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Achieving conservation outcomes in plant mitigation translocations: the need for global standards

Chantelle A. T. Doyle[1] · Thomas Abeli[2] · Matthew A. Albrecht[3] · Joe Bellis[4] · Bruno Colas[5] · Sarah E. Dalrymple[4] · Andreas Ensslin[14] · Jaime Espejo[6] · Paul L. A. Erftemeijer[10] · Margaux Julien[7] · Wolfgang Lewandrowski[9] · Hong Liu[8] · Axel Moehrenschlager[15] · Mark K. J. Ooi[1] · Deborah M. Reynolds[13] · Bertrand Schatz[16] · Mari Sild[11] · Timothy J. Wills[12] · Guillaume Papuga[17]

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Abstract
Many countries have legislation intended to limit or offset the impact of anthropogenic disturbance and development on threatened plants. Translocations are often integral to those mitigation policies. When translocation is used exclusively to mitigate development impacts, it is often termed a 'mitigation translocation.' However, both the terminology and processes vary regarding interpretation and application, resulting in inconsistent standards, often leading to poorly planned and implemented projects. These mitigation projects rarely achieve the intended 'no net loss' of protected species due to issues with timelines and procedures that result in the mortality of translocated individuals. Instead, such projects are often process driven, focused on meeting legislative requirements which enable the development to proceed, rather than meaningful attempts to minimise the ecological impact of developments and demonstrate conservation outcomes. Here, we propose to reframe mitigation translocations as conservation driven, ensuring best practice implementation and hence, a quantified no net loss for impacted species. These methods include redefining the term mitigation translocation to include conservation objectives and outlining issues associated with the mitigation translocation processes worldwide. We also nominate global standards of practice to which all proposals should adhere, to ensure each project follows a trajectory towards quantified success, with genuine impact mitigation. These proposed standards focus on building efficient translocation plans and improving governance to facilitate a transition from project centred to ecology-driven translocation. Employment of these standards is relevant to development proponents, government regulators, researchers, and translocation practitioners and will increase the likelihood of conservation gains within the mitigation translocation sector.

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✉ Chantelle A. T. Doyle
chantelledoyle50@gmail.com

Extended author information available on the last page of the article

在植物减损移植中实现保护成果——需要全球标准
许多国家制定了旨在减损或抵消人为干扰和开发对受威胁植物的影响的立法。移植通常是这些减损政策不可或缺的一部分。当移植专门用于减轻开发对受保护植物造成的影响时，它通常被称为"减损性移植"。然而，由于该术语和相关行动在诠释和实施方面各不相同，而导致标准不一致，最终形成计划和实施不当的项目。因为时间表和程序问题总会引起一些移植个体死亡，所以这些减损性的项目很少能实现预期的受保护物种的"零损失"。相反，此类项目通常是走过场，侧重于满足使开发能够继续进行的立法要求，而不是真正将开发的生态影响降至最低并展示保护成果的尝试。在此我们建议将减损性移植重新定义为以保护目标为驱动，使用最佳方法，从而确保受影响物种可量化的零损失。这些方法包括重新定义损减移植的词条以包括保护目标。我们还指出在全球范围内实施减损移植中出现的问题并提出了所有移植方案都应遵守的全球实践标准，以确保每个项目都遵循实现量化成功的轨迹，并真正减轻影响。这些拟议标准侧重于制定有效的移植规划和改进管理，促进从以项目为中心的移植转变为生态驱动的移植。这些标准的采纳与开发支持者、政府监管机构、研究人员，以及移植实施人有关，并将提升减损移植相关部门产生物种保护效益的可能性。

Keywords Salvage · Environmental offsetting · Environmental legislation · Compensation · Plant ecology · Plant conservation · Conservation translocation

Introduction

Under an increasingly global anthropogenic footprint (Lin et al. 2018), reports of biodiversity loss continue to escalate (Bradshaw et al. 2021). Humans have modified an estimated 70% of the earth's land surface (IPBES 2019), and 30–40% of all plant species are considered endangered (Corlett 2016; Pimm and Joppa 2015). Although in situ biodiversity protection and management must remain the principle of conservation, methods of conserving imperilled plant species also combine approaches based on ex situ germplasm preservation and in situ actions (Antonelli et al. 2020; Falk et al. 1996; Pearce et al. 2020). Translocation of plant species has become one principle method for restoring populations (Cochrane et al. 2007; Heywood 2019). Translocation may occur as a species-centred or community approach and is defined as the 'deliberate transfer of plants or regenerative plant material from an ex situ collection or natural population to a new location, usually in the wild' (Commander et al. 2018). Translocation can be used to reinforce existing populations (*reinforcement/augmentation*), restore previously lost populations (*reintroduction*), establish new populations within known ranges (*introduction*) or create new populations outside existing ranges (*assisted colonisation/assisted migration/ecological replacement*) (Brodie et al. 2021; Commander et al. 2018; IUCN 2013; Seddon 2010). As a practice associated with conservation aims, long-term translocation success is commonly defined as the establishment of a self-sustaining population (Menges 2008) that aims to retain sufficient genetic variation to adapt to environmental changes (DSEWPC 2013; IUCN 2013). Where translocation is applied to vegetation communities, as opposed to species, the aims do not differ; however, the methods and planning are more similar to those used in restoration ecology (see Fahselt 2007 for a synthesis); as such this paper addresses only species-centred translocations.

The frequency of plant translocation has increased dramatically in the past four decades (Armstrong et al. 2019; Brichieri-Colombi and Moehrenschlager 2016; Silcock et al. 2019; Julien et al. 2022a), with further increases forecast (Swan et al. 2018; Zimmer et al. 2019). Translocations have been used to recover plant populations declining due to a diverse array of threats, including climate change (Lunt et al. 2013; Vitt et al. 2010), pollution, and sedimentation (Ferretto et al. 2019; Paoli et al. 2020), restricted gene flow (Weeks et al. 2011) or habitat fragmentation (Dalrymple et al. 2012; Monks and Coates 2002). However, the greatest threat to plant biodiversity is habitat loss or degradation of populations by anthropic developments (Millenium Ecosystem Assessment 2005; Corlett 2016). Consequently, many countries have legislation which limits (or is intended to offset) the impact of land destruction on wild populations or threatened species (Harrop 1999; Maron et al. 2018, 2016). Translocations are often an integral part of the approach to limit these impacts (Germano et al. 2015; Liu et al. 2015) and development-driven translocations increasingly contribute to the global rise in recorded plant translocation projects (Julien et al. 2022a; Silcock et al. 2019; Liu et al. 2015). Despite this rising trend, there is uncertainty regarding the efficacy of such a method to offset biodiversity loss both in the academic literature (Allen 1994; Berg 1996; Bradley et al. 2021) and in governmental legislation (e.g. Australia, DSEWPC 2013, Canada; Henderson 2011). This uncertainty is largely due to the variability of success (Liu et al. 2012), even in well-designed conservation translocation programmes. However, the lack of clear definitions and standards, as well as constraints on time and resources, exacerbate the negative prospects and outcomes for mitigation translocations.

Reviews of the success of plant translocations as a conservation practice have identified mixed results (Albrecht et al. 2011; Godefroid et al. 2011; Guerrant 2012; Liu et al. 2015). The causes of failure are diverse but can include insufficient consideration of the ecology-specific requirements and life history traits of the translocated species (Julien et al. 2022a; Reiter et al. 2016; Turner et al. 2017), poor habitat suitability at recipient sites (Albrecht et al. 2019; Godefroid et al. 2011), small population sizes insufficient to buffer transplant shock or form a self-sustaining population (Guerrant and Fielder, 2004; Silcock et al. 2019) and stochastic events, such as extreme weather (Liu et al. 2012). Other factors associated with failure include inappropriate management of threats, inadequate timelines, and poor maintenance procedures (Brichieri-Colombi and Moehrenschlager 2016; Julien et al. 2022a). Consequently, best practice guidelines have been developed in various countries (Commander et al. 2018; CPC 2018; National Species Reintroduction Forum 2014; IUCN 2013) to preserve populations by creating or bolstering genetically diverse populations using both in situ conservation and supplementary ex situ collections, allowing them to self-sustain in the wild (IUCN 2013). However, the success of translocation to effectively preserve species or populations is debated (Drayton and Primack 2012; Klein and Arts 2022; Lesage et al. 2020). It depends on ecological and species-specific processes outlined above, as well as appropriate translocation protocols (Reiter et al. 2016), resourcing (Zimmer et al. 2019), and stakeholder and community support (Brichieri-Colombi and Moehrenschlager 2016; Klein and Arts 2022).

