present information for life-history traits of translocated (103 populations) and non-translocated (179 populations) populations. A Chi^2 test was applied for each criterion. *$p < 0.05$. B. Distribution of the flowering and translocation periods of the translocated populations.

poor understanding of the species. Root depth and germination mode were particularly poorly documented, although knowledge of these ecological traits is important for optimising translocation success. Very little information was also available on population ecology traits, with only 5.9% of pollination modes known, 10.8% of the dispersal modes, and 1% on dispersal distance.

Height, habitat type, and regional distribution were well-informed (>70%). However, the flowering period and generation time were relatively poorly documented, although this information seems crucial for translocation. Considering all criteria, there was no significant dif- ference in biology knowledge between translocated and non-translocated populations (W 78.5; P-value 0.38).

We also compared the flowering curve of the species involved in the translocation projects with the curve of the translocation periods rec- ommended in the protocols for these same species (Fig. 4B). The peak of flowering took place between May and July. From October, few species were in bloom until March. The translocation period curve was slightly lower in the middle of the flowering period.

3.5. Translocation protocol

Some crucial criteria, such as the part of the plant (96.1%), the number of individuals/area translocated (80.6%), were well docu- mented, even if one could have expected a value of 100% for these two essential pieces of information. Presence percentages were between 70 and 80% for the seed collection technique, the translocation period, and the extraction mode of individuals. Information about the protection of the host site was often available (83.5%). Other criteria were less met; the approximate distance between the source and host sites was only available in 77.7% of cases. Surprisingly, information on the vegetation of the host site was only available for 37.9% of the populations. More- over, it was common for the soil or vegetation to be described as similar but without further information. Indices used for monitoring were met for 62.1% of the population. The frequency and duration of monitoring were well-reported, with 76.1% and 80.7%, respectively.

The quality indices had a median value of 0.40 (1st quartile 0.27; 3rd quartile 0.47), which was really low (Fig. 5). This strongly in- dicates that protocols were inadequate, insufficiently detailed, and did not follow the guidelines. None of the study populations had a quality index higher than 0.67, meaning that at least one-third of the information is missing. In detail, one indicator scored well: 91.3% of translocation methods were suitable for the species studied. Several indicators counted in the middle: 60.2% chose a suitable host site, 51.5% consulted an organisation or expert, and 54.4% preferred an host site with similar soil. All other indicators were below 50%. Consider- ation of interactions was anecdotal, with 0% for pollinator consideration and 0.97% for mycorrhizae consideration.

3.6. Opinion of the CNPN on the derogation request

The model with the best AIC was selected, several factors influenced the acceptance of the derogation request (Fig. 6). Favourable files were more likely to contain translocations when the host site was protected, and improved quality between the source and host sites was visible. There was also a greater likelihood of having a post-translocation monitoring measure in favourable files.

In contrast, files with an unfavourable opinion were more likely to contain a proposal for a host site with a population of the same species already existing in the host site. Unexpectedly, translocations in unfavourable files are often planned at a suitable period. Finally, translocations of more than 50 individuals were less often accepted.

4. Discussion

This study comes at a turning point in French legislation. A decrease in the number of derogation requests evaluated by the CNPN was already visible in 2020, with regional scientific authorities having a more important role in scientific opinion. Plant translocation is a mea- sure often highlighted in derogation requests. It is largely time to assess what is suggested for translocation and make and enforce recommen- dations for improving the use and evaluation of this practice.

File distribution in time and space. The historical framework of derogation requests with plant translocation showed that the number of derogation requests related to protected plants increased steadily from 1996 to 2014 and seemed relatively stable. The files studied here were not evenly distributed over the French territory. This distribution can be related to the recent increase in the size of urban areas in France, particularly around large cities (*e.g.* Bordeaux in the Gironde depart- ment) and on the Mediterranean rim (Cerema, 2017).

