Mitigation translocation as a management tool

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In the absence of high standards of planning and monitoring, mitigation-translocation managers may be second-hand agents of biodiversity loss.

Abstract

Mitigation translocation is a subgroup of conservation translocation, categorised by a crisis-responsive timeframe and the immediate goal of relocating individuals threatened with destruction. However, the relative successes of conservation translocations with longer timeframes and broader metapopulation and ecosystem level considerations have been used to justify the continued implementation of mitigation translocations, without adequate *post-hoc* monitoring to confirm their effectiveness as a conservation management tool. Mitigation translocations now outnumber other conservation translocations, and understanding the effectiveness of mitigation translocations is critical given limited global conservation funding – especially if the mitigation translocations undermine biodiversity conservation by failing to save individuals. We assessed the effectiveness of mitigation translocations by conducting a quantitative review of the global literature. We found that mitigation translocations are not yet achieving their potential as an effective applied science, with most translocations focused predominantly on population establishment level questions, as is often seen in translocations more broadly, and less focus placed upon metapopulation and ecosystem outcomes despite these factors being more likely to influence ultimate success. Only a handful of studies included comparison of different management techniques to facilitate practitioners selecting the most effective management actions for the future. To align mitigation translocations with the relative success of other conservation translocations, it is critical that future mitigation

translocations conform to an established experimental approach to improve their effectiveness. Effective mitigation translocations will require significantly greater investment of time, expertise and resources in the future.

Introduction

One of the hallmarks of the Anthropocene is that wildlife extinctions are occurring at a rate thousands of times greater than background species losses (Ceballos et al. 2010). This rate is predicted to increase (Johnson et al. 2017), suggestive of a mass extinction event. A major contribution to this rate of extinction is the loss of populations due to habitat loss and land-use change (Foley et al. 2005). Intensive conservation actions, such as translocations (Beeton et al. 2010), have been recommended to mitigate the magnitude of these losses (Thomas 2011; Boyer et al. 2016). According to the IUCN (2013), conservation translocations are a demand-driven practice concerning “the deliberate movement of organisms from one site for release in another. It must yield a measurable conservation benefit at the levels of a population, species or ecosystem, and not only provide benefit to translocated individuals.” Mitigation translocation is a supply-driven subset of conservation translocation, and is “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” (Germano et al. 2015). Therefore, compared to the goal of augmenting or enhancing the viability of recipient populations for long term conservation benefit, the trigger for mitigation translocations is to prevent the mortality of the at-risk founder individuals (e.g. nuisance animals; Massei et al. 2010), populations (e.g. at a development site; Germano et al. 2015, Nally & Adams 2015), or a threatened taxon with the known global population threatened by human activity. Despite only slight differences in triggers and timescales between mitigation and other conservation translocations, the IUCN (2013) states 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". What remains to be understood is whether mitigation translocations currently do adhere to such rigorous analysis and design prior to implementation, and if they do not, whether it is possible for mitigation translocations to absorb the extra requirements of time and finances to do so. It is, therefore, disadvantageous to global conservation to ignore these two subgroups of translocations and the relative success of other conservation translocations should no longer be used to justify the continued use of mitigation translocations (Germano et al. 2015).

Translocation is often expensive (Caldecott & Kavanagh 1983; Maunder 1992; Carter & Newbery 2004; Seddon et al. 2005), and the success of translocations must be maximised to best use the limited global funding available for biodiversity conservation (Waldron et al. 2013). To facilitate better translocation outcomes, Armstrong and Seddon (2008) developed a list of key questions to address during a reintroduction event as one strategy to improve translocation success around the globe (Figure 2). Their questions focus on how a project addresses the population, metapopulation, and ecosystem implications of a translocation (Armstrong & Seddon 2008). At the population level, they consider a site's capacity to support a species and the viability of the founder group to maintain a self-sustaining population (Armstrong & Seddon 2008). This includes considerations of founder behavioural plasticity (Page et al. 2019), pre-release predator exposure (Frair et al. 2007), and habitat suitability (Johnson & Swift 2000). At the metapopulation level, translocations require the optimal allocation of individuals (Wolf et al. 1998), or population reinforcement at translocation sites (Armstrong & Seddon 2008). At the ecosystem level, translocations also have the potential to introduce parasites (Schaffer et al. 1981; Fernandez-de-Mera et al. 2003;

Thompson et al. 2010), disease (Caldecott & Kavanagh 1983; Woodford & Rossiter 1994; Kock et al. 2010), and non-native species (Ruesink et al. 1995; Manchester & Bullock 2000; Olden et al. 2006) into the recipient ecosystem (Armstrong & Seddon 2008). Approximately 1% of translocations result in subsequent environmental harm (Williamson & Fitter 1996). Factors at each of these three levels, therefore, interact to influence the likelihood of long-term translocation success and persistence. Notably, these guiding principles imply that success is characterised not simply by the self-sustained persistence of the translocated individuals or population, but that their persistence is also not damaging to the recipient ecosystem, nor to the metapopulation structure of the focal species as a whole (Armstrong & Seddon 2008).