What happens when translocation is applied to offset or mitigate the impacts of proposed developments? Whilst mitigation translocations are used as part of a suite of actions (Salzman et al. 2018) to achieve 'no net loss' (Maron et al. 2018), they do not, in most cases, follow best practice translocation guidelines, nor is their outcome sufficiently monitored (Julien et al. 2022a, b). There is thus concern about the

Table 1 Selection of representative definitions of Mitigation Translocation presented by year of citation

Citation	Type	Origin	Naming	Definition
Maunder (1992)	Article	International	Reintroduction Translocation	translocations undertaken ….as mitigation against land development
Berg (1996)	Book Chapter	The USA	Mitigation translocation	'..a general term used to describe a wide variety of actions taken to avoid, reduce, or compensate for the adverse impacts of development'
DSEWPC (2013)	Policy Statement	Australia	Salvage translocation	Translocation is ' … proposed as mitigation, compensation or offset for impacts on a species or its habitat as a result of actions referred under the EPBC Act [Commonwealth Environmental Legislation]…Salvage translocation involves the relocation of animals or plants from an area adversely affected by development to an area reserved or protected from ongoing impacts'
Germano et al. (2015)	Article	International	Mitigation translocation	'Translocations that are implemented in response to legislation or governmental regulation, with the intent of reducing a development project's effects on animals or plants inhabiting the site. These translocations are therefore, by nature, reactions to immediate anthropogenic threats to species under governmental protection'
IUCN (2013)	Guidelines	International	Mitigation translocation	'Involves the removal of organisms from habitat due to be lost through anthropogenic land use change and release at an alternative site. Permission for these development operations is often conditional on an obligation to mitigate or offset the impacts of the development. This is then claimed to be met by the translocation of individuals of key species from the site to be developed for release into further 'wild' sites'
CPC (2018)	Guidelines	USA	Mitigation	'Mitigation is a legal term for an action that is taken to offset the adverse impacts of development on US-listed species. For example, a parcel of land where a species occurs may be preserved as mitigation for developing a portion of the species' habitat'
Bradley et al. (2021)	Article	International	Mitigation translocation	'…. a subgroup of conservation translocation, categorised by a crisis-responsive time frame and the immediate goal of relocating individuals threatened with death'
Hennessey et al. (2021)	Article	USA	Mitigation translocation	'a class of projects designed primarily to translocate individuals away from the development site, with little or no effort to address habitat loss or enhance species conservation'

ability of mitigation translocations to complement genuine offsets of development impacts, where the practice is limited by pressures of rapid timelines and competing goals aimed at enabling development objectives (Bradley et al. 2021; Gardner and Howarth 2009; Germano et al. 2015). Despite being mandatory in many countries, outcomes are often difficult to verify due to client confidentiality (Doyle et al. 2022) or lack of published records (Gardner and Howarth 2009; Silcock et al. 2019). Additionally, most recipient sites are fragmented habitat or on land with unsecured tenure (~98%; Silcock et al. 2019). This is despite the process being, usually, well-funded (Germano et al. 2015; Julien et al. 2022b; Liu et al. 2015; Maunder 1992). Where reports are accessible, outcomes are mixed (Bradley et al. 2021; Germano et al. 2015; Liu e t al. 2012), and consequently, the process is cautioned as high risk and 'usually not effective' (Australian federal government; DSEWPC 2013). There are concerns that mitigation translocations foster development (Allen 1994; Kaye 2008) 'with little or no effort to address habitat loss or enhance species conservation (Hennessy et al. 2021)'.

To address the reported concerns surrounding the effectiveness of mitigation translocations, this paper aims to guide turning plant mitigation translocation into a coherent and effective conservation action. In detail, we a) propose a definition for mitigation translocations which includes conservation objectives, b) provide an overview of the mitigation process in different parts of the world, c) sum up the issues related to mitigation activities, and finally, d) nominate global standards to which all mitigation translocation

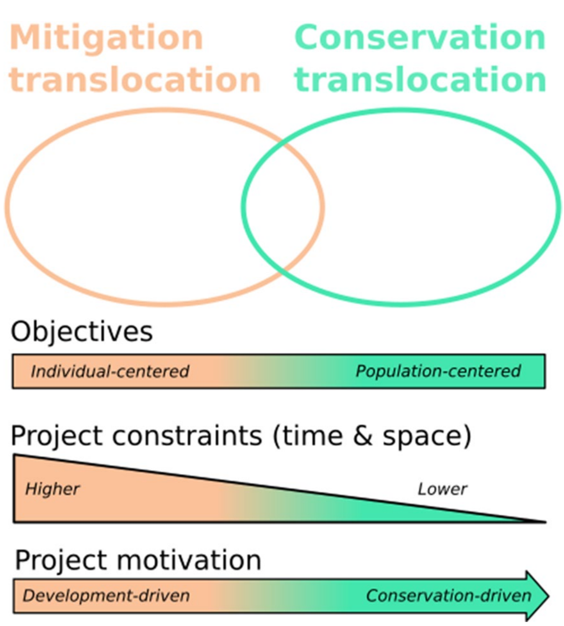

Fig. 1 Diagram representing the interplay between conservation and mitigation translocation. The objectives, project constraints and organisation differ between the two approaches but can coincide when mitigation projects set high conservation standards

proposals should adhere to turn process oriented projects into those with genuine net conservation gain.

Defining mitigation translocation

The earliest known and documented mitigation translocations were in the mid-1980s, occurring in the United States of America (USA) (Guerrant 2012), China (Liu et al. 2015), and Europe (Julien et al. 2022a). The first plant reintroduction documented by the Center for Plant Conservation Reintroduction Database is a mitigation translocation conducted in 1985 (Guerrant 2012). The term 'mitigation translocation' was first discussed in detail by Hall (1987) concerning extensive transplantations of plants occurring across California, USA, in response to development. Since then, various definitions have been applied (Table 1), all agreeing that mitigation translocation is implemented to save individuals of a species from a threat caused by anthropic development. Some definitions view mitigation-driven translocations as a subgroup of conservation translocations (Bradley et al. 2021; IUCN 2013). Others distinguish mitigation-driven translocation as unique, based on two key differences: objectives and crisis-responsive timeframes (Hennessy et al. 2021; Maunder 1992).

First, the objectives of mitigation translocations may differ from conservation ones. Conservation translocations aim to generate a measurable conservation benefit at a population (or species/ecosystem) level (IUCN 2013). By contrast, most mitigation translocations aim to meet legislative requirements by preserving individual-protected entities (Harrop 1999) to expedite development (Fig. 1). Consequently, mitigation translocations can constitute salvage operations to preserve individuals by moving them to other natural locations or can include the ex situ propagation of plants for subsequent planting, in nature, to compensate for those lost. This salvage or like-for-like approach means the outcome, in terms of success, is not straightforward. For example, suppose a mitigation translocation involves moving ten individuals into an extant population of a thousand. In that case, the translocated individuals are protected from immediate destruction or damage, meeting legislative requirements, but the population benefit remains equivocal unless there is an explicit genetic programme to quantify the added value to the recipient population. Alternatively, the ten individuals may be translocated into a new habitat with limited connectivity to other populations of the same species (Silcock et al. 2019), in this case establishment of a self-sustaining population becomes a concern, where minimum viable population numbers aren't met (Jamieson and Allendorf 2012). In both examples, the survival of translocated individuals will ensure that 'no net loss' can be claimed even though there may be population level or genetic losses.