The Mediterranean region is a biodiversity hotspot, particularly for

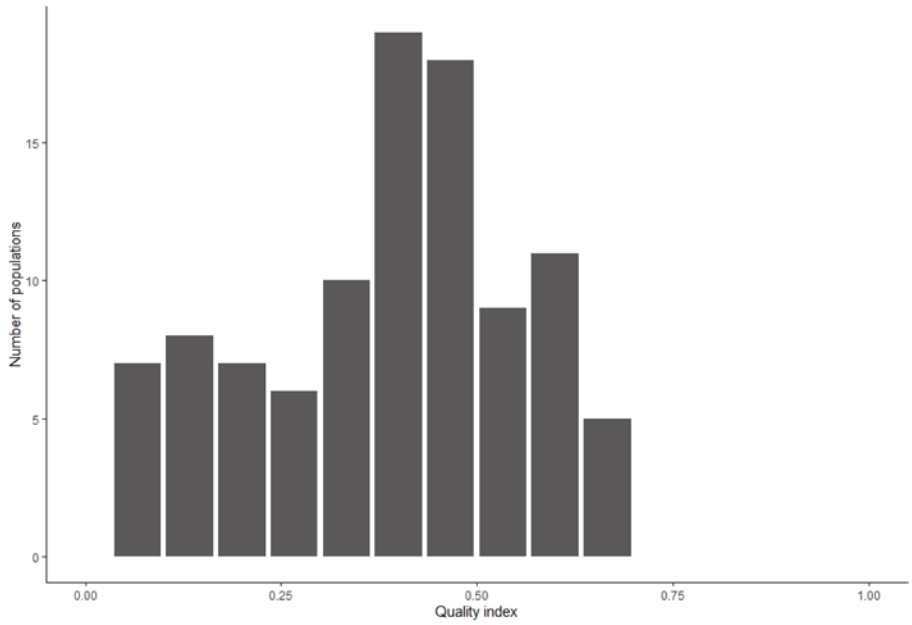

Fig. 5. Distribution of populations suggested to translocation according to their quality index.

Variable	Modality	N	Odds ratio	p-value
Protection of the host site	NO	81	Reference	
	YES	20	7.72 (1.71, 41.18)	0.01
Presence of the species on the host site	NO	51	Reference	
	YES	50	0.21 (0.05, 0.71)	0.02
Monitoring	NO	15	Reference	
	YES	86	12.33 (2.27, 114.84)	0.01
Number of translocated individuals	<10	15	Reference	
	Between 10 and 50	29	0.49 (0.09, 2.50)	0.39
	Between 50 and 250	18	0.12 (0.02, 0.78)	0.03
	>250	11	0.11 (0.01, 1.02)	0.06
	Missing value	28	0.60 (0.11, 3.27)	0.56
Suitable translocation period	NO	24	Reference	
	Missing value	30	0.04 (0.00, 0.20)	<0.001
	YES	47	0.04 (0.01, 0.16)	<0.001

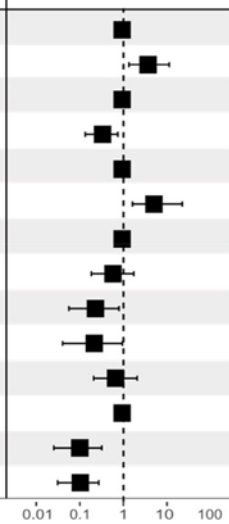

Fig. 6. Estimated odds-ratios between the CNPN opinion and different variables with 95% intervals under binary regression model. Modalities with an odds ratio> 1 are more likely to be present in files with a favourable opinion.

plants (Blondel et al., 2010; Schatz et al., 2014; Thompson et al., 2005), indicating a large number of rare plant species in the south of France (Myers et al., 2000), many of which being protected. There are also regional differences in the propensity to translocate them, depending on the regional services examining the derogation requests. Besides, translocated populations were more frequent in large-scale projects: when an urbanisation project is carried out over tens of hectares, it is harder to avoid impacts than with the burial of a cable on smaller areas and with fewer technical constraints.

Variable tendency to plant translocation. We would expect that the trend for a plant to be translocated would be the same for each land-use project, thus independent of the plant family, habitat, or type of project. However, we have shown substantial variations (8 times) according to the plant family and lower but still notable variation (4 and 3 times respectively) depending on the type of project and the habitat. Cyperaceae and Liliaceae were rarely translocated, whereas Apiaceae and Asteraceae are more often translocated. The most frequent family in the files was the Orchidaceae, yet less than 25% of their populations were suggested for translocation. This family contains relatively rare species, whose complex interactions with mycorrhizae and specific pollinators make the outcome of translocation uncertain (Schatz et al., 2014; Reiter et al., 2016). More generally, the geophytic root system (Orchidaceae, Liliaceae) and the presence in a wet habitat (Cyperaceae) (see after) could make their translocation more complex, which could explain the low translocation proposals for these families.

In contrast, the second most frequent family in the files was the Fabaceae, and almost 50% of populations from this family were sug-gested for translocation. The Fabaceae species seem simpler to trans- locate; many of them are annual species, and some are even commonly cultivated. Comparing feedback on translocations between different plant families would confirm whether it is appropriate to be reluctant to translocate certain families or not.

