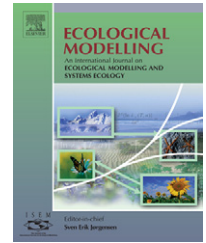


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Minimise long-term loss or maximise short-term gain? Optimal translocation strategies for threatened species

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ABSTRACT

Translocation is a useful management option for conservation of threatened animal species. It can be used to increase the range of a species, augment the numbers in a critical population, or establish new populations and hence spread the risk of extinction through local catastrophes. As it is an important and expensive conservation tool, translocation management decisions must be carefully considered, with the objective of the translocation project in mind. By analysing the translocation problem within a decision-theory framework, we find optimal management decisions that are rational and transparent. We illustrate our approach using a case study of the bridled nailtail wallaby (*Onychogalea fraenata*). Our particular translocation question is: if we have a set number of wallabies to translocate in each time period and two translocation sites, how many wallabies should we put at each site given the state of each population to maximise the benefit to the species? We model the translocated populations with first-order Markov chain stochastic population models, and use stochastic dynamic programming to determine the optimal management decisions. We look at two sites with different growth rates – one increasing and one decreasing – and compare the optimal strategies for two different objective functions. The first is a long-term persistence objective function, which maximises the persistence of translocated populations a large number of time steps after the end of the translocation program. The second maximises total population size at the end of the translocation program. Although these objective functions are similar, they generate surprisingly different optimal translocation strategies. When maximising the long-term persistence of the translocated populations, translocation decisions are not important as long as an increasing population is established. This indicates that site quality – rather than the number and timing of translocations – primarily determines the long-term persistence of populations. When maximising total population size, the optimal strategy is to add to the increasing population unless it is above a size where it is likely to reach its carrying capacity over the planning timeframe. As translocation decisions are important in fulfilling the objective, this objective function is more useful in creating practical advice for translocation managers. The discrepancy between the optimal strategies given by the two objectives demonstrates the importance of careful consideration when specifying the goals of a project. This observation applies not only to translocation programs, but any project where clear decision-making is needed.

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1. Introduction

Translocation is the deliberate, human-mediated movement of living organisms from one area to another (World Conservation Union (IUCN), 1987). This movement can be between wild and captive populations, or between two or more wild populations (Lubow, 1996; Tenhumberg et al., 2004). Translocations are usually carried out for one of three purposes (Fischer and Lindenmayer, 2000): to remove human–wildlife conflicts (e.g. Bradley et al., 2005; Goodrich and Miquelle, 2005; Strum, 2005), to restock game species (e.g. Singer et al., 2000), or to conserve species (e.g. Armstrong et al., 2002; Dullum et al., 2005; Tuberville et al., 2005). As a conservation tool, translocation can be used to increase the range of a species through reintroduction to an area from which it has been extirpated, or to increase numbers in a critical population by adding individuals from a wild or captive population. It is one of the main management options for restoration and conservation of threatened animal species (Fischer and Lindenmayer, 2000).

Although some translocation projects have been very successful in recovering threatened species, many are unsuccessful (Griffith et al., 1989; Wolf et al., 1996). A translocation project is considered a success if it results in a self-sustaining population (Griffith et al., 1989). Examples of successful translocations include the white stork (*Ciconia ciconia*) (Schaub et al., 2004), baboon (Strum, 2005), alpine ibex (*Capra ibex*), bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*), and bean goose (*Anser fabalis*) (Beck et al., 1994), as well as several game species (Griffith et al., 1989; Wolf et al., 1996). Publications reporting the failure of translocation projects are less numerous (e.g. Short et al., 1992; Struhsaker and Siex, 1998), although review studies show the success rates of translocation projects are low (Griffith et al., 1989; Wolf et al., 1996; Fischer and Lindenmayer, 2000). There are several factors that influence translocation success, including the number of animals released (Griffith et al., 1989; Wolf et al., 1996, 1998; Fischer and Lindenmayer, 2000; Matson et al., 2004), the habitat quality of the release area (Griffith et al., 1989; Wolf et al., 1996, 1998), the duration of the translocation project (Griffith et al., 1989), and the location of the release area in relation to the historical range of the species (Griffith et al., 1989; Wolf et al., 1996, 1998). Also important is the type of source population used (Griffith et al., 1989; Wolf et al., 1996; Fischer and Lindenmayer, 2000), the diet and reproductive traits of the translocated species (Griffith et al., 1989; Wolf et al., 1996, 1998), and whether the original cause of decline has been removed (Fischer and Lindenmayer, 2000).