Second, the crisis-responsive timeframe and administrative constraints associated with development projects can

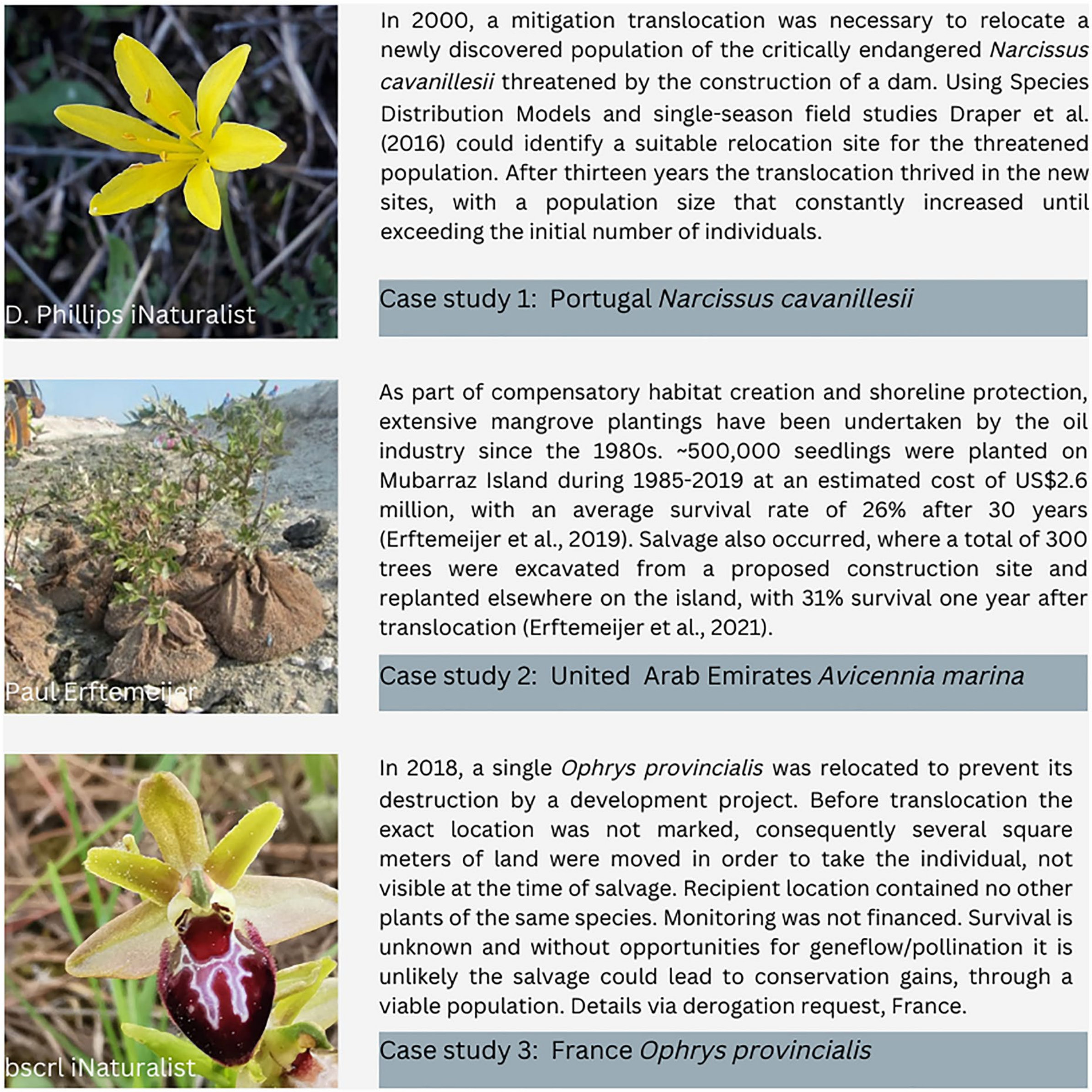

Fig. 2 Three case studies from mitigation translocations representing diverse situations where mitigation programmes included a translocation action

affect the translocation process. Short timeframes (Berg 1996; Germano et al. 2015) and lack of planning might limit the experimental approaches that require time to conduct ecological research, field test, and optimise planting strategy (Liu et al. 2012), as well as reducing opportunities to consult with species experts. Often the project completion timeframe, or mandated monitoring period outlined by consent authorities, is inadequate to evaluate the outcome, either at an individual or population level. Evaluating a translocation outcome can require decades of monitoring, depending on the species biology (Albrecht et al. 2019; Monks et al. 2012). The project's spatial constraints, in terms of available recipient locations, may also lead to a mismatch between the host habitat and the preferred or required ecological niche of the translocated species (Maschinski et al. 2012; Reiter et al. 2016; Ren et al. 2010) or be insufficient in size and connectivity to support a long-term viable population (Silcock et al. 2019).

However, the frontier between mitigation and conservation translocation is permeable (Fig. 1). Some mitigation translocations can be considered conservation if the project objectives are aligned with conservation standards (Fig. 2, Case study 1). Therefore, the IUCN (2013) uses the term mitigation translocation within a conservation framework. Indeed, the IUCN (2013) apply a clause that the outcomes are dependent on location and motivation and that 'rigorous analysis and great caution should be applied when assessing potential future conservation benefits [of mitigation translocations] and using them to mitigate or offset current development impacts'.

Currently, for mitigation translocations to meet the expectations of legislation, they are required to protect threatened entities and, in best case scenarios, achieve no net loss. These expectations do not present a conservation gain or measurable benefit at the population or species level because of numerous process-driven issues discussed above. To achieve a measurable benefit, we propose that mitigation translocation must be redefined as not simply a '*legal term for an action that is taken to offset the adverse impacts*' (Commander et al. 2018) but foremost as a conservation-driven endeavour with outcomes no worse than would have occurred if the development had not taken place. These outcomes would reflect every aspect of the species' status and ecology so that 'no net loss' is interpreted in its broadest and most stringent sense. We propose redefining mitigation translocation as *'a translocation explicitly to offset the negative impacts of the development, with the express aim of providing a measurable benefit to the species through quantified no net loss and viability of populations equal to or exceeding what would have occurred in the absence of the development.'*

The remainder of this article presents the underlying rationale for including concepts such as 'quantified no net loss' in the working definition and is which can be validated through comparison with wild reference populations, long-term monitoring or population viability analysis.

A diversity of legislative pathways

The number of countries practising mitigation translocations is unquantified; however, at least 37 (equating to 18.8% of the world's 197 countries) have incorporated a voluntary or legislated payment for ecosystem service mechanisms which aim to offset or mitigate biodiversity impacts of human-mediated disturbances (GIBOP 2018). Most nations employing these mechanisms have environmental legislation, and although the sector has an estimated value of US$2.5–8.4 billion per annum, transparency is a problem (Salzman et al. 2018).

Many countries have environmental protection laws but the application of these can vary, based on federal, state or county jurisdictions (e.g. USA; S1) or rely on the encouragement or oversight of external forces, such as professional botanists, community groups or concerned individuals (e.g. China; S1). Examples of translocation applications within environmental protection laws are included in Supplementary Material S1. Despite variance in the application of relevant law, the underlying legislative mechanisms to offset or mitigate impacts often include derivations of a four-step hierarchy: Avoid, Minimise, Restore, and Offset (BBOP 2012; Berg 1996) and include some form of Environmental Impact Assessment (Morgan 2012). The translocation of plants can be applied within the four-step hierarchy in varying locations, depending on the regulators' perspective. In France, for instance, translocation falls under a minimisation action or accompanying measure (when translocation occurs within or outside the impacted site, respectively) (Julien et al. 2022a). However, the practice equally fits within planning tools to offset developments (Kujala et al. 2022; Maron et al. 2018) or may be incorporated with larger restoration scale actions (Evans et al. 2021; Maron et al. 2012). As demonstrated by Doyle et al. (2022), accessing specific details of mitigation translocations can be difficult, and consequently, some case study examples have been drawn from personal experience and grey literature (Supplementary Material S1).