More surprisingly, the tendency to translocate a plant appeared to be influenced by the type of project. The most parsimonious explanation would be that some projects (photovoltaic, cable burial, industry) are characterised by a greater

possibility to modify their spatial footprint that is to avoid or reduce their impact on protected plants. On the contrary, other projects (urbanisation, tourism facilities) have a spatial footprint more imposed by existing infrastructures and are less flexible to avoid impacts. The area associated with each project type could also influence the tendency to translocate plants, but we do not have enough replicates to test this alternative hypothesis.

The species most often suggested for translocation are found in the most common habitats (agricultural habitats, clearings, and coastal habitats). We have noticed that coastal habitats are often subject to translocation. This may be related to the fact that these habitats are still very much subject to the increasing human footprint, or that trans- location seems easier to achieve, as they are often sandy environments. In contrast, very few translocations are suggested for species present in bogs, grasslands, or heathlands, indeed due to a more significant avoidance effort on this more sensitive habitat type. A more substantial effort to avoid translocations into wetlands could have been anticipated as this habitat is particularly threatened (Clare et al., 2011).

Mitigation hierarchy. The French guidelines on the mitigation hi- erarchy classify translocation as a reduction measure if plants are moved into the project area or if there is sufficient feedback on translocations of the species (Alligand et al., 2018). However, the risks of failure when translocated into the project area can be more significant as the trans- located individuals are often locked into the middle of a land planning project, with various disturbances and no possibility of expansion. Therefore, the probability of success is not increased when translocation occurs into the project area. Translocation should remain experimental wherever individuals are moved and thus be an accompanying measure. Interestingly, when a translocation is suggested, the difference between gross and residual impacts was more significant than when no trans- location was planned. This result may mean that less effort is put into mitigating impacts when a translocation is suggested. But it may also be a sign that translocation is only suggested when it is more challenging to mitigate the impacts.

In all cases translocation should be a last resort. It is essential to devote more effort to avoidance and reduction and make better use of translocations (Regnery, 2017; Alligand et al., 2018). However, trans-

locations are increasingly used (Bradley et al., 2020) without better results. The low use of avoidance has been criticised in several previous studies, as it is the measure that most reduces impacts, especially on plants (Clare et al., 2011; Regnery, 2017; Phalan et al., 2018; Bigard et al., 2020). Indeed, there is a great deal of uncertainty about the success of several measures, especially because it is challenging to assess biodiversity losses and gains (Maron et al., 2012). Translocation is even more uncertain; mitigation cannot be guaranteed (Fahselt, 2007). Translocations can therefore be proposed to support other measures but cannot be considered as sufficient measures in themselves. Moreover, the use of translocation must be justified by showing the impossibility of achieving good avoidance and reduction measures.

Life-history traits. Life-history traits are essential criteria to consider before translocation. Indeed, biology and ecology knowledge are crucial for successful translocations (Cogoni et al., 2013; Commander et al., 2018; Draper et al., 2016). We showed that some criteria were better known and described in the files for species suggested for trans- locations: generation time, flowering period, dispersal mode, and vegetation preferences. This shows that there is some effort to know the plants that are being considered for translocation. But this remains su- perficial, and many other criteria are poorly described. For example, the pollination mode is essential to know: if the plant is entomophilous (like more than 80% of angiosperms; see Ollerton et al., 2011), it is necessary to ensure that its pollinators are present at the host site. This information also determines the distance at which individuals are transplanted from each other. In the same vein, in the case of clod translocation, it is essential to know the depth of the roots. This is a parameter difficult to find in the literature but easy to measure in the field. A life history trait of a plant species that is not well known in the literature can be studied before establishing a translocation protocol. For example, in an urban planning project in Portugal, a study of the biology of the plant was carried out and allowed suitable decisions to be made for the trans- location protocol (Draper et al., 2016). Similarly, germination tests are necessary prior to sowing (Godefroid et al., 2016). Many species have a dormancy mechanism, and direct seeding without pre-treatment may give poor results. The absence of information on species biology and ecology in the derogation requests may reflect a lack in online databases and botanical literature. Thus, these translocation operations can also be an opportunity to fill in this missing information and thus provide col- lective feedback to improve these operations.

Thus, we strongly recommend that the biological and ecological el- ements are indicated in the derogation requests based on the existing literature. The absence of a criterion in a file does not mean that it is unknown to those carrying out the translocation. It must be demon- strated at the derogation stage that these traits are indeed known, and it should be suggested that measures be taken prior to translocation for traits that remain unknown.