In this paper, we focus on optimising the number and timing of translocations. In particular, we look at the optimal allocation of animals between two sites of differing quality. We formulate the problem within a decision-theory framework—a procedure that allows us to determine optimal decisions for a specific objective that are transparent, justifiable, and have a rational basis (Shea, 1998).

Decision theory is the mathematical theory that underpins rational decision-making. It involves systematic consideration of the goals of the decision maker, the choices available, the possible outcomes, the relationships between

choices and outcomes, and the probability of occurrence of the outcomes (Maguire, 1986; Shea, 1998; Haight et al., 2000). The purpose is to find decisions that are most likely to meet the stated goals. Decision theory can be applied through the use of qualitative tools, most richly developed in economics, or with optimisation methods from applied mathematics (Possingham et al., 2001). In this paper, we frame and solve the translocation problem within a decision-theory context, using stochastic dynamic programming—an algorithm that determines optimal state-dependent strategies (Bellman, 1957). We apply this framework to a case study on the bridled naitail wallaby (*Onychogalea fraenata*). Only two previous studies have used stochastic dynamic programming to examine translocation strategies—Lubow (1996) found optimal strategies for translocation between two wild animal populations, and Tenhumberg et al. (2004) found optimal strategies for translocation between a wild and captive population of Arabian oryx (*Oryx leucoryx*). We introduce a new element to the problem by focusing on the allocation of captive individuals between two wild populations. Specifically, we ask the question: if we have a set number of animals to translocate in each time period and two translocation sites, how many animals should we put at each site given the size of each population?

2. Model

2.1. Model scenarios

In each scenario, we assume there is a captive source population and two sites to which individuals can be translocated. The dynamics of the source population are not considered explicitly—it is assumed to produce a set number of ‘excess’ individuals available for translocation in each time step. Management decisions focus on the allocation of these individuals between the two translocation sites. We determine the optimal management decisions using stochastic dynamic programming. In the first scenario, we make decisions to maximise the expected number of persisting populations many years after the end of the translocation program. In the second scenario, we make decisions to maximise the expected total number of individuals existing in the wild at the end of the program.

2.2. Stochastic population model

We use a first-order Markov chain stochastic population model to describe the dynamics of each translocated population. These models follow only the number of females, which assumes that females always have the opportunity to mate regardless of male abundance. These models also ignore the age structure of the populations. We label the translocated populations A and B, which are limited to a maximum size of K_A and K_B , respectively. This population size limit can be interpreted as the carrying capacity of the translocation site. The Markov chain transition matrix for each population from time step (t) to time step ($t + 1$) is $\mathbf{M} = \mathbf{L}\mathbf{S}$, the matrix product of the recruitment matrix \mathbf{L} and the survival matrix \mathbf{S} . This assumes that within each time step survival occurs before

reproduction—only surviving individuals can reproduce. Our population model is similar to that in [Tenhumberg et al. \(2004\)](#) and is described briefly below.

Each element of the survival matrix S , $s_{i,j}$, is the probability of i individuals surviving to time $t + 1$, given j individuals at time t , with $0 \leq i \leq K$ and $0 \leq j \leq K$. This is given by the binomial probability

$$s_{i,j} = \begin{cases} \binom{j}{i} \mu^{j-i}(1-\mu)^i, & \text{if } 0 \leq i \leq j \\ 0, & \text{otherwise} \end{cases}$$

where μ is the individual death probability for each time step.