Most commonly, translocations are undertaken by environmental consultant companies hired by the agencies that are benefitting from the development (e.g. Australia, the USA, Canada; S1). These companies undertake environmental assessments, and consequently, the interpretation of the extent of impacts can vary. Translocations may also be administered internally by government departments (e.g. Chile; S1) or may be ad hoc by proponent developers where concepts of social responsibility or social pressure are applied (e.g. UAE and China; S1). The commonality between nations appears to be an inconsistency in translocation protocols, maintenance, and monitoring duration and lack of compliance. Most nations apply a variation of the Environmental Impact Assessment process and, in theory, prioritise avoidance (Supplementary Material S1).

Key issues of mitigation translocations

Plant translocation is a costly and resource-intensive process with mixed success (Dalrymple et al. 2012; Godefroid et al. 2011; Julien et al. 2022b; Liu et al. 2015; Maunder 1992). Silcock et al. (2019) found that 45% of all plant translocations had a < 50% survival after one year, which illustrates the difficulty of achieving no net loss unless plans anticipate attrition. Although mitigation projects often include large budgets (for instance, US$1.5 million (equiv.) dedicated to translocating species impacted by China's Hongshui River hydropower plant project; Liu et al. 2012), translocations designed to offset anthropic conflicts are less likely to succeed than those originating in a conservation context (Fischer and Lindenmayer 2000; Germano et al. 2015; Sullivan et al. 2015). Compounding the many ecological factors which can limit translocation success are factors unique to the mitigation process. Of all the factors impeding conservation outcomes in mitigation translocations, four stand out: the lack of clear conservation targets or measures of success, the impact of the project constraints, the absence of a regulation institute and the lack of coordination amongst projects to assess cumulative impacts. In this section we examine these four main factors. A complete list of issues impacting mitigation translocations, including issues common to conservation translocations, is included in Table S1.

Lack of clear conservation target

Evaluating translocation success is critical to assessing the validity of the mitigation action to offset or mitigate the development impact. However, the lack of conservation-centred aims, such as a self-sustaining population (Menges 2008) and net improvement of the conservation outlook (DSEWPC 2013), means that it is impossible to compare success between mitigation and conservation projects (Gardner and Howarth 2009; Pavlik 1996). Further without conservation-centred aims, the translocation method may be inappropriate. Most mitigation translocations aim to directly salvage individuals from imminent destruction (i.e. salvage translocation; Silcock et al. 2019), where avoidance (as per the 4-step hierarchy) cannot be achieved. Thus, the success of such a project is often legally associated with like-for-like targets of no net loss measured through the survival of the impacted individuals. However, direct salvaging rarely achieves no net loss as the stress induced by transplanting inevitably leads to some attrition (Erftemeijer et al. 2021; Pavliscak and Fehmi 2021) (Fig. 2, Case Study 2). Also, it is impossible to assess the impact of translocation-induced stress on the plant lifespan (compared to expected). Therefore, from the outset, individual survival and no net loss targets are questionable in their effectiveness in mitigating impacts (Bull et al. 2016; Kujala et al. 2022) unless attrition is expected, and augmentation of losses are planned. To demonstrate a genuine offset and, ideally, net improvement, mitigation translocations should prove survival and reproduction is equal to or greater than the number of individuals lost to the development activities through targets aligned with criteria, such as survival, health, reproduction, and recruitment (Godefroid et al. 2016). In instances where loss thresholds are anticipated, additional plants can be propagated to augment attrition (e.g. *Dianella amoena*; GHD 2021).

In addition to net gain, conservation objectives for translocations increasingly incorporate genetic considerations to optimise population fitness, increase adaptability to environmental change and minimise deleterious impacts such as inbreeding, outbreeding depression or swamping (Van Rossum and Hardy 2022; Weeks et al. 2011). For mitigation translocations, this is arguably more complex as it includes both the composition of donor plants from the affected population and the impacts of this composition on the viability of a new or augmented existing wild recipient population (Bragg et al. 2021; Shapcott et al. 2009). Although augmentation may be beneficial by increasing population fitness, its effects may also be negligible when the recipient population is already self-sustaining. Alternatively, augmentation could lead to outbreeding depression or genetic swamping (Van Rossum and Hardy 2022). Although best practice guidelines outline genetic considerations (Commander et al. 2018; CPC 2018), incorporating conservation genetic components with a mitigation project will require collaboration with population geneticists. Additional funding and resources will be required to identify genetically appropriate collections, translocation designs, and conservation targets (e.g. *Philotheca* offset translocation; Shapcott et al. 2015).

Project constraints

The schedule imposed by the development project (and approved in conditions of the consent) usually reduces the time devoted to planning and implementing the translocation. This can lead development proponents to remove individual organisms from a site without following best practice standards of design and experimentation (Gardner and Howarth 2009) outlined in Guidelines (Commander et al. 2018; CPC 2018; National Species Reintroduction Forum 2014). These standards include identifying relevant species biology, physiology, and ecology (e.g. reproductive cues, species-specific pollinator, bacterial and mycorrhizal associations) as well as optimum propagation, growing methods and planting conditions (e.g. nutrient profile or irradiance; Zandonadi et al. 2021). The Guidelines also encourage thorough consideration of species-specific management and maintenance requirements (e.g. pests and diseases, disturbance regimes). These factors are common limitations in conservation translocations and when overlooked in any translocation, compound failures (Table S1). Constraints particularly exacerbated by the mitigation schedule are detectability and accurate species identification, planting design and monitoring timelines.

Evaluating the project's impacts on biodiversity depends first on detectability (Garrard et al. 2015) and appropriate species identification. Assessments require time to detect individuals with varied phenology, ephemeral species and those with climate- and disturbance-sensitive emergence cues, which depending on the season, can vary several orders of magnitude (e.g. Orchids; Bell 2020) or be retained in the soil seed bank. Detectability or misidentification constraints can lead to missing or limiting the recorded occurrence of some species of conservation interest and under-evaluation of the project's impact on those taxa (Garrard et al. 2015). Consequently, proponents could underestimate the extent of the translocation and lose appropriate material during collection, which is especially problematic regarding the genetic diversity captured.

Time constraints can also directly impact planting design and maintenance schedules. In a best practice translocation, the collecting and planting dates should be adjusted to the species' phenology (Albrecht et al. 2019) and when weather conditions are favourable for planting. In addition, the planting protocol needs aftercare provisions to manage threats, such as weed invasion or herbivory. Extreme weather events and climate variables might require supplementary watering through droughts, planting over several vegetative seasons to avoid the impact of extreme climatic years (Guerrant and Kaye 2007) or provision to hold plants until optimal seasonal conditions (Pavliscak and Fehmi 2021). However, the timelines and planning associated with mitigation projects may be too time or cost sensitive to accommodate unanticipated changes to translocation schedules.

Finally, the project's schedule, often approved by regulatory authorities, rarely matches the timeframes required to monitor the outcome of the translocation in terms of long-term survival, the establishment of a self-sustaining population through reproduction and recruitment and net gains to the species (Albrecht et al. 2019). Whilst rapid failure could be evaluated within one to five years of the translocation (Silcock et al. 2019), Godefroid et al. (2011) record a downward trend over the years post-translocation. Seddon (2010) proposes that population viability assessment should extend over ten to twenty years, depending on the species life history. Such timing often exceeds the project schedule, and to our knowledge, no jurisdiction requires a time threshold commensurate with measuring conservation outcomes (IUCN 2013). Thus, the lack of targets associated with conservation outcomes means that the project duration can become the default time for development proponents to invest in a mitigation translocation.