To facilitate an adaptive approach, translocation projects are encouraged to adopt a scientific rationale to address the key questions in translocation biology (Armstrong & Seddon 2008; Moseby et al. 2014; Daniels et al. 2018). The selection of *a priori* goals prioritises translocation design to answer key questions and assess success through targeted monitoring. Targeted monitoring (such as recording the survival rates of individuals with or without supplementary feeding) is more efficient than unfocused monitoring (such as collecting data for a suite of variables e.g. survival, habitat features, and predator density with no prior plan), as it avoids collecting purely descriptive data unrelated to management (Nichols & Williams 2006; Taylor et al. 2017). Targeted monitoring is also more likely to identify causes of failure and inform future translocation practice to maximise success (Sutherland et al. 2010; Taylor et al. 2017). *A priori* goals, therefore, promote systematic adaptive management practices and increase the chance of future translocation success (Taylor et al. 2017; Daniels et al. 2018) or recovery of a translocation program in the event of a sub-optimal beginning.

The propensity for translocations to consider *a priori* goals (Armstrong & Seddon 2008), as well as other key questions in translocation biology (Table 1), has been recently investigated (Taylor et al. 2017). The trend from translocation studies over the last two decades has shown a promising increase in testing *a priori* hypotheses, although there remains a focus on assessing the short-term establishment of populations rather than the long-term persistence and wider metapopulation and ecosystem level dynamics (Taylor et al. 2017); however, this review did not distinguish between the different types of translocation, and how each responded to the call for more adaptive management.

Mitigation translocations generally receive greater financial support in aggregate than other conservation translocations (Germano et al. 2015), although individual programs are often less well-funded and less co-ordinated in their planning than other types of conservation-oriented programs (such as ACT Government 2017; Sutton 2019). Despite caution from the IUCN (2013) regarding mitigation translocations in offsetting development impacts, the number of mitigation translocations undertaken has substantially increased within the last 20 years (Miller *et al.* 2014; Romijn & Hartley 2016), and now outnumber other conservation translocations (Germano et al. 2015). Mitigation translocations are still regarded by the public as a more humane, species-specific, and effective solution to human/wildlife conflict than traditional culling programs, and this has contributed significantly to their increasing frequency (Massei et al. 2010). While mitigation translocations theoretically reduce wildlife mortality, they have a history of high failure rates (Sullivan et al. 2015). Proponents often fail to monitor the long-term success of such translocations (Massei et al. 2010), and there is often a lack of publicly-accessible results (Nash 2017; Silcock et al. 2019). Furthermore, without the same conservation-oriented goals as other conservation translocations, they often fail to follow scientific best practice (Germano et al. 2015). Consequently, mitigation translocations are rarely represented in the scientific literature (Armstrong & Seddon 2008; Germano et al. 2015; Taylor et al. 2017), perhaps due to a reluctance to report failures (Germano et al. 2015). There is, therefore, a lack of scientific evidence to assess the effective use of mitigation translocation for their intended purpose of reducing anthropogenic wildlife mortality and promoting biodiversity conservation. With high failure rates, a lack of monitoring, and minimal scientific rationale, the efficacy of mitigation translocations is questionable: are the majority of cases simply removing wildlife for a socially acceptable death out of the public eye (phased destruction; Jackson et al. 1983), and, therefore, not an effective management tool (Germano et al. 2015)?

The value of translocations that follow a strategic experimental framework has been strongly advocated (Armstrong & Seddon 2008; Taylor et al. 2017). However, as mitigation translocations are globally underrepresented within the literature (Germano et al. 2015), the increased adoption of a scientific framework is largely informed by other conservation translocations, and it remains unclear whether mitigation translocations follow the same recent recommendations for best practice (Armstrong & Seddon 2008; IUCN/SSC 2013). If mitigation translocations fail to follow accepted scientific best practice (Germano et al. 2015), it is unlikely that their success is being maximised, leading to a waste of conservation dollars. This review aims to determine if mitigation translocations have adopted a strategic, systematic approach to management, and to assess their efficacy as a management tool. We aimed to evaluate whether published mitigation translocations (i) considered the population, metapopulation, and ecosystem level repercussions of a translocation event, (ii) included *a priori* hypotheses (Schaffer et al. 1981), (iii) compared management techniques to inform future management and allow an adaptive approach, and (iv) were more likely to result in a self-sustaining translocated population if each of these factors were considered.

