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Review

An assessment of the published results of animal relocations

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Abstract

We reviewed 180 case studies and a number of theoretical papers on animal relocations published in 12 major international scientific journals over the last 20 years. The study focused on re-introductions, supplementations and translocations (sensu IUCN, 1996. IUCN/SSC Guidelines for Re-introductions. 41st Meeting of the IUCN Council, Gland, Switzerland, May 1995. Http://iucn.org/themes/ssc/pubs/policy/hinte.htm.). We did not assess introductions. Re-introductions were the most common type of relocation (116/180); three quarters of these were conducted for conservation purposes. Supplementations (48/180) and translocations (36/180) occurred less frequently, and both were commonly carried out for reasons other than conservation. Simple descriptive statistics were used to analyse factors influencing relocation success. Translocations that aimed to solve human–animal conflicts generally failed. Re-introduction success was not found to have changed over the last two decades, but re-introductions appeared to be more successful when the source population was wild, a large number of animals was released ($n > 100$), and the cause of original decline was removed. More complex trends were found for the effect of predation and the use of supportive measures such as provision of food or shelter, or predator control prior to release. The success of 47% of re-introductions was uncertain at the time case studies were published in journals. This was partly due to the lack of generally accepted and widely applied criteria to assess success. Very few case studies (3%) reported the cost of the relocation attempt. We conclude that there were three primary aims for animal relocations. These were to solve human–animal conflicts, to restock game populations, and conservation. Our extensive review of the present literature leads us to conclude that the value of animal relocations as a conservation tool could be enhanced through (1) more rigorous testing for the appropriateness of the approach in a given case, (2) the establishment of widely used and generally accepted criteria for judging the success or failure of relocations, (3) better monitoring after a relocation, (4) better financial accountability, and (5) greater effort to publish the results of relocations, even ones that are unsuccessful.

Keywords: Translocation; Re-introduction; Supplementation; Relocation; Re-introduction success

Contents

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1. Introduction

Relocating animals within their range, or to parts of their former range, has become a popular tool in wildlife management, both for conservation and other purposes (Griffith et al., 1989; Kleiman, 1989; Stanley Price, 1991; Wolf et al., 1996). However, several previous studies suggest that many relocations are not successful (Griffith et al., 1989; Kleiman, 1989; Dodd and Seigel, 1991; Short et al., 1992; Wolf et al., 1996), and can be very expensive (e.g. Kleiman et al., 1991; Lindburg, 1992; Rahbek, 1993). This has led to an increased interest in what factors influence the success of relocations.

Investigations by Griffith et al. (1989) and Wolf et al. (1996) used mailing surveys to wildlife managers in selected countries in an attempt to identify some of the ecological factors influencing the success of bird and mammal relocations. Reading et al. (1997) employed a similar approach to evaluate the importance of anthropogenic factors. Although these reviews provide excellent summaries of some of the important issues, they are based on data not generally accessible to wildlife managers — people who are typically reliant on published material. Moreover, most previous reviews have (1) been limited geographically and addressed only ecological or anthropogenic issues (Griffith et al., 1989; Wolf et al., 1996; Reading et al., 1997), (2) have lacked a systematic empirical approach (Kleiman, 1989; Stanley Price, 1991), and/or, (3) have dealt with certain taxonomic groups (Dodd and Seigel, 1991; Stanley Price, 1991; Short et al., 1992).

We employed an approach different from earlier reviews where mailing surveys were used, and we assessed a large number of case studies as well as theoretical papers on animal relocations that have been published in major journals throughout the world over the last 20 years. Thus, our overarching objective was to explore the outcomes of relocations through a detailed literature review and summarise important unifying key themes. We acknowledge that by using published material, our sample of case studies may be several years older than assessments from mailing surveys. Also, our sample may only be a subset of all relocations because the results from a large number of relocations are never published. However, we took this approach because there are abundant published case studies on animal relocations. Therefore, an analysis and summary of the large existing body of published work may be a useful starting point for conservation biologists and wildlife managers, especially those relatively unfamiliar with the topic.