Absence of standardised regulations and accountability

To avoid a net loss of biodiversity, the conduct of a translocation under a legal framework must be evaluated to assess if the resources devoted align with the project goals. Likewise, there must be a method to assess if, and when, the project goals have been reached. This can be achieved through adoption of standards. However, standards applied to mitigation translocations are often inconsistent between countries and approval agencies. For example, standards may be based on expert opinion (e.g. Estonia; S1), the advice of the consultant developing the plan (e.g. Canada; S1) or there may be no regulatory requirements. Instead, compensatory actions can be voluntary undertaken by the proponent developer (e.g. UAE; S1) or at the behest of concerned scientists (e.g. China; S1). The absence of standardised approval agencies (in Australia, Doyle et al. 2022), a lack of transparency in outcomes (Germano et al. 2015; Doyle et al. 2022) and limited resources allocated to state controllers for compliance (in France; Julien et al. 2022a) compounds the problem, through restricting the evaluation of programmes. The lack of legal standards for a minimum effort requirement (time, quantity, success criteria, monitoring, and maintenance) leads to inconsistent approval pathways and compliance (Doyle et al. 2022) and ambiguous interpretations of 'no net loss'. In select cases, net gain is a required success criterion, although it is inconsistently applied, sometimes at the discretion of the development proponent rather than a regulator (e.g. Canada, CH2M 2017) or may change with the transfer of government (e.g. US Compensatory Mitigation Policy 2016, redacted in 2018).

Coordinated conservation and cumulative impacts

Mitigation translocations unevenly impact geographical locations and species (Julien et al. 2022a), but they are often concentrated in urban areas or growth corridors. When many projects impact the same species, attempting to mitigate loss through local translocations may not be sufficient to avoid the global threat to the species. In heavily developed urban landscapes fragmentation leads to smaller habitat patches, with increased distance between them and alters population dynamics because of reduced migration rates amongst extant populations. Depending on the dominant mating system (Charlesworth 2006), the repeated loss of individuals through fragmentation might alter key processes such as pollination efficiency and dispersal dynamics amongst populations (Breed et al. 2015; Ghazoul 2005), meaning small and isolated populations are more likely to suffer from deleterious ecological and stochastic genetic processes (Frankham 2005; Heinken and Weber 2013; Lacy 2000).

Cumulative impacts on a single species must be assessed to properly evaluate its actual conservation status (and limit additional impact) and where identified, genetically optimised translocations may be required (Bragg et al. 2021). Furthermore, a lack of publicly accessible results and data sharing are a barrier to mitigation translocations achieving genuine conservation outcomes where failures are not shared (Doyle et al. 2022; Silcock et al. 2019).

Moving from mitigation translocation to coherent conservation plans

Mitigation translocations have generated ethical concerns amongst scientists and practitioners since the 1980s (California Native Plant Society 1991; Bradley et al. 2021). Despite formal cautions against the practice as a last resort to be used in instances where avoidance is impossible (Cerema 2018; DPE 2019; DSEWPC 2013; National Species

Reintroduction Forum 2014), development projects involving translocation to offset impacts on threatened species seem more acceptable to compliance agencies, even when the likelihood of a successful outcome is unknown (Julien et al. 2022a; Fahselt 2007).

Despite uncertainties, mitigation translocations do represent an opportunity to generate genuine conservation gains if objectives, resources, timelines, and funding align with conservation outcomes (Fig. 2, Case Study 1). Here, we discuss moving from project-centred translocation to ecology-driven translocation. This focus on ecology will increase the likelihood of no net loss and ideally, a net gain in number of individuals and/or population viability. We first focus on improving translocation projects by setting standards based on quantifiable objectives and hierarchised checkpoints. We then propose a governance scheme to turn mitigation translocation into effective conservation actions that rely on data sharing, funding allocation and collaboration amongst conservation actors.

Building efficient translocation plans

Quantifying success and completion criteria

Knowing if a project has been successful requires both defining metrics and timelines for success. Achieving both should then constitute project completion. Mitigation translocations should have the same long-term target as conservation translocations (Menges 2008) and net improvement of the conservation outlook for the species (DSEWPC 2013). Conservation targets aligned with development completion criteria force agencies to move from simple salvage translocation to a population perspective, integrated with national or global conservation objectives.

However, due to the time-sensitive nature of development, as well as the life history of species, it is not always practicable to rely solely on the long-term success criteria of a self-sustaining population. Indicators of a 'trajectory towards success' should also be included as completion criteria and consist of time-dependent milestones or short and medium criteria tailored to life history (Monks et al. 2012; Reiter et al. 2016). For example, long-lived perennial species may not reproduce for decades, meaning success criteria must be centred on survival, health, and a stable translocated population. Regardless, before project completion species-relevant benchmarks or success indicators should demonstrate a) net gain OR b) no net loss AND recruitment rates (sexual or asexual) equal to a benchmark wild population OR c) no net loss and stable or increasing population quantified using count data or Population Viability Analysis (Brigham and Thomson 2003; Menges 2000). Short-term milestones should track progress towards completion criteria and act as trigger thresholds for remedial interventions, such

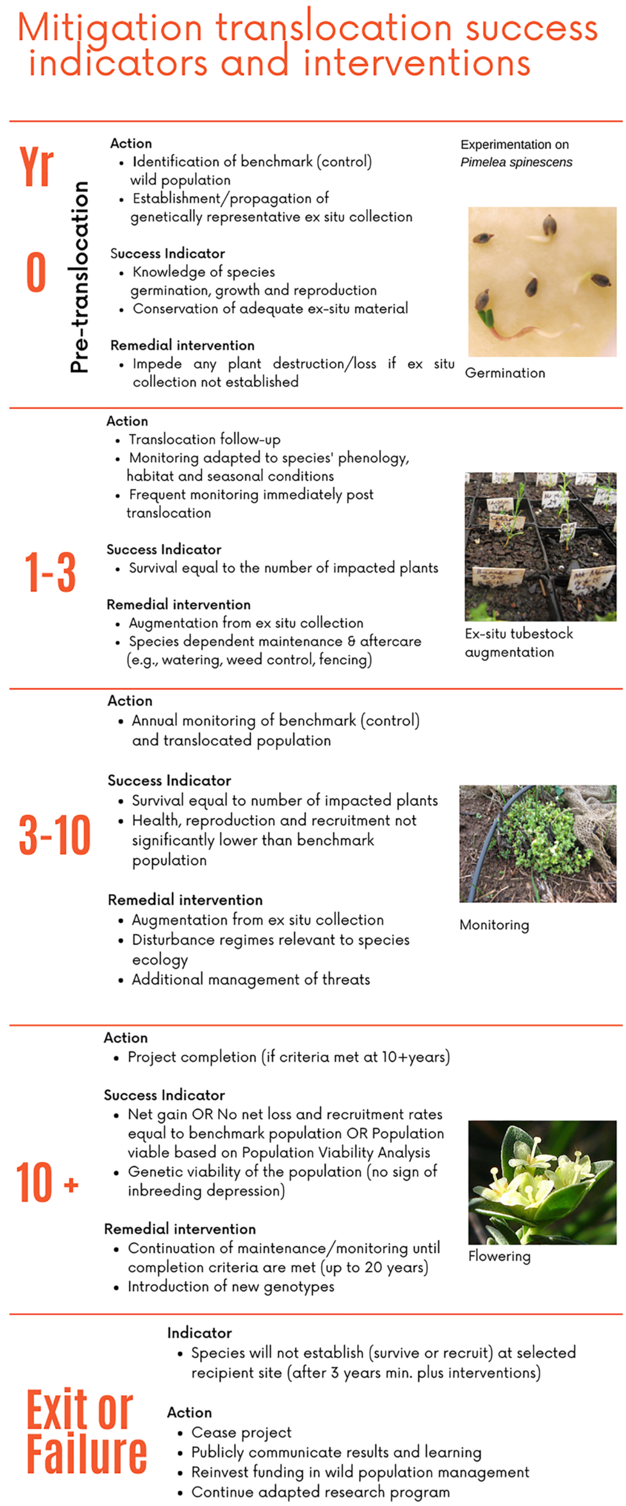

Fig. 3 Mitigation translocation, example translocation for herbaceous species including short-, medium- and long-term success indicators and remedial interventions where indicators are not met. Images D. Reynolds

as augmentation and threat mitigation, where plant numbers in the translocated population fall below no net loss.