Methods

A quantitative review of the translocation literature was undertaken using Scopus (24 March 2019) to identify all papers that cited Armstrong and Seddon (2008) for the years 2008-2019 inclusive. This search produced 486 publications, which were reduced to 283 by exclusion of non-empirical datasets, publications that could not be sourced in English (Apollonio et al. 2001; Azeredo & Simpson 2004; Yoshio et al. 2009; Barri & Cufré 2014; Jian et al. 2017; Ren 2017; Choperena-Palencia & Mancera-Rodríguez 2018), and publications that were not publicly available (Wacher 1986). The 283 papers were then separated into mitigation-motivated or other conservation-motivated translocations. Publications describing the same translocation event were synonymised, ultimately resulting in a dataset of 59 reported mitigation translocations.

An article search using the search terms 'mitigation AND translocation' on the Scopus database (29 July 2020) returned 200 papers between 2008 and 2020, reduced to 198 post-exclusion of one paper that could not be sourced in English (Born 2015), and one that could not be sourced (Box et al. 2019). Only 28 of the 198 papers were actually mitigation translocations according to our rubric (Table 1). Only one of these 29 papers cited Armstrong and Seddon (2008), the seminal work in the last 20 years on how to maximise the success of a translocation. Therefore, for the purposes of this review, the dataset was derived only from papers that cited Armstrong and Seddon (2008), as a way to more easily locate papers that involved wildlife translocations, rather than studies where the term "translocation" was used in another sense. Furthermore, we felt it critical to identify projects that were clearly aware of the importance of an evidence-oriented project framework. In the context of wildlife translocations, the most highly regarded of such frameworks, judging by citations, is that of Armstrong and Seddon (2008), and we assumed that awareness of this framework underpinned the test of how many studies actually followed the suggested adaptive management framework.

As the IUCN (2013) has encouraged mitigation translocations to follow the same protocols as other conservation translocations, we analysed whether mitigation translocation papers addressed the 10 key questions developed by Armstrong and Seddon (2008) said to be critical in maximising translocation success. The whole body of text from each publication was searched for any consideration of Armstrong and Seddon's (2008) 10 key questions in reintroduction biology (Table 1). 'Question 7' was removed from the analysis due to the assumption stated by Armstrong and Seddon (2008) that all translocations implicitly consider this question and 'Question 10' was removed as none of the studies addressed this question, as most only included a single species translocation. 'Question 2' was divided into part (a) pre-release management and (b) post-release management. Translocations were only considered self-sustaining if reported as such within the publication. Papers reporting model predictions or recommendations were removed from analyses which tested the influence of variables on the self-sustaining nature of a population, as this factor was non-applicable, reducing the dataset to 54 papers. Papers were also categorised according to taxa, and calculated as percentages of the total to understand which groups have the most mitigation translocations undertaken.

To determine whether the questions answered influenced translocations becoming self-sustaining, we analysed a 9x2 contingency table to see if the number of translocations that answered the nine questions (Question 7 and 10 removed, and Question 2 split into two) differed between translocations that were self-sustaining and those that were not. Questions were then grouped into four categories (population establishment (Q1-2), population persistence (Q3-4), metapopulation (Q5-6), and ecosystem (Q8-9)) and analysed using a 4x2 contingency table to determine if translocations that resulted in self-sustaining populations included an equal number of questions from each category.

Mitigation translocation publications were also classified as: (i) no inclusion of *a priori* hypotheses, or (ii) inclusion of *a priori* hypotheses. Publications which stated goals for the paper but were analysing an old dataset (the goals had no influence on the design/structure of the original translocation event) were not considered to test *a priori* hypotheses. To determine whether project success was influenced by the inclusion of *a priori* goals, we used a Fisher's exact test.