To construct the recruitment matrix L , we first find the probability distribution that a given number of females have a given number of female offspring. We assume that females can have at most one newborn in each time step. We assume a probability λ that a female has one newborn in a given time period, and a probability f that the newborn is female. Then the probability that a female has zero female newborns in a time period is

$$b_{0,1} = (1 - \lambda) + \lambda(1 - f),$$

which is the probability that the female does not produce any newborns in the time period, plus the probability that the female produces a male newborn. The probability that a female has one newborn female in a time period is

$$b_{1,1} = \lambda f,$$

which is the probability that the female produces one offspring and it is female. We set $b_{i,1} = 0$ for all $i > 1$. [Tenhumberg et al. \(2004\)](#) generalise these equations so that more than one offspring can be born in each time period. The probability that j females have i newborns can then be obtained as follows:

$$b_{i,j} = \begin{cases} \sum_{k=0}^i b_{k,j-1} b_{i-k,1}, & \text{if } i \leq j, \\ 0, & \text{otherwise} \end{cases}$$

Density dependence enters the population model at high population densities, as the population cannot exceed the carrying capacity, K . At densities close to K , reproduction is truncated to ensure the total number of animals remains less than or equal to K . From the birth probabilities $b_{i,j}$, we can calculate the elements of the recruitment matrix L , $l_{m,n}$, as the probability that the population changes from n individuals to m individuals due to reproduction,

$$l_{m,n} = \begin{cases} b_{m-n,n}, & \text{if } n \leq m < K \\ 1 - \sum_{i=n}^{K-1} b_{i-n,n}, & \text{if } m = K \\ 0, & \text{if } m < n \text{ or } m > K \end{cases}.$$

The processes of immigration and emigration are not considered, as we believe that in cases of threatened species with isolated translocation sites and low population densities dispersing animals are unlikely to survive and reproduce.

2.3. Stochastic dynamic program (SDP)

Stochastic dynamic programming is a mathematical optimisation method. It can be applied to any stochastic model that is driven by a Markov chain where the system being managed has a finite set of states and where a series of sequential decisions must be made ([Bellman, 1957](#); [Mangel and Clark, 1988](#); [Lubow, 1996](#)). This SDP determines the exact optimal strategy for translocation, which is dependent on the management objective and the state of the system. The population model has three states: how long the translocation project has been going ($t = 0, \dots, T$), the number of individuals in the first site at time t ($n_t^A = 0, \dots, K_A$), and the number of individuals in the second site at time t ($n_t^B = 0, \dots, K_B$). There will be an optimal action for each state—that is the decisions are state-dependent. Changes in the state of each population through births and deaths are governed by the Markov chain transition matrices M_A (for population A) and M_B (for population B). We can change the state of the populations by translocating individuals into them. In each time period, X individuals from the source population are allocated between populations A and B. The decision variable d is an integer value between 0 and X . Population A receives d translocated individuals, while population B receives $X - d$ individuals. Translocation is assumed to occur early in the time step, before the death and birth processes.

Stochastic dynamic programming works by stepping backwards from the terminal time T where the final reward – a value given to each state based on the extent to which it satisfies the objective – is received. For each time step prior to the terminal time, all possible decisions, d , are evaluated for every combination of possible population sizes. The score for each decision is determined by the dynamic programming equation ([Bellman, 1957](#)):

$$S(t, n_t^A, n_t^B, d) = \sum_{i=0}^{K_A} \sum_{j=0}^{K_B} V(t + 1, i, j) m_{i, n_t^A + d}^A m_{j, n_t^B + X - d}^B, \quad (1)$$

which depends on the time step in the translocation program t , the sizes of populations A and B (n_t^A and n_t^B) and the translocation decision d . V is the value of optimally translocating individuals from time $t + 1$ to the end of the program, given that populations A and B are in states i and j , respectively, at time $t + 1$. Since the state of the population at time $t + 1$ is uncertain, we must consider all possible future states and weight them by their probability of occurrence. In this equation, m^A is the element of transition matrix M_A containing the probability that $n_t^A + d$ individuals at time t become i individuals at time $t + 1$, and $m_{j, n_t^B + X - d}^B$ is the element of the transition matrix M_B containing the probability that $n_t^B + X - d$ individuals at time t become j individuals at time $t + 1$. The optimal decision at time t , assuming all future decisions are optimal, is the one that produces the highest score:

$$V(t, n_t^A, n_t^B) = \max_{d=\{0,1,\dots,X\}} S(t, n_t^A, n_t^B, d). \quad (2)$$