In instances success cannot be achieved (i.e. failure) all milestone remedial interventions must have been attempted before exiting the project. An example timeline of actions, success indicators, and remedial interventions is shown in Fig. 3. Notwithstanding, the maintenance and monitoring of the translocation should continue until the completion criteria are met.

Building a minimum consent standard

To obtain consent and align the project with conservation objectives, the proponent must demonstrate that the mitigation translocation will, at a minimum, be equivalent to wild populations or (ideally) have achieved a net gain for the species. This implies that the population created must equal those impacted and that reproduction rates (sexual or asexual) will be equivalent to a wild benchmark or control population (Table 2, Fig. 3). Translocation type (e.g. reinforcement/augmentation, introduction, reintroduction) should also support the assertion of net conservation gain. Reinforcement, for instance, should not be considered a valuable conservation gain where the recipient population is already self-sustaining or where there is a risk of swamping. Instead, reinforcement only should be used in instances of small, declining, or fragmented populations, and supported by genetics (Ottewell, 2015).

Although most mitigation translocations are generally not focused on improving science (Bradley et al. 2021), proposals should still demonstrate planning consideration following best practice Guidelines, including design and feasibility, implementation, monitoring, and adaptive management (Table 2). However, because the dimensions of each project vary, requirements will likewise vary. Practically, standards must be adaptive to fit each project, based on a hierarchy of minimum ecological and logistical needs to achieve a successful translocation.

Planning the project

Mitigation translocations often function as crisis response programmes, where project timelines severely limit the resources devoted to project planning, implementation, and completion (Bradley et al. 2021). However, we must escape the crisis-management program and prioritise species and ecological issues. Due to the unique environmental needs of species and the complexities of identifying suitable habitats and securing tenure, the consideration of translocation should be incorporated in the early phases of the development pipeline. Many development projects have been in the planning phase for years before they undertake ecological assessments. Planning should thus be based on the IUCN (2013) process for scoping, design, and assessment of translocation feasibility, which enables correct planning of key steps of the project.

The evaluation of impact (through impact assessment) should be the first issue to be considered, along with pathways to avoidance. Quantification of impact (physical and genetic) must be incorporated early in the process, with provisions for repeat surveys, due to detectability issues. This also allows practitioners to sample the population and collect material for ex situ conservation.

Second, the planning should demonstrate adequate time to identify and develop appropriate protocols to manage and monitor relevant species' ecological, physiological, and habitat factors (e.g. specific pollinators, mycorrhizae, soil and microclimate, hydrology, sediment, and bioturbation in marine systems; Tomlinson et al. 2022). Such considerations have been applied to less than 5% of the projects in France (Julien et al. 2022a). Planning should also consider factors to promote optimum health of the introduced plants (Commander et al. 2018) and avoid damage to the recipient populations (DPE 2019).

Post-project management and trigger thresholds for remedial intervention must be circumscribed from the start where success criteria are not met (Fig. 3 provides an example). Considerations will include introducing disturbance regimes that facilitate recruitment and/or growth, such as fire (Coates et al. 2006; Monks et al. 2018), biomass thinning (Ruprecht et al. 2010), strategic mowing or grazing (*Aster amellus;* Muller 2002; Smith et al. 2018), or supplementary planting where survival rates fall below no net loss (Fig. 3, Table 2). Additional planning options are included in Table S1.

Finally, although budgets are often much larger in mitigation than conservation translocation projects (Germano et al. 2015; Doyle unpub. data), a clear view of necessary research, planning, and maintenance allows adequate allocation of funds and resources (staff) across the required timeframe, instead of being weighted towards the initial planning and physical movement phase with little allocation towards long-term maintenance (Doyle unpub. data).

Translocation proposal standards

Specific protocols have been developed for frequently translocated species (e.g. *Pimelea spinescens;* PsRT 2013). Where these protocols exist, they expedite the translocation

Table 2 Checklist of standards which should be addressed in mitigation translocation proposals

Mitigation translocation proposal checklist	Standard of translocation		
	1	2	3
Administrative considerations			
Relevant permits and approvals	X	X	X
Project overview; details of impacts to source population and site species, number of impacted individuals, intended translocation type	X	X	X
Secure land tenure and roles clearing articulated and agreed	X	X	X
Completion criteria (e.g. 80% survival after 10 years, evidence of one generation of recruitment)	X	X	X
Measurable project goals with short, medium and long term objectives aligned with survival, reproduction, and recruitment	X	X	X
Specified monitoring and reporting frequency	X	X	X
Thresholds for remedial intervention if goals are not being met (based on life history attributes)	X	X	X
Risk assessment, outlining limitations of the plan effectiveness and risks of off-target impacts to other species and the recipient site	X	X	X
Timeline sufficient to effectively plan, implement, maintain, and monitor	X	X	X
Species expert consultation (where available)		X	X
Current and future threat management protocols (herbivory, stochastic impacts, vandalism)		X	X
Confirmation of and funding for a long-term monitoring and maintenance program of minimum duration (e.g. 10 years) or until the population is determined (likely) self-sustaining		X	X
Specified interventions if goals fall below set thresholds (e.g. augmentation ongoing annually until 80% survival retained for five years)		X	X
Confirmed handover strategy outlining who/how the translocated population will be monitored post-completion		X	X
Efforts to engage with relevant stakeholders (research, government, community, traditional custodians)		X	X
Data and reporting repository details or transparency		X	X
Consideration/evidence of cumulative impacts			X
Integration of translocation plan within landscape connectivity framework or territorial landscape planning/conservation planning			X
Ecological considerations			
Species background, including conservation status, population size, ecology, physiology, and life history relevant to assigning project goals	X	X	X
Site suitability assessment (soil, hydrology, aspect, vegetation assemblage)	X	X	X
Consideration of propagule type (adult salvage, vegetative part, tubestock, seedling or seed) based on known or similar species	X	X	X
Consideration of ex situ germplasm conservation methods for insurance augmentation (using best practice Guidelines, e.g. Martyn-Yenson, 2021)	X	X	X
Hygiene, pathogen, and disease management protocols	X	X	X
Multiple translocation blocks (as insurance) and a combination of propagule types (seed and tubestock)		X	X
Identification and monitoring plan for benchmark (control) wild population against which success criteria can be tracked		X	X
Examination of source population composition and structure (e.g. sex ratio, age, spatial arrangement, genetic relatedness) and how this will be reflected in the translocated population		X	X
Adaptive management of the site in response to species' requirements (e.g. maintaining fire, grazing, or other disturbance, or undertaking biomass thinning)		X	X
Examination of limiting factors to the establishment – disease and pathogen sensitivity, mycorrhiza, unique pollinators, reproductive, or germination cues (e.g. fire, temperature thresholds)		X	X
Pilot translocation to identify limitations and refine protocols			X
Population viability analysis			X
Species distribution modelling (SDM) to confirm future climate habitat suitability			X
Population genetics to optimise collection and planting protocols			X
Analysis of metapopulation dynamics and connectivity between translocated and wild populations			X

Standards should be assigned (or agreed to) by relevant planning approval or compliance agencies. Level divisions are provided as examples only. Level 1 represents the minimum standard and should only be approved in small-scale, individual or community projects (e.g. < 10 plants, local groups seeking small-scale developments or single residence expansion). Level 2 presents a general standard that should be considered for most translocations (e.g. urban developments or small-scale infrastructure). Level 2 should not be considered if the translocation applies to an entire local population or may result in a local extinction if it fails. Level 3 should be applied to all government-led or large-scale projects, such as mining and industry, when resources are available to support industry leading, best practice standards. Level 3 should also apply to translocations where large numbers of individuals or over half the local population are being impacted. Evidence must be provided to regulatory or consent authorities that all factors have been considered when preparing a proposal. Table S1 expands on these considerations to address specific issues. Compliance or adherence to Standards should be undertaken by nominated authority process, ensure consistent standards, and can provide regulators and compliance agencies with guidance on success targets and trigger thresholds for remedial intervention. However, such protocols do not exist for most species. Furthermore, the paucity of data sharing limits the ability to improve standards (See Key issues of mitigation translocations).