Translocation period. The fact that an ecological trait is well documented in a derogation request does not mean that this information is well used to optimise the translocation success, as shown here with the translocation period. The ideal translocation period varies according to the biology and ecology of the studied species. However, certain periods such as the flowering period should be avoided, as the plant is more sensitive, particularly in its interaction with the mycorrhizae. It is also necessary to avoid periods of high heat, especially in the Mediterranean area, which could cause water stress to the translocated individuals (Commander et al., 2018; Dillon et al., 2018). We showed that trans- locations were done preferably between September and October. Sur- prisingly, some translocations were recommended in summer, especially in September, which is still a warm and dry period in the Mediterranean area, accounting for a large part of the translocations studied here. In the derogation requests, it is often planned to start work in fall (October to Mid-December), which corresponds to the periods of least sensitivity for other taxonomic groups. It, therefore, seems appropriate to ask the land planner to justify the period chosen for the translocation.

Translocation protocol. The basic criteria for translocation proto- col, host site, and post-translocation monitoring were met quite often. However, none of the translocation protocols in the files reached a quality that should be expected given the decades-long practice of derogation requests in France. Despite recommendations (IUCN/SSC,

2010; Maschinski and Albrecht, 2017; Commander et al., 2018), in- teractions with pollinators and mycorrhizae have hardly been taken into account, although these interactions can be critical criteria (Moir et al., 2012; Winder et al., 2021). Similarly, possible problems concerning the genetics of translocated populations were never addressed, although this can be important (Maschinski and Albrecht, 2017; Van Rossum and Hardy, 2020).

Many protocols in the derogation requests lacked essential information. For example, some files simply mentioned that the trans- location protocol would be carried out after authorisation. This is not an option: the CNPN must provide scientific and technical opinions on the enhanced measures. How can an informed opinion be given if the pro- tocol has not yet been designed? And if the CNPN gives a favourable opinion, how to be sure that the protocol will be well-designed? Indeed, once a project is accepted, it is difficult to keep track of what is done, which reduces the interest in the collective construction of feedback by species.

Similarly, the selection criteria of the host site were sometimes not yet known, which made it impossible to determine whether it is suitable for the translocated species. However, the ecological characteristics of the host site are one of the most important criteria for successful translocation (Noël et al., 2011; Albrecht and Long, 2019; Draper et al., 2019). The mitigation hierarchy legislation does not require a detailed protocol: for offset measures, it is necessary to demonstrate their feasi- bility and effectiveness (MEDDTL, 2012; Alligand et al., 2018). But translocation is mostly experimental, classified as accompanying mea- sures, and therefore do not require demonstration. The question of the usefulness of the measure arises: if the translocation proposal does not provide feedback to improve the practice of translocation and does not take all necessary precautions to obtain a viable population, it does not seem helpful to suggest a translocation. Overall, translocation protocols do not adopt an experimental scientific approach, although this is one of the most important criteria for success (Silcock et al., 2019).

CNPN opinion. In a derogation request, many elements are considered for the CNPN to give a favourable opinion. Translocation is far from being the central element, yet we have shown that a derogation request had a greater chance to have a favourable opinion when certain criteria

of the translocation protocol were met. Indeed, when the host site for the translocation was protected, and post-translocation monitoring was planned, the derogation request had a favourable opinion more often.

Interestingly, when the number of individuals to be translocated exceeded 50, the chances of obtaining a favourable opinion for the derogation request decreased. This is surprising because where impacts have been well reduced, translocation seems less relevant for only a few remaining individuals, although this is suggested in some of the dero- gation requests reviewed here. In addition, translocating a large number of individuals (a minimum of 50 according to certain authors) increases the viability of the translocated population (Godefroid et al., 2011; Maschinski and Albrecht, 2017; Silcock et al., 2019). Another surprising result, which is difficult to explain, is that files with an unfavourable opinion more often had a favourable translocation period for the species.

Recommendations. The choice of the host site with a precise and argued selection method is crucial for the success of the translocation (Maschinski and Albrecht, 2017; Albrecht and Long, 2019). Indeed, unfavourable conditions for the translocated species can quickly lead to failure. It is, therefore, necessary to choose a site with similar vegetation and soil as the source site. Once selected, the potential risks of the host site (like trampling, harvesting, herbivory) should be identified (Jusai- tis, 2005). Some of them can be eliminated by protecting the host site (Godefroid et al., 2011; Fenu et al., 2016; Dillon et al., 2018) through the installation of fences or by giving a protection status. According to certain authors, watering is also a factor increasing the success of a translocation, especially in dry conditions (Dillon et al., 2018; Silcock et al., 2019).

Translocating as close as possible to the source site is often recom- mended, but alternatives can be justifiable. Considering climate changes, host sites close to the source sites may prove unfavourable in the not-too-distant future. Therefore, it can be recommended to trans- locate further north or to a higher altitude to anticipate the effects of climate change and be locally adapted (Diallo et al., 2021).