We compare the optimal decisions for two different management objectives. The long-term persistence objective func-

Table 1 – Ranges of demographic parameters for bridled naitail wallabies

Parameter	Established range	Source
Birth probability (probability of a female giving birth to one offspring in a 4-month period—approximation to λ , the probability of a female giving birth to one offspring in a 4-month period that survives to recruitment)	0.89–1	Johnson (1997); Fisher et al. (2000).
Death probability (probability of an individual dying in a 4-month period, μ)	0.01–0.46	Fisher (1998); Fisher et al. (2000); Pople et al. (2001).
Ratio of female:male newborns	0.5	McCallum et al. (1995).

tion maximises the expected number of persisting populations ε time steps after the end of the translocation project (time T). This is specified by the equation:

$$V_1(T, n_T^A, n_T^B) = (1 - (m_{0, n_T^A}^A)^\varepsilon) + (1 - (m_{0, n_T^B}^B)^\varepsilon), \quad (3)$$

where $(m_{0, n_T^A}^A)^\varepsilon$ is the element of the transition matrix M_A^ε containing the probability that population A, containing n_A individuals at the end of the translocation project, will become extinct within ε time steps. Likewise, $(m_{0, n_T^B}^B)^\varepsilon$ is the element of the transition matrix M_B^ε containing the probability that n_B individuals in population B at the end of the project will go extinct within ε time steps.

The total population size objective function maximises the total number of individuals in the final time step of the translocation program. The equation describing this objective is:

$$V_2(T, n_T^A, n_T^B) = n_T^A + n_T^B. \quad (4)$$

Eqs. (1) and (2) are used recursively, backwards over time, starting with the terminal condition (3) or (4). In this way, we find the optimal translocation decision at any time for any state of the populations.

2.4. Case study

To demonstrate the approach, we apply it to a case study of bridled naitail wallabies. The bridled naitail wallaby was once distributed throughout the semi-arid inland of eastern Australia, from Charters Towers in the north to the Murray River in the south (Johnson, 2003). Threatening processes, such as land clearing, predation, and competition with livestock reduced the species to a small population in Taunton National Park, near Dingo in Central Queensland (Lundie-Jenkins, 2001; Johnson, 2003). It has recently been successfully reintroduced to Idalia National Park, near Blackall (Johnson, 2003). The bridled naitail wallaby is currently listed as endangered and, according to its 1997–2001 Recovery Plan, needs to be re-established at two more sites to satisfy the conditions of recovery (Lundie-Jenkins, 2001).

Bridled naitail wallabies have one offspring at a time, but breed continuously in the wild and may raise up to three young per year (Lundie-Jenkins, 2001). We model recruitment by making each time step of the SDP equal to 4 months, so at each 4-month interval a female may produce a female offspring that survives to recruitment. This is a simplification of the species' life-history, as the primary purpose of the case

study is to illustrate a novel method of making decisions about translocation. A literature review of articles on the demography of the species established ranges for model parameters, as shown in Table 1. We choose birth and death parameters from within these ranges that create an interesting management situation.

In both scenarios, the translocation program is assumed to run for 4 years or 12 time steps. Translocation occurs in the first eleven time steps ($t=0 \dots 10$), with two individuals available each time. The final reward, given by the objective function, is received at the terminal time, $T=11$. The carrying capacity K of each site is set at 30 individuals. We calculate an approximation of the per capita growth rate r for each population using the equation:

$$R = \sum_{i=1}^K i m_{i,1} \approx E \left(\frac{n_{t+1}}{n_t} \right),$$

where $m_{i,1}$ is an element of a Markov chain transition matrix, n_t and n_{t+1} the number of individuals in the relevant population at times t and $t+1$, respectively, and $E(\cdot)$ means expectation.