Where specific protocols are absent, we propose the adoption of translocation proposal standards which incorporate planning and are based on administrative and species-specific ecological factors (Table S1, Table 2). Mitigation translocations, although legally required, will differ in their footprint (number of individuals destroyed), scope, and the initial size of the impacted population. For example, in Australia, private citizens and large corporations may be equally required to mitigate impacts on threatened plants. However, the scope and resources at the disposal of each will vary. To consider these differences, we provide a checklist of actions (Table 2) within a hierarchised framework that distinguishes basic, normal, and gold standards of mitigation translocation. Many of the items within these actions are derived from existing Guidelines (Commander et al. 2018; CPC 2018) and policies (DPE 2019), which should be referred to for more detailed information. However, our checklist also addresses key gaps in the planning process, which are unique to mitigation translocations.

This checklist can be utilised by ecologists when developing translocation plans and considered by approval agencies to assess the strength of a translocation proposal as an undertaking that mitigates impact. To be widely adopted, translocation standards should be relatively straightforward and adaptable based on species, project scope, footprint, and funding whilst also accommodating the inherent variability between resources provided to compliance agencies. Although we propose three levels of standards, with example instances where they apply, assigning acceptable standards remains the remit of development approval or compliance agencies.

Improving project governance to build coherent conservation plans

The global increase in offsetting and mitigation processes (Evans et al. 2021) reflects a growing attempt to manage the impact of direct destruction and land use on biodiversity. However, as with offsetting (Kujala et al. 2022), the translocation process requires joint actions and a commitment across stakeholders and state/national borders to achieve gains. A global framework is required to reinforce key points of governance: sharing knowledge of mitigation translocation, facilitating joint actions for conservation plans, and securing funding and resources commensurate with conservation-focused timelines.

Share knowledge

Quantifying translocation outcomes and identifying species-specific techniques are only possible with a public centralised repository or database. Multiple authors have called for global and regional plant translocation databases (Godefroid et al. 2011; Godefroid and Vanderborght 2011; Liu et al. 2015), as well as the publication of client reports protected by confidentiality agreements (Silcock et al. 2019; Doyle et al. 2022), each of which could enhance translocation efficiency and optimise procedures.

A translocation database also aids in tracking cumulative impacts, that is, the frequency and extent of mitigation translocations impacting the same species and can inform consent standards. A translocation database can also help regulators determine what impact is acceptable and how to adapt the translocation conditions of consent accordingly. Consideration of cumulative impacts is already recognised in some environmental legislation (e.g. Canada's Environmental Assessment Act); however, translocations are rarely specifically included in these assessments.

Several initiatives have emerged worldwide to sort translocation project information into databases. We can cite TransPLanta (Spain), ANPC Translocation Database (Aus), TransLoc (Europe and Mediterranean basin), IDPlant (Italy) and Center for Plant Conservation Reintroduction Database (USA). However, many contributions are voluntary and conservation focused and little information comes from mitigation translocations. Additionally, data accessibility is not always free, limiting practitioners' involvement.

We propose, at minimum, a national registry of translocation which record species, source, and recipient location (denatured if required), number of individuals and life stages, outcome, and free access to the technical report. Data could be drawn from mandatory contributions or client reporting and permits (Doyle et al. 2022) and aligned with public Offset Registries (e.g. https://offsetsregister.wa.gov.au/public/home/), which are necessary to reliably trace cumulative impacts (Kujala et al. 2022). Such a database can also be used to preemptively identify species' ecological requirements and refine species-specific protocols. Ultimately, centralisation or communication between existing platforms will enable peer-to-peer learning plus data interrogation by research institutions and regulatory authorities to improve the tracking of cumulative impacts on international scales.

Joint conservation projects

The scale and extent of development footprints vary dramatically, and in some instances, the impact on protected entities might sometimes be limited to a few individuals. For example, in Julien et al. (2022a), 60% of the translocations studied involved less than 50 individuals. In that case, it is hard for regulatory authorities to enforce best practice translocation because of the cost, planning and time constraints associated with achieving conservation-scale outcomes when a small number of plants are impacted (Fig. 2, Case Study 3). For the same reasons, we do not support small independent individual transplants (site-to-site salvage), especially when the recipient population is viable. Alternatively, we encourage joint projects between proponent developers, where costs and processes associated with a best practice translocation can be mutualised, such as the experimental approach to assess germination requirement, ecological niche or genetic structure.

Translocation proposals, whether joint or single proponent, should also demonstrate community and First Nations or Indigenous engagement and multi-stakeholder collaboration (e.g. government agencies/researchers/gardens) to enable sharing of skills, resources, and facilities. We propose one example of an integration model to enhance collaboration (Fig. 4), however, collaborators or responsible roles may vary based on the project scope. In this model, we identify three key actors besides the proponent: the regulation entity, the ecological expert, and the land manager.

The regulation entity is most often attributed to a state agency. Although the organisation of government varies based on region, they generally are responsible for legislation/regulation, proposal review, compliance, and interagency sharing of data (Australia; Doyle et al. 2022). These agencies are or should be, also responsible for tracing cumulative impacts.

Ecological or species experts are typically responsible for assessing environmental impacts, preparing a translocation proposal, providing species-specific advice, conducting experiments or field trials, and undertaking the translocation. Different institutions may fill this role; however, independent consultants often conduct assessments, manage budgets and the project, whilst a botanical garden or conservatory can organise the propagation and translocation. Research centres can be involved in species-specific research where there are gaps in ecological understanding or population viability assessment, which is more reliably based on stable growth rates than the population size, and interpretation can require specialist skills (Robert et al. 2015).

Finally, land managers or natural resource agencies should assist with site selection, maintenance, and monitoring. Their knowledge of fine-scale habitat dynamics is key to ensuring persistence over long-term specific conditions. The groups may include Traditional Custodians, community agencies, or local government.