To assess whether mitigation translocations applied an active adaptive management approach (Palmer et al. 2016) the dataset was divided into two categories. These were publications that: (i) included one or more management techniques in addition to the translocation, such as supplementary feeding, and (ii) those that did not obviously include a management action other than the translocation intervention. This distinction follows the analysis by Taylor et al. (2017), which investigated whether reintroductions in general were effective as an applied science, and considered the comparison of management actions as "studies that directly assist decisions by explicitly comparing alternative management actions". As the selection of mitigation translocation over inaction in the face of anthropogenic disturbance represents an *a priori* expectation that translocation can avoid wildlife mortality, we only considered "management actions" to include additional management efforts applied in conjunction with the translocation, to assist decision makers to understand the most effective means of mitigation translocation for the future. To determine if implementing management techniques influenced a translocated population to become self-sustaining, we used a Fisher's exact test. A one-tailed *p*-value was selected, due to the assumption that management actions would improve, rather than decrease, the probability of a translocation being self-sustaining.

Chi-square analyses (expected values calculated as 50% of the total) were employed to determine if mitigation translocations were equally divided into self-sustaining and not self-sustaining translocated populations. Chi-squared analyses were also used to determine if more key questions, or more categories (establishment, persistence, metapopulation, and ecosystem) were addressed by different studies. For these analyses expected values were based on the assumption that all questions were equally likely to be addressed.

Results

Most publications focused on mammals (37%), birds (29%), and herpetofauna (19%); invertebrates (2%) were the least considered taxa. Significantly fewer mitigation translocations resulted in self-sustaining populations than non-self-sustaining populations ($\chi^2_1 = 21.41$; $p < 0.001$; Figure 2A). .No difference was found in the questions addressed between self-sustaining and non-self-sustaining translocated populations ($\chi^2_8 = 2.18$, $p = 0.975$).

There was no difference in the number of questions answered within the four categories (population establishment, population persistence, metapopulation, ecosystem) between self-sustaining and non-self-sustaining populations ($\chi^2_3 = 4.78$, $p = 0.188$; Figure 2B and C). There was also no overall difference in the number of questions addressed in each of the four categories ($\chi^2_3 = 2.98$, $p = 0.395$). In total, 66% (39 studies) of all mitigation translocations addressed establishment-level questions in translocation biology, while 78% (46 studies), 58% (34 studies), and 88% (52 studies) addressed persistence-level, metapopulation-level, and ecosystem-level key questions, respectively (non-exclusive). The inclusion of *a priori* goals had no influence in producing self-sustaining translocations (one tailed $p = 0.550$; Figure 3A&B). Testing of management techniques did not produce more self-sustaining translocations than those that did not (one-tailed $p = 0.611$; Figure 3C&D).

Discussion

Less than one quarter of mitigation translocations resulted in the establishment of self-sustaining populations. As there is likely a strong bias by consultants contracted by private companies against publishing unsuccessful translocation efforts, the overall proportion of self-sustaining populations is likely to be lower than we found. This supports previous evidence that successful outcomes are less likely for translocations driven by factors such as economic motivations or human-wildlife conflict rather than primarily conservation motivations (Fischer & Lindenmayer 2000; Germano et al. 2015; Sullivan et al. 2015; Wolfe et al. 2018). 'Success' in mitigation translocations is also less likely to be considered as the establishment of a self-sustaining population. For many mitigation translocations, the end result is considered the effective resolution of the human-wildlife conflict rather than any longer-term goals of establishing new populations (Massei et al. 2010).

Although many mitigation translocations can involve threatened species, as was found in this review (89% of studies), they can also involve abundant or relatively common species, where conservation-oriented factors such as population viability are less likely to be considered (Massei et al. 2010). We found mitigation translocations largely ignored the wider implications of a translocation event at the metapopulation and ecosystem level. Where specific research questions were included in planning, mitigation translocations focused on a small number of readily-answerable questions principally around whether the focal species was native to the recipient ecosystem (Q8) and the appropriate population size (Q1) and suitable habitat (Q3) for the translocation. Establishment-level questions are generally easier to answer but are not usually the ultimate determinant of translocation success (Armstrong & Seddon 2008). Whilst the majority of mitigation translocations are generally not focused on improving science, they still need to be conducted following the same process of design and implementation as conservation translocations if they are to successfully prevent species mortality in response to land use change or human-wildlife conflict (IUCN/SSC 2013). Therefore, whether or not mitigation translocations also have a conservation objective beyond addressing a human-wildlife conflict, or varying conservation objectives according to different taxa, the translocation requires strategic planning and adaptive management, in order to be considered an effective translocation with sound ethics according to IUCN (2013) guidelines.