It is essential to detail translocation protocols in derogation requests to allow their proper evaluation. The CNPN must be able to give an informed opinion based on recommended measures in derogation

requests. Besides, many translocations have been carried out over the years, so feedback should be available. Feedback helps to avoid repeating the same mistakes and to repeat a given protocol that gave good results. To choose the suitable protocol, an expert in the taxon studied or botanical institutions are essential. But the opinion of the CNPN experts is only advisory: decision-makers can go against this opinion. Moreover, the French administration decides to request or not the opinion of the CNPN for each file. Unfortunately, the opinion of the experts is optional, as it gives less weight to environmental scientists.

Finally, it is essential to monitor after translocations (Fenu et al., 2019; Godefroid et al., 2011; Monks et al., 2012). This monitoring should last at least ten years for annuals and longer (often 30 years) for perennials. Short-term monitoring does not provide sufficient informa- tion on the establishment of a population (Drayton and Primack, 2012; Jusaitis, 2012). A count of the vegetative and flowering individuals should be carried out to obtain informative monitoring data, and these data should be transmitted to the environmental authorities. Where possible, a control site can be defined by considering a non-impacted site with a population of the same species in good conservation status. Thus, the monitoring allows comparing the control population with the translocated population to determine what is due to interannual climatic variations (Colas et al., 1997, 2008; Menges, 2008; Monks et al., 2012). The aim of the monitoring is also to establish collective feedback to improve the success of future translocations.

Conclusion. To improve the practice of mitigation translocation, it is necessary to strengthen its description at the stage of derogation request. Having avoided and reduced the impact and thus the need for trans-location as a last resort, applications for derogation should more clearly detail the ecological characteristics of the species concerned and argue the translocation protocol they wish to implement. More scientific rigour should also be required based on the guidelines for protocol translocation development and the collective construction of experience feedback to ensure no net loss of protected plant species.

Author statement

Margaux Julien: Methodology, Investigation, Analysis, and Writing. **Bruno Colas**: Methodology, Validation and Supervision. **Serge Muller**: Resources and Validation. **Bertrand Schatz**: Methodology, Validation, and Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the CNPN for granting us access to these confidential files
for this study. We also warmly thank the colleagues of the CNPN (particularly those of the ECB commission) for the fruitful discussions on

References

Abeli, T., Dixon, K., 2016. Translocation ecology: the role of ecological sciences in plant translocation. Plant Ecol. 217, 123–125. https://doi.org/10.1007/s11258-016-0575-z.

Albrecht, M.A., Guerrant, E.O., Maschinski, J., Kennedy, K.L., 2011. A long-term view of rare plant reintroduction. Biol. Conserv. 144, 2557–2558. https://doi.org/10.1016/ j.biocon.2011.07.021.

Albrecht, M.A., Long, Q.G., 2019. Habitat suitability and herbivores determine reintroduction success of an endangered legume. Plant Divers 41, 109–117. https://doi.org/10.1016/j.pld.2018.09.004.

Alligand, G., Hubert, S., Legendre, T., Millard, F., Müller, A., 2018. Théma - Evaluation environnementale. Guide d'aide à la définition des mesures ERC. Conseil Général du Développement Durable, MTE, Paris, France.

Atkinson, S.F., Bhatia, S., Schoolmaster, F.A., Waller, W.T., 2000. Treatment of biodiversity impacts in a sample of US environmental impact statements. Impact Assess. Proj. Apprais. 18, 271–282. https://doi.org/10.3152/147154600781767349.

BBOP, 2012. Standard on Biodiversity Offsets. Business and Biodiversity Offsets Programme, Washington D.C.

Becker, R.A., Wilks, A.R., Brownrigg, R., Minka, T.P., 2013. Maps: draw geographical maps. R Packag. version 2, 3–6.

Bigard, C., Pioch, S., Thompson, J.D., 2017. The inclusion of biodiversity in environmental impact assessment: policy-related progress limited by gaps and semantic confusion. J. Environ. Manag. 200, 35–45. https://doi.org/10.1016/j.jenvman.2017.05.057.

Blondel, J., Aronson, J., Bodiou, J.-Y., Boeuf, G., 2010. The Mediterranean Region:Biological Diversity in Space and Time. Oxford University Press.

Bradley, H.S., Tomlinson, S., Craig, M.D., Cross, A.T., Bateman, P.W., 2020. Mitigation translocation as a management tool. Conserv. Biol. 1–31 https://doi.org/10.1111/cobi.13667.