Joint translocation planning should also consider wider nature conservation programmes, including restoration plans of specified areas or enhancing connectivity between remnant vegetation patches. Therefore, it includes the mitigation

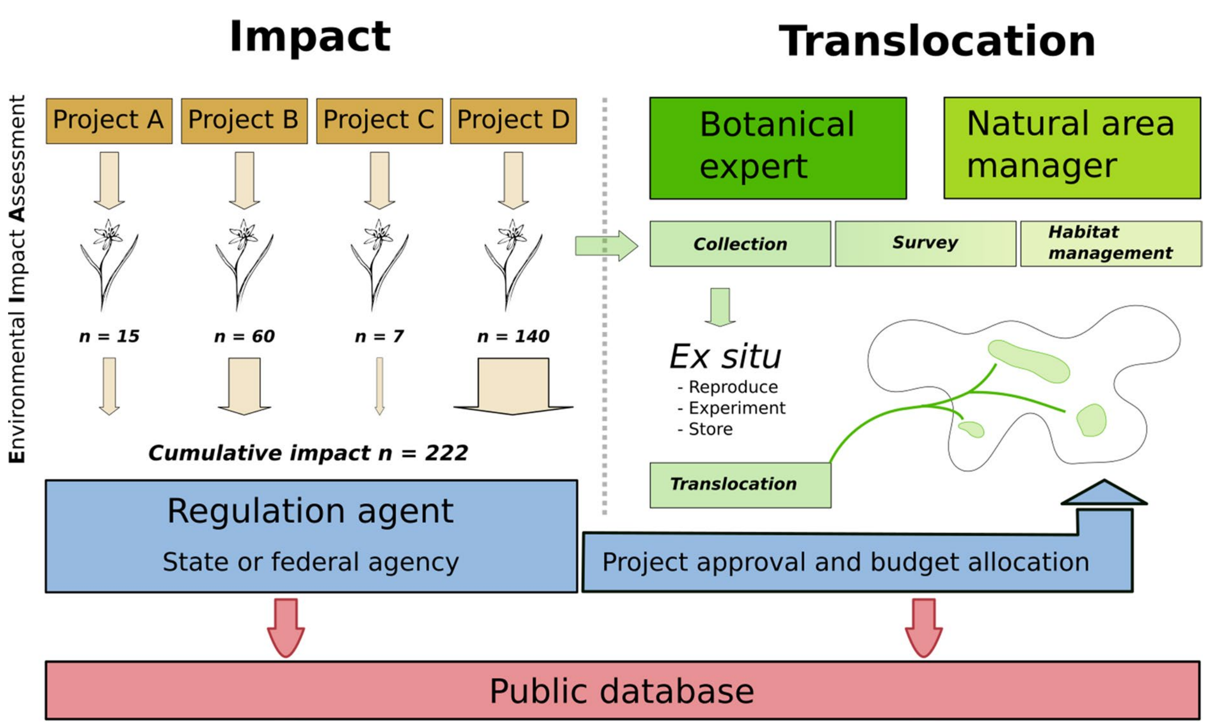

Fig. 4 Example of joint action of several stakeholders and development proponent/s to build a coherent translocation plan, with pooled funding, that will track cumulative impacts

action in a larger perspective that will benefit the whole ecosystem.

Share or distribute funding

Mitigation translocations are usually well funded (Doyle unpub. data; Germano et al. 2015). However, the funding allocation is often uneven, distributed towards the planning and physical relocation phases. Funding may then cease when the development is completed or be insufficient to continue with the maintenance and monitoring required to ensure project success (Doyle unpub. data). As part of minimum standards (Table 2) funding or resources, such as staff, must be adequate for ongoing maintenance, monitoring, and supplementary actions. To achieve this, we advocate several options.

First, the pooling of funding and planning between small projects to build a coherent transplanting program (Fig. 4). In this scenario, the repartition and distribution of financial resources could be managed through a trust, independent third party, internally by member agreement (independently audited) or government regulators. In the final scenario, pooled funding can act as a bond associated with the completion criteria.

Alternatively, funding may be allocated in advance to contractors who undertake the contractual responsibility of population maintenance. The contractors or site managers would then be responsible for delivering translocation completion criteria. Funding could also be allocated for species-relevant research where more knowledge is needed to plan the translocation or demonstrate minimum completion criteria.

Finally, where translocation outcomes are deemed uncertain due to species long generation times or event-specific reproductive cues (such as a fire at long, 20 + year intervals), proponents should fund the management of wild populations at protected sites as a buffer against the net loss of species and as part of cumulative impact avoidance. We also propose a small levy on all translocation projects to fund the maintenance of a registry or database, which will facilitate data sharing.

Further considerations

In situ biodiversity management must remain the principle of conservation, with the risks and uncertainties increasing over time due to climate change. Thus, the use of mitigation translocation is cited as a last resort in instances where avoidance (BBOP 2012) cannot be achieved (DPE 2019; DSEWPC 2013). Approval authorities must always assess if avoidance has been considered appropriately before mitigation is considered. Despite mitigation translocation having many limitations in realising no net loss targets, we have proposed solutions to improve the efficiency of the process through this paper. Nevertheless, some challenges remain ahead to further increase our capabilities to moderate biodiversity loss due to direct anthropic impact.

One key challenge to be overcome is international collaboration to adopt a biogeographical perspective in plant conservation, because managing species loss within national borders is no longer sufficient (Brodie et al. 2021). Governing bodies must homogenise standards to progress towards shared conservation. Data sharing and collaboration between species conservation and translocation projects could minimise cumulative impacts, facilitate habitat connectivity and promote robust population structure in target species. However, important barriers must be removed, particularly when legislation differs across countries. Recent international projects such as the European Life project Seed Force set the path towards global action plans for conserving flora. Applying consistent translocation standards, outlined in this paper, represents the first step towards genuine mitigation of impacts and conservation gains.

The success and completion criteria for vegetation community translocations will vary from the benchmarks proposed above and are not dealt with explicitly in this paper. However, success criteria should be based on restoration targets such as those outlined by the Society for Ecological Restoration, where many countries have region-specific National Standards (SERA 2021). Where vegetation community salvage has occurred, measures of success and completion are often based on the complexity of floristic diversity against a baseline or benchmark community (e.g. Dufourq and Shapcott 2019). Future discussions about success and completion criteria for vegetation community mitigation are required.

As part of choosing a future where biodiversity continues to be maintained, we need to critique legislation that does not meet these goals and propose valid options for improving conservation outcomes alongside sustainable development (ICSU/ISSC 2015). The idea of compensating for a biodiversity loss is laudable, but the long-term commitments required to assess translocation success currently weaken the process. Consequently, a paradigm shift is needed regarding implementing the mitigation procedure. This shift requires moving from process-driven mitigation to an obligation for consistent standards and transparent, accurately evaluated results. Hence, the mitigation process would end when the no net loss is scientifically proven.

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Authors and Affiliations

Chantelle A. T. Doyle[1] · Thomas Abeli[2] · Matthew A. Albrecht[3] · Joe Bellis[4] · Bruno Colas[5] · Sarah E. Dalrymple[4] · Andreas Ensslin[14] · Jaime Espejo[6] · Paul L. A. Erftemeijer[10] · Margaux Julien[7] · Wolfgang Lewandrowski[9] · Hong Liu[8] · Axel Moehrenschlager[15] · Mark K. J. Ooi[1] · Deborah M. Reynolds[13] · Bertrand Schatz[16] · Mari Sild[11] · Timothy J. Wills[12] · Guillaume Papuga[17]

[1] Centre for Ecosystem Science, University of New South Wales, Sydney, Australia

[2] Department of Science, Roma Tre University, Rome, Italy

[3] Center for Conservation and Sustainable Development, Missouri Botanical Garden, 4344 Shaw Blvd., St. Louis, MO, USA

[4] School of Biological and Environmental Sciences, Liverpool John Moores University, Liverpool, UK

[5] Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Systématique et Evolution, Orsay, France

[6] Laboratorio Productos Naturales y Botánica, Pontificia Universidad Católica de Chile, Santiago, Chile

[7] Ecotonia, Eguilles, France

[8] Department of Earth and Environment and Institute of Environment, Florida International University, 11200 SW 8th Street, Miami, FL, USA

[9] Kings Park Science, Department of Biodiversity Conservation and Attractions, Kings Park, WA, Australia

[10] School of Biological Science, University of Western Australia, Crawley, WA, Australia

[11] Tallinn Botanic Garden, Tallinn, Estonia

[12] The Ecology Office, VIC, Warranwood, Australia

[13] Victoria University, Melbourne, VIC, Australia

[14] Conservatory and Botanic Garden of the City of Geneva, Geneva, Switzerland

[15] IUCN Species Survival Commission Conservation Translocation Specialist Group, Calgary, AB, Canada

[16] CEFE, CNRS, University of Montpellier, EPHE, IRD, Montpellier, France

[17] AMAP, Univ Montpellier, CIRAD, CNRS, INRAE, IRD, Montpellier, France