Despite the need for mitigation translocations to follow an adaptive management approach, technical difficulties and resource demands limit the likelihood of the critical metapopulation and ecosystem level questions being addressed during mitigation translocations (Taylor et al. 2017), perhaps explaining their lack of success. As mitigation translocations are crisis-responsive, the short timeframe over which they operate probably limits any ability to address these more challenging questions (Berg 1996). However, failure to address questions at the metapopulation and ecosystem level will likely lead to continued project failure - as reported for the majority of studies within this review - due to inappropriate distribution of individuals among sites, introduction of non-native parasites, or flow-on effects for the ultimate species composition (Waldron et al. 2013). In the future, managers therefore need to be more strategic with their use of conservation dollars, with a broader acceptance of the time and money required to achieve effective mitigation translocations. With the more reliable, effective reduction of wildlife mortality from land-use change through translocation, mitigation translocations can play a larger role within conservation planning.

In order for mitigation translocations to become integrated within conservation planning, it is also necessary to reduce ambiguity around what constitutes a mitigation translocation. As a supply-driven method (Germano et al. 2015), mitigation translocations can include those aligned with preventing species extinction, as was the case for many studies within this review, but can also include the removal of 'nuisance' animals, commonly snakes or large carnivores near urban areas, as well as consultants walking in front of bulldozers 'relocating' wildlife disturbed in a development footprint. The latter two forms of translocation are performed by people with a range of expertise, adhering to an ambiguous range of legislative and policy controls. Wildlife translocated as the result of these human-wildlife conflicts, particularly herpetofauna, often do not survive (Reinert & Rupert Jr 1999; Nowak *et al.* 2002; Sullivan *et al.* 2015; Devan-Song *et al.* 2016; Wolfe *et al.* 2018). Government regulators may also be unaware of the ethics criteria set by the IUCN (2013) and so may fail to impose them on the proponents of the translocations, with the added challenge that the proponents may be reluctant to embrace the genuine costs of conducting rigorous mitigation translocations unless required to do so by legislation. Even in countries such as Australia, which has a much more rigorous legislative and policy framework than many places in the world, the appropriate legislation (at least at the national level), the *Environment Protection and Biodiversity Conservation Act 1999,* imposes no strict and specific requirements for a translocation plan or post-translocation monitoring. Also, with no clear strategy for recipient site selection, state regulators have to work out what to do with populations with no prior management plan and no overarching strategy, leading to ineffective conservation outcomes. Even for mitigation translocations aligned with broader conservation objectives, as were the majority within this study, there is little evidence for mitigation translocations following a sound scientific paradigm (Germano et al. 2015; Lennon 2019). As the grey literature on mitigation translocations is impenetrable, the scale of the problem is likely much larger than observed within the scientific literature. Therefore, what this study and others within the literature (Germano 2015; Sullivan et al. 2015; Lennon 2019) show is a shuttered glimpse into an action that may appear like a form of conservation management in principle, but in actuality might be a threat to wildlife conservation, and an act of greenwashing that is a threat to biodiversity conservation. Until we have real numbers on this, and a real understanding, both within science and policy and outside it, this is a major challenge to conservation.

The inclusion of *a priori* goals and testing/comparing management options did not influence the result of self-sustaining mitigation translocations. However, this does not negate the value of including these in translocation design, as their primary reason for inclusion is to use the least amount of conservation dollars and maximise the knowledge gained for future translocations (Armstrong & Seddon 2008). To continue improving translocation techniques, and to facilitate practitioners selecting the most appropriate management actions, it is critical to compare management techniques (Taylor et al. 2017). Broadly speaking, as many mitigation translocation studies that we analysed were built around a scientific paradigm as were built upon no apparent rationale, suggesting that there is still improvement required in linking translocation science with project implementation. Yet this lack of comparative approach did not appear to hinder the success of these translocations, raising the question of whether such comparisons are as relevant for mitigation translocations as those motivated by other intentions. We posit that they are, but that success is often poorly defined and poorly assessed in mitigation translocations (Germano et al. 2015). The desire of developers to continue justifying mitigation translocation as a management tool for conservation in lieu of protecting natural areas from development has hindered long-term monitoring and resolution of a consistent definition of 'success'. We found that the questions that require long-term monitoring, including the impacts to the recipient ecosystem (Q9) and carrying capacity of different recipient sites (Q6), were addressed the least (including Q10 which was never addressed as the majority of translocations were for single species). We argue that a mere assessment of 'success' as the resolution of the original land-use conflict through relocation is not enough (Massei et al. 2010), and that the aim to establish a self-sustaining population integrated with the recipient ecosystem (Griffith et al. 1989), and the larger metapopulation structure (Armstrong & Seddon 2008), should be the end goal of all translocations.