Brooker, R.W., Brewer, M.J., Britton, A.J., Eastwood, A., Ellis, C., Gimona, A., Poggio, L.,Genney, D.R., 2018. Tiny niches and translocations: the challenge of identifying suitable recipient sites for small and immobile species. J. Appl. Ecol. 55, 621–630. https://doi.org/10.1111/1365-2664.13008.

Bull, J.W., Gordon, A., Watson, J.E.M., Maron, M., 2016. Seeking convergence on the key concepts in 'no net loss' policy. J. Appl. Ecol. 53, 1686–1693. https://doi.org/10.1111/1365-2664.12726.

Cerema, 2017. Catégorisation urbaine des communes [WWW Document]. URL. https://en.populationdata.net/maps/france-urbanization-communes-2017/.

Clare, S., Krogman, N., Foote, L., Lemphers, N., 2011. Where is the avoidance in the implementation of wetland law and policy? Wetl. Ecol. Manag. 19, 165–182. https://doi.org/10.1007/s11273-011-9209-3.

Cogoni, D., Fenu, G., Concas, E., Bacchetta, G., 2013. The effectiveness of plant conservation measures: the *Dianthus morisianus* reintroduction. Oryx 47, 203–206. https://doi.org/10.1017/S003060531200169X.

Colas, B., Kirchner, F., Riba, M., Olivieri, I., Mignot, A., Imbert, E., Beltrame, C., Carbonell, D., Fréville, H., 2008. Restoration demography: a 10-year demographic comparison between introduced and natural populations of endemic *Centaurea corymbosa* (Asteraceae). J. Appl. Ecol. 45, 1468–1476. https://doi.org/10.1111/j.1365-2664.2008.01536.x.

Colas, B., Olivieri, I., Riba, M., 1997. *Centaurea corymbosa*, a cliff-dwelling species tottering on the brink of extinction: a demographic and genetic study. Proc. Natl. Acad. Sci. U.S.A. 94, 3471–3476. https://doi.org/10.1073/pnas.94.7.3471.

Commander, L.E., Coates, D.J., Broadhurst, L., Offord, C.A., Markinson, B., Matthes, M., 2018. Guidelines for the Translocation of Threatened Plants in Australia. Australia Network for Plant Conservation. https://www.anpc.asn.au/product/guidelines-for-the-translocation-of-threatened-plants-in-australia/.

Dalrymple, S.E., Banks, E., Stewart, G.B., Pullin, A.S., 2012. A meta-analysis of threatened plant reintroductions from across the globe. In: Plant Reintroduction in a Changing Climate. Island Press/Center for Resource Economics, Washington, DC, pp. 31–50. https://doi.org/10.5822/978-1-61091-183-2_3.

Dalrymple, S.E., Godefroid, S., Orsenigo, S., Abeli, T., 2020. Frankenstein's work or everyday conservation? How reintroductions are informing the de-extinction debate. J. Nat. Conserv. 56, 125870. https://doi.org/10.1016/j.jnc.2020.125870.

Davies, C.E., Moss, D., Hill, M.O., 2004. Eunis Habitat Classification Revised. European Environment Agency. http://nature.eionet.eu.int/activities/products/eunishaben.html.

Diallo, M., Ollier, S., Mayeur, A., Fernandez-Manjarres, J., García-Fernandez, A., Iriondo, J.M., Vaissière, A., Colas, B., 2021. Plant translocations in Europe and the Mediterranean: geographical and climatic directions and distances from source to host sites. J. Ecol. 109, 2296–2308. https://doi.org/10.1111/1365-2745.13609.

Dillon, R., Monks, L., Coates, D., 2018. Establishment success and persistence of threatened plant translocations in south west Western Australia: an experimental approach. Aust. J. Bot. 66, 338–346. https://doi.org/10.1071/BT17187.

Draper, D., Marques, I., Iriondo, J.M., 2019. Species distribution models with field validation, a key approach for successful selection of receptor sites in conservation translocations. Glob. Ecol. Conserv. 19 https://doi.org/10.1016/j.gecco.2019.e00653.

Draper, D., Marques, I., Iriondo, J.M., 2016. Acquiring baseline information for successful plant translocations when there is no time to lose: the case of the neglected critically endangered *Narcissus cavanillesii* (Amaryllidaceae). Plant Ecol. 217, 193–206. https://doi.org/10.1007/s11258-015-0524-2.

Drayton, B., Primack, R.B., 2012. Success rates for reintroductions of eight perennial plant species after 15 years. Restor. Ecol. 20, 299–303. https://doi.org/10.1111/j.1526-100X.2011.00860.x.

the subject. Finally, we also thank Camille Filippi for proofreading the English.