The scope of this study was considerably wider than in previous reviews — we reviewed publications dealing with all kinds of animal species in all countries of the world. In addition, because information available from published case studies often lacks detail, the questions addressed in this paper were considerably broader than those asked in previous mailing surveys.The key aims of this paper were to identify (1) where relocations have taken place, (2) what the purposes of relocations are, (3) what types of animals are commonly relocated, (4) what factors influence the success of relocations, and (5) what issues need to be addressed to make animal relocations a more efficient conservation tool in future. We are acutely aware that both mailing surveys and reviews of published literature are likely to be biased toward successful relocations (Reading et al., 1997). As the methods in this study were different from those employed in earlier assessments of animal relocations, an important additional objective was to compare and contrast the results of the two approaches and search for unifying themes common to both. Animal relocations were the focus of our review. While we acknowledge the potential importance of relocations of plants as a conservation tool (Maunder, 1994), it was beyond the scope of this study to examine them.

2. Methods

2.1. Definition of terms

In this paper, we define relocations as any intentional movement by humans of an animal or a population of animals from one location to another. In doing this, we attempt to create a neutral overarching term, and thus hope to avoid the confusion which other terms may cause [“translocation” for example has been used as both the overarching term (e.g. Griffith et al., 1989) and for a particular type of relocation, i.e. the “capture and transfer of free-ranging animals from one part of their historic geographic range to another” (Kleiman, 1989)]. Apart from this exception, our definitions follow those of the IUCN (1996). Hence, we distinguish between four types or relocations, (1) introductions, (2) re-introductions, (3) translocations, and (4) supplementations.

Introduction describes the attempt to establish a species outside its recorded distribution. *Re-introductions* are the “attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct”. A *translocation* is the “deliberate and mediated movement of wild individuals or populations from one part of their range to another”. *Supplementations* occur when individuals are added to an existing population of conspecifics (IUCN, 1996).

The source of relocated animals may be wild or captive for introductions, re-introductions and supplementations, but using the above definition, only wild animals are moved in translocations. There may be overlap between the terms supplementation and translocation if the source population of a supplementation attempt is a wild population. The remainder of this paper will deal exclusively with re-introductions, translocations and supplementations, and will not further discuss issues relating to introductions.

2.2. Literature search

We searched 12 major international journals believed to be likely to contain relevant case studies (see Table 1). Additional articles from other journals that had been collected opportunistically over the past 5 years also were examined for case studies. The search generally covered all volumes of these journals from 1979 to 1998. Journals first issued after 1979 were searched from the year of first publication. Some papers dealt with more than one case study (e.g. if different release techniques were employed and the reported studies were, therefore, essentially different). In addition, a number of papers dealt with the same case study (e.g. in the case of repeated reporting through time). Hence, the number of papers containing case studies did not equal the actual number of case studies. Multiple releases of the same species into the same area over a period of time were treated as a single case study.

2.3. Creation of a database and analysis of data

A database of all suitable literature was created. The following questions were posed for each case study. (1) What taxonomic group was examined? (2) In which part of the world did the relocation take place? (3) In what year was the case study apparently first reported in the literature? The aim of this question was to detect broad trends in the frequency and success of relocations through time. (4) Was the only objective to conserve the species released? (5) What type of relocation was undertaken (using the definitions listed above)? (6) Did the individuals released originate from a captive or wild population? (7) What was the cost of the relocation? (8) Were predators absent in the release area? (9) Were any supportive measures taken? These were defined as soft release, predator control, provision of food or shelter, habitat modification, special veterinary care, etc. Studies that somehow pre-conditioned animals prior to release or gradually exposed individuals to their new environment were defined as “soft releases”. (10) Was the reason for the original decline explicitly stated? (11) If so, was it successfully addressed before the relocation took place? (12) Was the relocation a success?

For the purpose of this review, a re-introduction was considered successful if it resulted in a self-sustaining population (Griffith et al., 1989). As this may take a long time (Dodd and Seigel, 1991), the success of many re-introductions had to be classified as “unknown”. The success of translocations could not easily be determined as it was dependent on the objective of the specific

Table 1
Summary of the journals searched and the types of relocation studies and animals relocated