Translocation is very much a conservation tool of the Anthropocene (Corlett 2015), encompassing everything from mitigation translocations and reintroductions to assisted colonisation (Lunt et al. 2013) and rewilding (Jørgensen 2015; Sweeney et al. 2019). With bold aspirations comes substantial capacity for unintended consequences for both ecology (May & Spears 2011; Abbott & Haynie 2012; Colman et al. 2014) and evolution (Laikre et al. 2010). Avoidance of this risk is the motivation for a robust scientific rationale to underpin all translocations and reintroductions (Armstrong & Seddon 2008). Mitigation translocations have in the past been criticised for lacking this robustness (Germano et al. 2015; Sullivan et al. 2015), and there has been an ongoing call for better evidence to support translocation biology over the last two decades (Sutherland et al. 2010; Kemp et al. 2015; La Haye et al. 2017; Taylor et al. 2017). In common with other forms of conservation translocation (Taylor et al. 2017), mitigation translocations have not yet reached their potential as an effective applied science.

There are a number of factors which limit the capacity of a mitigation translocation to meet the same strict scientific rationale as is common for other conservation translocations. In situations with no effective means of diverting development away from significant natural areas, managers are left to make the best of a bad situation (Berg 1996). The speed and scope of infrastructure development can lead to developers ‘saving’ individual organisms from a site and conducting translocations in an *ad hoc* manner without any feasibility analysis (Gardner & Howarth 2009). We argue that without the capacity to conduct a well-planned translocation at least addressing as many key questions in translocation biology as possible, such translocations should be avoided wherever possible. It is also critical to address the apparent imbalance between management actions and monitoring. Monitoring as standard practice for mitigation translocations will help inform best practice, and reduce the loss of conservation dollars spent on ineffective management techniques. However, of greatest importance is the adequate protection of natural areas using the mitigation hierarchy of avoidance, minimisation, and compensation/offsetting when implementing disturbance activities (Gardner et al. 2013; Ekstrom et al. 2015). Translocation should be the final option within a hierarchical decision framework for mitigating biodiversity loss, and all other options for avoidance and minimisation of disturbance should be exhausted prior to the selection of translocation as a management option.

In the event that mitigation translocation is the most, or only, appropriate course of action, then it is critical to maximise its efficacy as a management tool. It is therefore of high priority for future mitigation translocations to follow the same strategic framework as other conservation translocations, namely to promote and monitor long-term success through planned experimental research at the population, metapopulation, and ecosystem levels of the translocation. This raises questions as to the appropriate agency, timeframe, and investment required to conduct these programs. With the recognition that mitigation translocations are not so simple as the altruistic (or, in some cases, mandated) aim of capturing the animals and releasing them into whatever habitat is available nearby, comes the recognition that they probably require greater investments of time, resources and, most importantly, expertise than they are currently provided. Without significantly greater investment, many mitigation translocations will continue to simply change the location in which their target animals are killed.

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Table 1. Variables searched for within the mitigation translocation paper dataset, with definitions and explanations for how criteria were met.

Variable/term	**Definition by Armstrong and Seddon (2008)**	**Within this study, paper considered as addressing variable if:**
Question 1	How is establishment probability affected by size and composition of the release group?	The paper mentioned either population size or composition, as well as how this influenced the survival/establishment of translocated individuals (through *post hoc* analysis or experimentation).
Question 2a	How are post-release survival and dispersal affected by pre-release management?	There is mention of a pre-release management technique (e.g. different types of soft-release structures), but must also mention experimental testing or comparison with another technique to understand the benefit to survival or dispersal.
Question 2b	How are post-release survival and dispersal affected by post-release management?	There is mention of a post-release management technique (e.g. supplementary feeding), plus mention of experimental testing or comparison with another method to understand the benefit to survival or dispersal.
Question 3	What habitat conditions are needed for persistence of the reintroduced population?	There is any mention of habitat conditions considered when selecting the translocation site including temperature/climate, vegetation, predator abundance/ management, soil, geology, and slope.
Question 4	How will genetic makeup affect persistence of the reintroduced population?	There is mention of genetic testing, modelling or monitoring such as relating to inbreeding, ancestry, genetic diversity, and the need for future population supplementation.
Question 5	How heavily should source populations be harvested?	Stated reason for the number of founders selected, e.g. if construction threatened an entire population as many as possible was removed, or modelled how many founders