This study is supported by funding from the ANRT (n°2018/0536) as part of a CIFRE partnership with the company Ecotonia.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2021.114064.

Fahselt, D., 2007. Is transplanting an effective means of preserving vegetation? Can. J. Bot. 85, 1007–1017. https://doi.org/10.1139/B07-087.

Fenu, G., Bacchetta, G., Charalambos, S.C., Fournaraki, C., Giusso del Galdo, G. Pietro, Gotsiou, P., Kyratzis, A., Piazza, C., Vicens, M., Pinna, M.S., de Montmollin, B., 2019. An early evaluation of translocation actions for endangered plant species on Mediterranean islands. Plant Divers 41, 94–104. https://doi.org/10.1016/j.pld.2019.03.001.

Fenu, G., Bacchetta, G., Christodoulou, C.S., Cogoni, D., Fournaraki, C., Gian Pietro, G., del, G., Gotsiou, P., Kyratzis, A., Piazza, C., Vicens, M., de Montmollin, B., 2020. A common approach to the conservation of threatened island vascular plants: first results in the Mediterranean basin. Diversity 12, 157. https://doi.org/10.3390/d12040157.

Fenu, G., Cogoni, D., Bacchetta, G., 2016. The role of fencing in the success of threatened plant species translocation. Plant Ecol. 217, 207–217. https://doi.org/10.1007/s11258-015-0517-1.

Gardner, T.A., Von Hase, A., Brownlie, S., Ekstrom, J.M., Pilgrim, J.D., Savy, C.E., Stephens, R.T.T., Treweek, J., Ussher, G.T., Ward, G., Ten Kate, K., 2013. Biodiversity offsets and the challenge of achieving No Net Loss. Conserv. Biol. 27, 1254–1264. https://doi.org/10.1111/cobi.12118.

Germano, J.M., Field, K.J., Griffiths, R.A., Clulow, S., Foster, J., Harding, G., Swaisgood, R.R., 2015. Mitigation-driven translocations: are we moving wildlife in the right direction? Front. Ecol. Environ. 13, 100–105. https://doi.org/10.1890/140137.

Godefroid, S., Le Pajolec, S., Van Rossum, F., 2016. Pre-translocation considerations in rare plant reintroductions: implications for designing protocols. Plant Ecol. 217, 169–182. https://doi.org/10.1007/s11258-015-0526-0.

Godefroid, S., Piazza, C., Rossi, G., Buord, S., Stevens, A.D., Aguraiuja, R., Cowell, C., Weekley, C.W., Vogg, G., Iriondo, J.M., Johnson, I., Dixon, B., Gordon, D., Magnanon, S., Valentin, B., Bjureke, K., Koopman, R., Vicens, M., Virevaire, M., Vanderborght, T., 2011. How successful are plant species reintroductions? Biol. Conserv. 144, 672–682. https://doi.org/10.1016/j.biocon.2010.10.003.

Iucn/Ssc, 2013. Guidelines for Reintroductions and Other Conservation Translocations, Ecologial Applications. Gland, Switzerland. https://portals.iucn.org/library/efiles/documents/2013-009.pdf.

Jusaitis, M., 2012. Serendipity during long-term monitoring of translocation trials. Australas. Plant Conserv. 20, 8–10. https://search.informit.org/doi/10.3316/informit.011299822787479.

Jusaitis, M., 2005. Translocation trials confirm specific factors affecting the establishment of three endangered plant species. Ecol. Manag. Restor. 6, 61–67. https://doi.org/10.1111/j.1442-8903.2005.00220.x.

Kennedy, N., 2020. Forest Plots from Regression Models. R Packag. https://rdrr.io/cran/forestmodel/.

Liu, H., Ren, H., Liu, Q., Wen, X., Maunder, M., Gao, J., 2015. Translocation of threatened plants as a conservation measure in China. Conserv. Biol. 29, 1537–1551. https://doi.org/10.1111/cobi.12585.

Maron, M., Hobbs, R.J., Moilanen, A., Matthews, J.W., Christie, K., Gardner, T.A., Keith, D.A., Lindenmayer, D.B., McAlpine, C.A., 2012. Faustian bargains? Restoration realities in the context of biodiversity offset policies. Biol. Conserv. 155, 141–148. https://doi.org/10.1016/j.biocon.2012.06.003.

Maschinski, J., Albrecht, M.A., 2017. Center for plant conservation's best practice guidelines for the reintroduction of rare plants. Plant Divers 39, 390–395. https://doi.org/10.1016/j.pld.2017.09.006.