Journal	No. of articles	No. of case studies	No. of reintroductions	No. of translocations	No. of supplementations	No. of mammals	No. of birds	No. of others
Wildlife Man.	15	21	6	7	11	6	15	0
Rest. Ecology	3	3	1	1	1	1	0	1
Biol. Cons.	25	52	47	4	2	32	12	8
Cons. Biol.	8	10	4	3	6	4	6	0
Wildl. Res.	4	5	0	3	2	3	1	1
Oryx	4	4	3	1	0	4	0	0
Zoo Biology	4	4	3	0	1	0	4	0
Herp Review	1	1	1	0	0	0	0	1
Int. Zoo Yb.	10	11	11	0	0	10	1	0
Wildl. Soc.B.	21	36	16	15	16	15	21	0
Biod. & Cons.	2	2	1	0	1	1	0	1
J. Mammal.	1	1	1	0	0	1	0	0
Others	26	30	22	2	8	12	18	0
Total	124	180	116	36	48	89	79	12

translocation, which in many cases was not clearly stated. Therefore, we only defined "failures" to be translocations that clearly did not meet the objective specified in that paper. Similarly, the success of supplementations could rarely be determined due to very different objectives. For example, if one individual of a highly endangered species from a captive population joins a wild population, this may be perceived as a success. If the aim of supplementation is to increase hunting resources, however, generally a much larger proportion has to survive for the supplementation to be perceived as successful.

The methodology described here was highly dependent on what authors of case studies chose to publish. This meant that (a) information extracted often could only show broad trends, and (b) even given the simple questions above, the set of answers was often incomplete.

In addition to the relatively detailed case studies, a number of review articles was examined. The case studies reported in Short et al. (1992) examined 25 re-introductions of Australian marsupials, and each one was included in the overall database of case studies. Other review studies will be discussed briefly later, but were not included in the database as they generally reported insufficient detail on individual case studies to facilitate assessment using the suite of questions listed above.

2.4. Reporting of results

Results are presented using simple tables and histograms only. More refined statistical techniques (e.g. regression analysis) as used previously, for example by Griffith et al. (1989) and Wolf et al. (1996), seemed inappropriate, both because of relatively sparse information available from most articles, and because such techniques may (unintentionally) mislead decision-makers. This is because statistical models may overestimate the chances of success when they are extrapolated to different environmental conditions. Hence, we did not test for statistical significance of our findings, but merely aimed to illustrate some of the most prevalent broad trends apparent in the data.

3. Results

3.1. General trends

The database comprised 180 studies from 124 journal articles (including the review article by Short et al., 1992; Table 1). Most case studies (116/180) dealt with re-introductions, and fewer with translocations (36/180) or supplementations (48/180). (Note that the potential overlap between translocations and supplementations made it possible for case studies to fall into more than one category; hence the different categories do not sum to the total number of case studies.) Birds (79/180) and mammals (89/180) together accounted for 93% of all relocation studies examined, whereas amphibians, reptiles and invertebrates accounted for 7% of studies ($n=12$). Of 116 re-introductions, 87 (75%) re-introductions were conducted exclusively for conservation purposes, while the remainder (25%) either (1) did not clearly state the purpose of reintroduction, (2) had aims in addition to conservation, or (3) had aims other than conservation.

A relatively large proportion ($n=15$; 43%) of re-introductions in North America (i.e. USA and Canada; $n=35$) was carried out for unknown reasons or reasons other than conservation ($n=15$). Australia and New Zealand showed a similar trend with 11 of 36 (31%) re-introductions undertaken for reasons unknown or other than conservation (Fig. 1). Note, however, that this was largely an artefact arising from the inclusion of the Australian review article by Short et al. (1992). This article accounted for eight of the 11 case studies (detailed information about the purpose was not explicitly stated and no assumptions were made). No such distortion occurred for North America. In all other parts of the world, conservation was the primary objective for re-introductions in the overwhelming majority of cases (Fig. 1).

Of 36 translocations, 15 (42%) were conducted for conservation, 15 (42%) were carried out for reasons other than conservation, and six (16%) did not clearly state the purpose of translocation. Of the 15 translocations for reasons other conservation, the majority (9/15 = 60%) were to solve a conflict between humans and animals.

All supplementation attempts we examined dealt with mammals ($n=11$; 23%) or birds ($n=37$; 77%; Table 2). The vast majority of mammal supplementations were for conservation ($n=10$; 91%), and the purpose of the remaining supplementation attempt was not explicitly stated ($n=1$; 9%). Unlike mammals, a large portion of bird supplementations was not motivated by conservation purposes alone ($n=15$; 41%); 80% of these ($n=12$) took place in the USA. In 22% ($n=8$) of all bird supplementations, the aim was not explicitly stated. A total of 18% of bird supplementations was completed for conservation purposes. Individuals came mostly from wild source populations in the case of mammals (8/11 = 73%), but originated mostly from captive populations (breeding programmes) for birds (31/37 = 84%).