The birth probability is set at $\lambda=0.9$ for each population, and the death probability is set at $\mu_A=0.2$ for population A and $\mu_B=0.4$ for population B. Given these parameters, R is 1.15 for population A and 0.87 for population B. We thus explore a situation in which population A is increasing and population B is decreasing. In cases where the long-term persistence objective function (3) is used, we look at results for two values of ε (the amount of time after the end of the translocation project at which the persistence of populations is assessed). These are 32 time steps (10 years 8 months), and 128 time steps (42 years 8 months). Powers of two are used to simplify calculations by enabling the repeated squaring of a matrix.

3. Results and discussion

The use of a carrying capacity K in the SDP is mathematically convenient, but is not particularly realistic for the bridled naitail wallaby. For this reason, the most relevant and applicable results of the SDP are those not affected by carrying capacity. The focus of analysis is therefore on the optimal decisions when both populations are small.

3.1. Long-term persistence objective

For the SDP with the long-term persistence objective function (3), optimal decisions are dependent on the number of

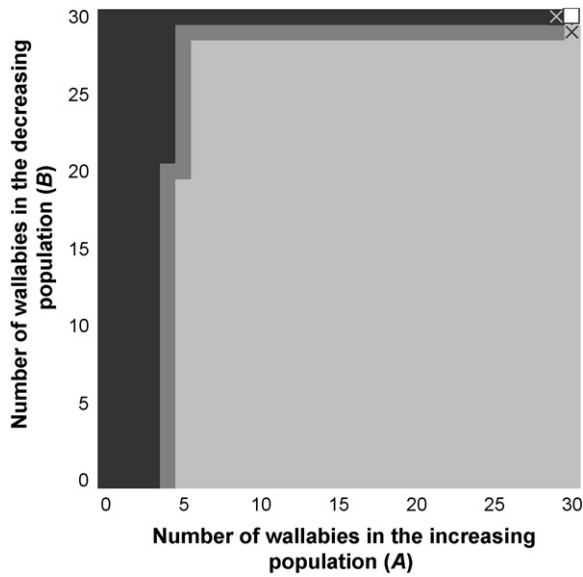


Fig. 1 – Optimal translocation decisions for each population state at the start of the project ($t = 0$), with the long-term persistence objective function where $\varepsilon = 32$. Dark grey, add both available wallabies to the increasing population (A); medium grey, add one wallaby to each population; light grey, add both available wallabies to the decreasing population (B); dark grey with cross, two equally optimal decisions—to add both to the increasing population (A), or add one to each population; light grey with cross, two equally optimal decisions—to add both to the decreasing population (B), or add one to each population; white, all decisions are equally optimal.

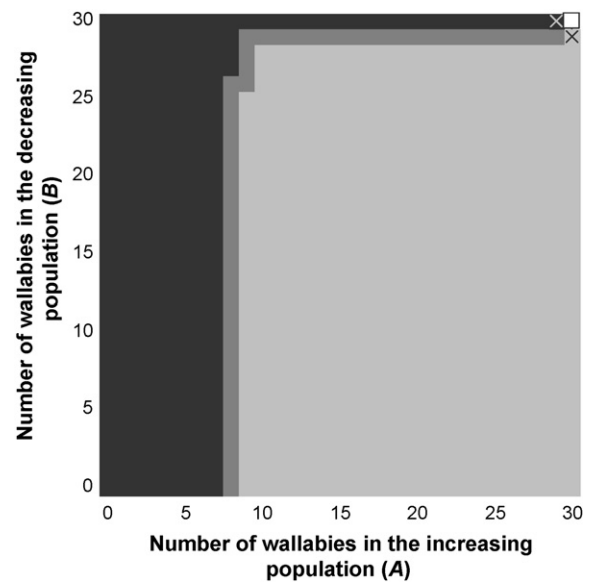


Fig. 2 – Optimal translocation decisions for each population state at the end of the project ($t = 10$), with the long-term persistence objective function where $\varepsilon = 32$. Dark grey, add both available wallabies to the increasing population (A); medium grey, add one wallaby to each population; light grey, add both available wallabies to the decreasing population (B); dark grey with cross, two equally optimal decisions—to add both to the increasing population (A), or add one to each population; light grey with cross, two equally optimal decisions—to add both to the decreasing population (B), or add one to each population; white, all decisions are equally optimal.