MEDDTL, 2012. Doctrine relative a la sequence eviter, reduire et compenser les impacts sur le milieu naturel 9. https://www.ecologie.gouv.fr/sites/default/files/Doctrine%20ERC.pdf.

Menges, E.S., 2008. Restoration demography and genetics of plants: when is a translocation successful? Aust. J. Bot. 56, 187–196. https://doi.org/10.1071/BT07173.

Moir, M.L., Vesk, P.A., Brennan, K.E.C., Hughes, L., Keith, D.A., McCarthy, M.A., Coates, D.J., Barrett, S., 2012. A preliminary assessment of changes in plant-dwelling insects when threatened plants are translocated. J. Insect Conserv. 16, 367–377. https://doi.org/10.1007/s10841-011-9422-7.

Monks, L., Coates, D., Bell, T., Bowles, M., 2012. Determining success criteria for reintroductions of threatened long-lived plants. Plant Reintroduction a Chang. Clim. Promises Perils 53, 189–209. https://doi.org/10.5822/978-1-61091-183-2_11.

Morgan, R.K., 2012. Environmental Impact Assessment : the State of the Art 5517. https://doi.org/10.1080/14615517.2012.661557.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858. https://doi.org/10.1038/35002501.

Noël, F., Prati, D., van Kleunen, M., Gygax, A., Moser, D., Fischer, M., 2011. Establishment success of 25 rare wetland species introduced into restored habitats is best predicted by ecological distance to source habitats. Biol. Conserv. 144, 602–609. https://doi.org/10.1016/j.biocon.2010.11.001.

Ollerton, J., Winfree, R., Tarrant, S., 2011. How many flowering plants are pollinated by animals? Oikos 120, 321–326. https://doi.org/10.1111/j.1600-0706.2010.18644.x.

Phalan, B., Hayes, G., Brooks, S., Marsh, D., Howard, P., Costelloe, B., Vira, B., Kowalska, A., Whitaker, S., 2018. Avoiding impacts on biodiversity through strengthening the first stage of the mitigation hierarchy. OryX 52, 316–324. https://doi.org/10.1017/S0030605316001034.

R Core Team, 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. http://web.mit.edu/r_v3.4.1/fullrefman.pdf.

Regnery, B., 2017. La compensation écologique : concepts et limites pour conserver la biodiversité, Muséum nat (Paris).

Reiter, N., Whitfield, J., Pollard, G., Bedggood, W., Argall, M., Dixon, K., Davis, B., Swarts, N., 2016. Orchid re-introductions: an evaluation of success and ecological considerations using key comparative studies from Australia. Plant Ecol. 217, 81–95. https://doi.org/10.1007/s11258-015-0561-x.

Schatz, B., Gauthier, P., Debussche, M., Thompson, J.D., 2014. A decision tool for listing species for protection on different geographic scales and administrative levels. J. Nat. Conserv. 22, 75–83. https://doi.org/10.1016/j.jnc.2013.09.003.

Silcock, J., Simmons, C.L., Monks, L., Dillon, R., Reiter, N., Jusaitis, M., Vesk, P.A., Byrne, M., Coates, D.J., 2019. Threatened plant translocation in Australia: a review. Biol. Conserv. 236, 211–222. https://doi.org/10.1016/j.biocon.2019.05.002.

Thompson, J.D., Lavergne, S., Affre, L., Gaudeul, M., Debussche, M., 2005. Ecological differentiation of Mediterranean endemic plants. Taxon 54, 967–976. https://doi.org/10.2307/25065481.

Tinker, L., Cobb, D., Bond, A., Cashmore, M., 2005. Impact mitigation in environmental impact assessment: paper promises or the basis of consent conditions? Impact Assess. Proj. Apprais. 23, 265–280. https://doi.org/10.3152/147154605781765463.

Van Rossum, F., Hardy, O.J., 2020. Guidelines for genetic monitoring of translocated plant populations. Conserv. Biol. https://doi.org/10.1111/cobi.13670.

Wickham, H., Averick, M., Bryan, J., Chang, W., D'Agostino McGowan, L., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T.L., Miller, E., Bache, S.M., Müller, K., Ooms, J., Robinson, D., Seidel, D.P., Spinu, V., Takahashi, K., Vaughan, D., Wilke, C., Woo, K., Yutani, H., 2019. Welcome to the tidyverse. J. Open Source Softw. 1686 https://doi.org/10.21105/joss.01686.

Winder, R., Kranabetter, J., Pedlar, J., 2021. Adaptive management of landscapes for climate change: how soils influence the assisted migration of plants. In: Soils and Landscape Restoration. Elsevier, pp. 275–297. https://doi.org/10.1016/B978-0-12-813193-0.00010-2.