		would be sustainable to remove.
Question 6	What is the optimal allocation of translocated individuals among sites?	There is mention of more than one release site and how a decision was made to split individuals between them.
Question 7	Should translocation be used to compensate for isolation?	All papers considered to answer this question due to the assumption stated by Armstrong and Seddon (2008) that all translocations implicitly consider this question.
Question 8	Are the target species/taxon and its parasites native to the ecosystem?	It is stated that the translocation is a reintroduction (meaning it is within the original range of the species), or what is said to be suitable habitat.
Question 9	How will the ecosystem be affected by the target species and its parasites?	There is mention of how the translocation will impact the surrounding ecosystem of the translocation site, such as grazing pressure on vegetation, function as an ecosystem engineer or ecological replacement for a locally extinct species.
Question 10	How does the order of reintroductions affect the ultimate species composition?	There is a multiple species translocation, and there is mention of how the order of translocations was decided, and how this influenced species composition in the system.
A priori goals	Research and monitoring targets are identified *a priori* to translocation taking place.	There are goals stated within the text (e.g. quantify demographic parameters related to survival and reproduction) that were not made post-collection of data (e.g. genetic study to look at bottlenecking years after translocation – as these goals did not appear to influence the original translocation design).
Mitigation translocation	By the IUCN/SSC (2013) and Germano et al. (2015): supply-driven translocations, where the current population is	Mitigation translocations occur both as a response to threatened individuals (e.g. nuisance animals), up to populations (e.g. at a development site), as well as in response to an immediate crisis for the preservation of a

	under threat of local extinction and translocation is required to mitigate the impending threat.	threatened taxon, where the known global population is threatened by human activity
Testing/comparing management actions	By Taylor et al. (2017): Studies that directly tested one or more management actions, either by *a priori* predictive modelling or a posteriori analysis of field data.	The mention of at least one trial of a management action, other than the translocation itself.

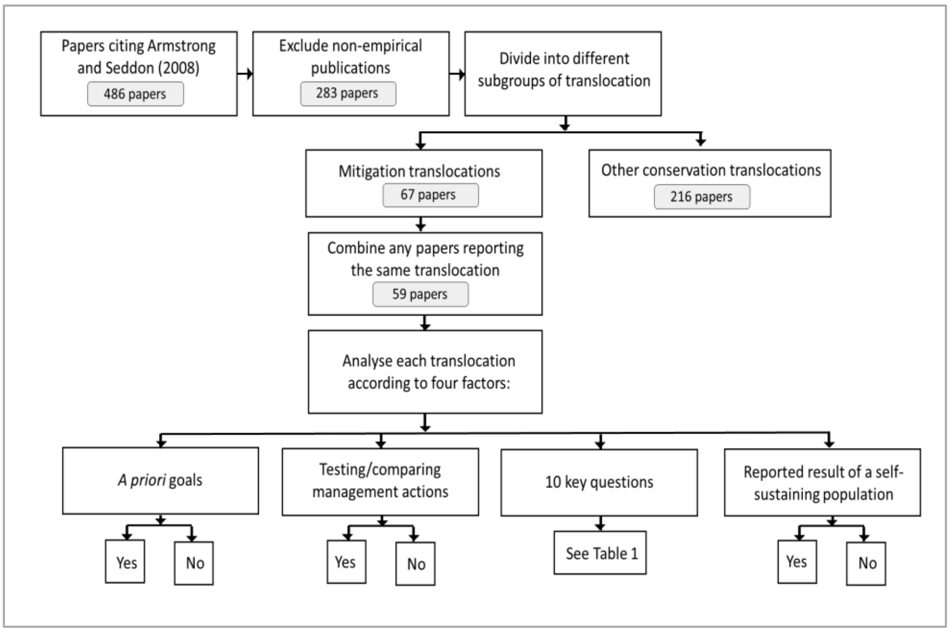

Figure 1. PRISMA Flowchart illustrating how the data was subdivided and analysed. Refer to Table 1 for the listed ten key questions in translocation biology from Armstrong and Seddon (2008).