individuals in the increasing population (A) (Figs. 1–4). Decisions are not affected by the number in the decreasing population (B), except where that population is very close to the imposed carrying capacity. This indicates that the long-term metapopulation persistence probability is affected by the size of the increasing population, rather than the size of the decreasing population. This is because the decreasing population is likely to go extinct regardless of translocation efforts. In fact, even if it has the maximum of 30 wallabies at the end of the translocation project, population B still has a probability of 0.91 of going extinct within 32 time steps, and a probability of almost 1 of going extinct within 128 time steps. Maximising the long-term metapopulation persistence therefore relies on the establishment of the increasing population. The optimal strategy is to boost the increasing population up to a level where it has a high probability of long-term persistence. If there is a sufficiently high probability that population A will persist, a greater increase in the metapopulation probability of persistence is achieved by adding to population B. Therefore, excepting the effects of carrying capacity, there is a threshold level of population A below which it is optimal to add to A, and above which it is optimal to add to population B. This threshold level is affected by the amount of time left until the end of the translocation project, and the amount of time after the end of the translocation project

at which the metapopulation probability of persistence is assessed.

The threshold at which population A is sufficiently established increases as the translocation project progresses. This occurs for both values of ε : 32 (Figs. 1 and 2) and 128 (Figs. 3 and 4). Early on in the translocation project the threshold is lower, as population A may increase of its own accord throughout the project. Towards the end of the translocation project it becomes more important to ensure population A is established, as future opportunities for supplementation are limited. The threshold is therefore higher closer to the end of the project. This threshold is also affected by the amount of time after the end of the translocation project at which the metapopulation probability of persistence is assessed (ε). If the persistence of populations is assessed 32 time steps, or 10 years and 8 months, after the end of the translocation project, the population level at which population A is sufficiently established ranges from four to eight individuals (Figs. 1 and 2). In contrast, if the persistence of populations is assessed 128 time steps, or 42 years and 8 months, after the end of the translocation project, the population level at which population A is sufficiently established is much higher, between 15 and 29 individuals (Figs. 3 and 4). As ε increases, the probability that population A will go extinct within ε time steps of the end of the project increases. It therefore requires

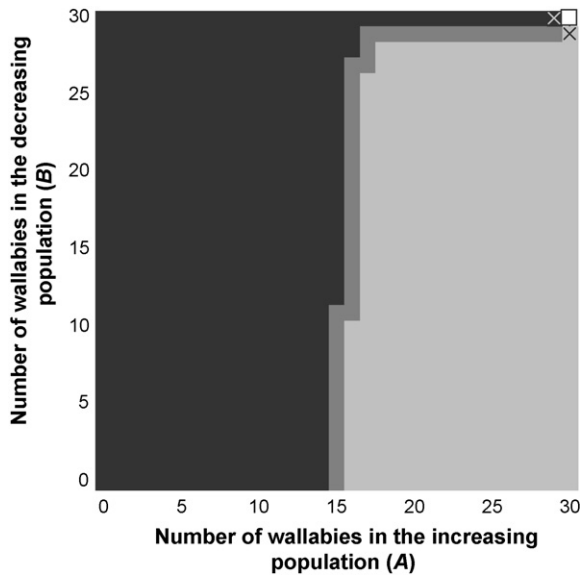


Fig. 3 – Optimal translocation decisions for each population state at the start of the project ($t=0$), with the long-term persistence objective function where $\varepsilon = 128$. Dark grey, add both available wallabies to the increasing population (A); medium grey, add one wallaby to each population; light grey, add both available wallabies to the decreasing population (B); dark grey with cross, two equally optimal decisions—to add both to the increasing population (A), or add one to each population; light grey with cross, two equally optimal decisions—to add both to the decreasing population (B), or add one to each population; white, all decisions are equally optimal.