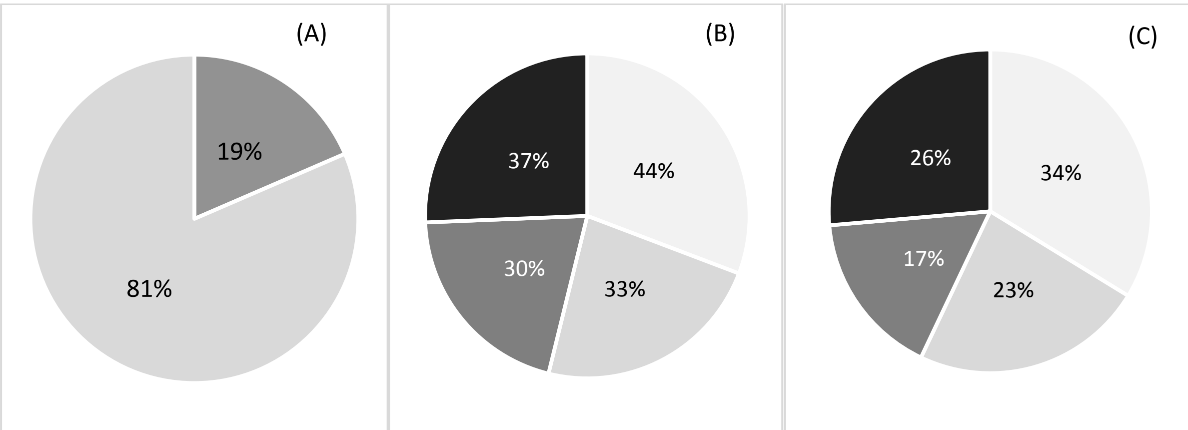

Figure 2. (A) The proportion of mitigation translocation papers that reported the result of a self-sustaining (dark grey) or non-self-sustaining population (pale grey). (B) The proportion of self-sustaining populations resultant from mitigation translocations that addressed questions at the establishment (white-grey), persistence (pale grey), metapopulation (dark grey) and ecosystem (black) level. (C) The proportion of non-self-sustaining populations resultant from mitigation translocation papers that addressed establishment (white-grey), persistence (pale grey), metapopulation (dark grey) and ecosystem (black) level questions.

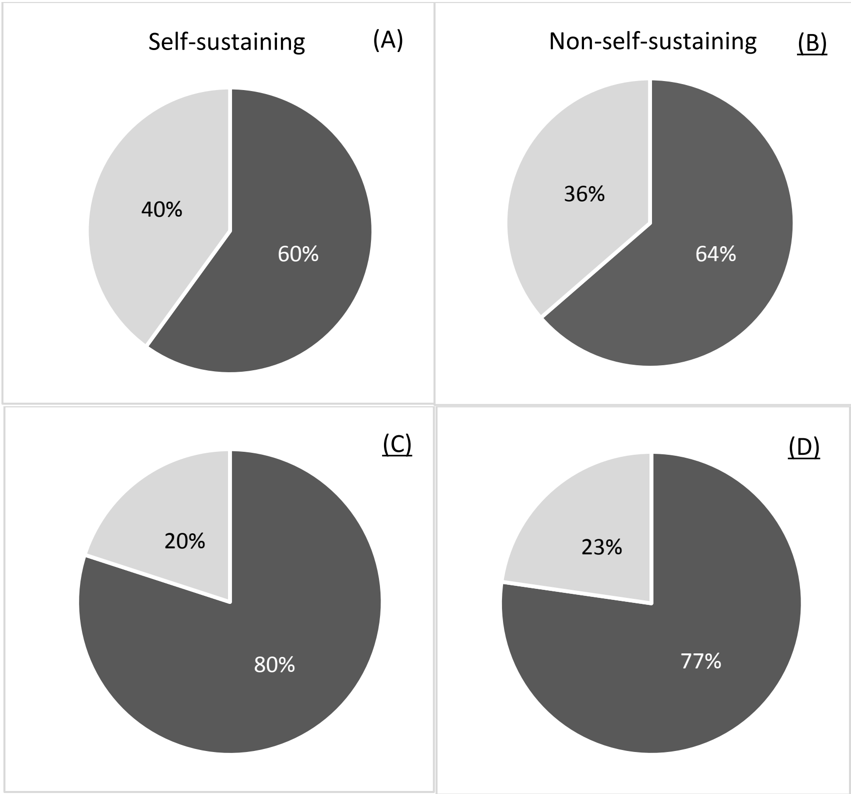

Figure 3. The proportion of (A) self-sustaining and (B) non-self-sustaining mitigation translocations that did (dark grey) or did not (pale grey) state *a priori* goals and the proportion of self-sustaining (C) and non-self-sustaining (D) mitigation translocations shown to test (dark grey), or not test (pale grey), at least one management technique.