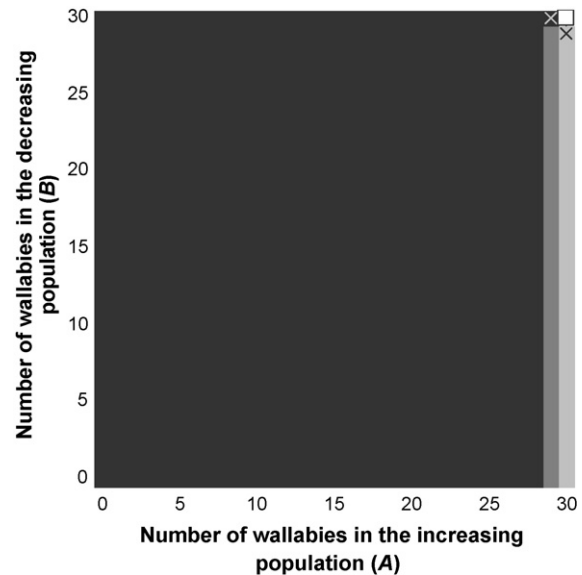


Fig. 4 – Optimal translocation decisions for each population state at the end of the project ($t=10$), with the long-term persistence objective function where $\varepsilon = 128$. Dark grey, add both available wallabies to the increasing population (A); medium grey, add one wallaby to each population; light grey, add both available wallabies to the decreasing population (B); dark grey with cross, two equally optimal decisions—to add both to the increasing population (A), or add one to each population; light grey with cross, two equally optimal decisions—to add both to the decreasing population (B), or add one to each population; white, all decisions are equally optimal.

more supplementation to protect it from extinction within that period.

In this situation, we implicitly assume that the habitat quality remains constant over the ε time steps following the translocation project. If the sites are protected from human interference then this might be a reasonable assumption. Otherwise, such a long-term objective may not be reasonable. This objective highlights the importance of ensuring that the threat to an endangered population is removed from the site before individuals are translocated into the site. If the population has a growth rate of less than one, then long-term extinction is likely, regardless of translocation efforts.

3.2. Total population size objective

The optimal translocation strategy using the total population size objective function (4) shows similar trends to the optimal strategy using the long-term persistence objective function. Optimal decisions are again dependent on the number of individuals in the increasing population (A) rather than the number in the decreasing population (B) (Figs. 5 and 6). There is a threshold level of population A below which it is optimal to add to A, and above which it is optimal to add to population B. However, instead of representing a level at which population A is sufficiently established, this threshold represents a level at which population A is likely to increase to carrying

capacity within the translocation project. If population A is above this level, adding additional animals would be wasteful as it is likely to increase to carrying capacity of its own accord. However, if population A is below this level, it is unlikely to increase to carrying capacity within the translocation project and should be supplemented. This threshold increases as the translocation project progresses. At the start of the translocation project ($t=0$), it is optimal to add to population A if it has less than 11 individuals (Fig. 5). By the last decision in the translocation project ($t=10$), it is optimal to add to population A if it has less than 24 individuals (Fig. 6). As there is only one time step left in the translocation project, population A is not likely to reach the carrying capacity of 30 unless it contains at least 24 individuals.

The optimal translocation strategies for both objective functions show similarities—the optimal decisions are dependent on the number of individuals in the increasing population (A), and change over the time period of the translocation project. However, these objectives give very different threshold levels for adding to the increasing population, and these thresholds are affected by the amount of time left in the project, and – in the case of the long-term persistence objective function – the amount of time after the end of the translocation project at which the metapopulation probability of persistence is assessed. The fulfilment of both objectives depends on the state of the increasing population (A), and the

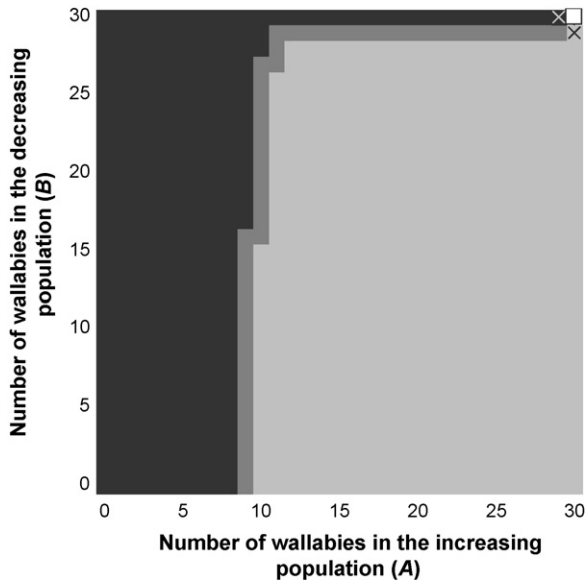


Fig. 5 – Optimal translocation decisions for each population state at the start of the project ($t=0$), with the total population size objective function. Dark grey, add both available wallabies to the increasing population (A); medium grey, add one wallaby to each population; light grey, add both available wallabies to the decreasing population (B); dark grey with cross, two equally optimal decisions—to add both to the increasing population (A), or add one to each population; light grey with cross, two equally optimal decisions—to add both to the decreasing population (B), or add one to each population; white, all decisions are equally optimal.

decreasing population (B) is supplemented only when it is not suitable to add to A. This indicates the importance of site quality – represented in this problem by the population growth rate – for both the abundance and persistence of populations.

3.3. Future directions

This method provides a useful framework to generate rules of thumb for translocation managers when the specifics of translocated populations are known. However, a real-life situation in which we know all population parameters would be extremely unlikely. A more useful model would be one in which at least one of the parameters for a population is unknown. We could incorporate this into the current SDP by assuming a prior distribution for the unknown parameter, and updating this distribution in each time step according to information obtained about the population dynamics. This has not been done before in research into translocation strategies and will be addressed in a future study.

Testing the ideas presented in this paper will be difficult for threatened taxa because of the limited amount of replication possible for species with small population size. Cheaper and more replicable introductions occur in other applied population biology fields, like biocontrol establishment for weed management (Shea and Possingham, 2000). The principles and theory developed here could be tested using such systems.

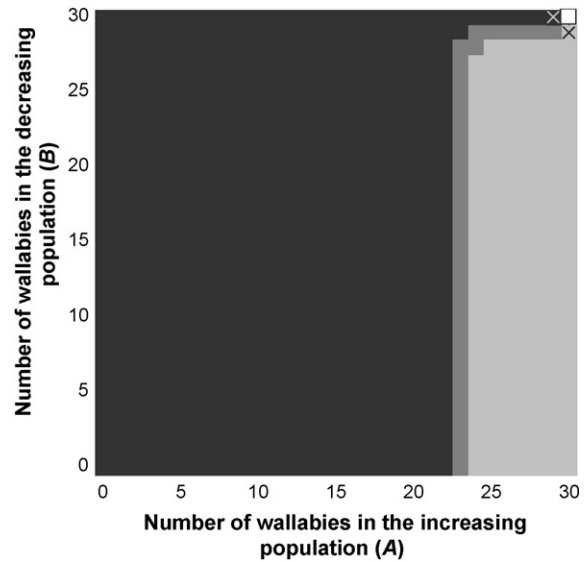


Fig. 6 – Optimal translocation decisions for each population state at the end of the project ($t=10$), with the total population size objective function. Dark grey, add both available wallabies to the increasing population (A); medium grey, add one wallaby to each population; light grey, add both available wallabies to the decreasing population (B); dark grey with cross, two equally optimal decisions—to add both to the increasing population (A), or add one to each population; light grey with cross, two equally optimal decisions—to add both to the decreasing population (B), or add one to each population; white, all decisions are equally optimal.

4. Conclusions

This research shows the utility of stochastic dynamic programming for developing rules of thumb for conservation and wildlife managers charged with establishing populations. One key principle emerges from both objectives used: both the abundance and persistence of populations are heavily influenced by site quality, as represented by population growth rate. This indicates the importance of removing threat from sites where a population might exist. This study also demonstrates the necessity of having a clear goal for decision-making. The two objectives used in this study give optimal strategies that are essentially different, although they show similar trends. We conclude that the choice of an appropriate and specific objective is critical for translocation programs, or any other venture where clear decision-making is needed.

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