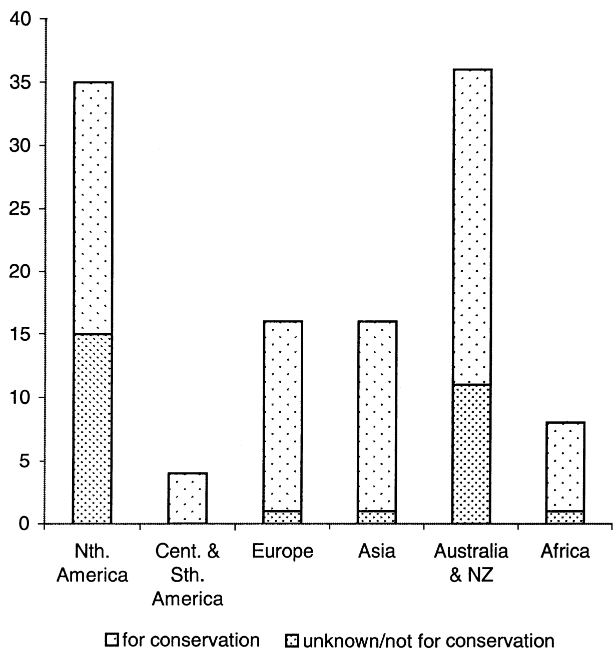

Fig. 1. Reintroduction purposes in 116 case studies examined.

Table 2
Summary of all supplementations examined in case studies ($n=48$)

	Mammals	Birds
Captive source population	3	31
Wild source population	8	6
Conservation purposes only	10	14
Not only conservation purposes	0	15
Purpose uncertain	1	8

3.2. Costs

Costs were reported in only six studies. Cohn (1993) estimated the annual cost of the re-introduction programme for Californian condors (*Gymnogyps californianus*) to be US $1,000,000. The total institutional cost for rehabilitating confiscated Bornean gibbons (*Hylobates muelleri*) in Sarawak was calculated to be UK $10,000 per year (Bennett, 1992). The rehabilitation and re-introduction cost of sea otters (*Enhydra lutris*) after the Exxon Valdez oil spill was estimated to be US $80,000 per individual released, or a total of US $17 million (Estes, 1998). Kleiman et al. (1991) estimated the cost of re-introducing golden lion tamarins (*Leontopithecus r. rosalia*) to be approximately US $22,000 per surviving individual. Bangs and Fritts (1996) reported the expected combined cost for two re-introduction projects for the gray wolf (*Canis lupus*) in central Idaho and the Yellowstone National Park respectively to be US $ 6,700,000 over a period of approximately eight years.

3.3. Re-introduction success through time

Of 116 re-introductions, 30 (26%) were classified as successful, 31 (27%) were classified as failures, while the outcome of 55 (47%) re-introductions was classified as unknown at the stage of publication. Success rates were highly variable between years. The success of more recent studies tended to be more likely to be classified as uncertain than of previous studies, with 51% of studies from the 1990s in that class (Table 3). These trends did not appear to change when only re-introductions for conservation purposes were considered ($n=87$) with 20 (23%) successes, 23 (26%) failures and 44 (51%) studies with an uncertain outcome.

Table 3
Reintroduction success through time

Year	No. of studies	No. of successes	No. of failures	No. unknown
Unknown	6	1 (17%)	1 (17%)	4 (67%)
Pre 1970	3	1 (33%)	2 (67%)	0 (0%)
1970s	9	5 (56%)	1 (11%)	3 (33%)
1980s	38	13 (34%)	8 (21%)	17 (45%)
1990s	60	10 (17%)	19 (32%)	31 (51%)
Total	116			

3.4. Re-introduction success throughout the world

Fig. 2 summarises the success rates of re-introductions for conservation purposes throughout the world. All parts of the world show that for a large proportion of case studies, success was uncertain at the time of publication (51%). Other features worth emphasising are the high failure rate in Australia and New Zealand (56%; $n=25$) and the relatively small proportion (10%; $n=20$) of definite failures in the USA.

3.5. Re-introduction success in relation to source population

Of the 116 re-introductions, 52 had a captive and 45 had a wild source population. The status of 19 source populations was unknown. The success rate for re-introductions with a wild source population was higher (31%) than for re-introductions which originated from a captive population (13%). The same ranking was apparent if only re-introductions for conservation purposes were considered ($n=87$), with a 29 and 15% success rate from wild and captive populations respectively.

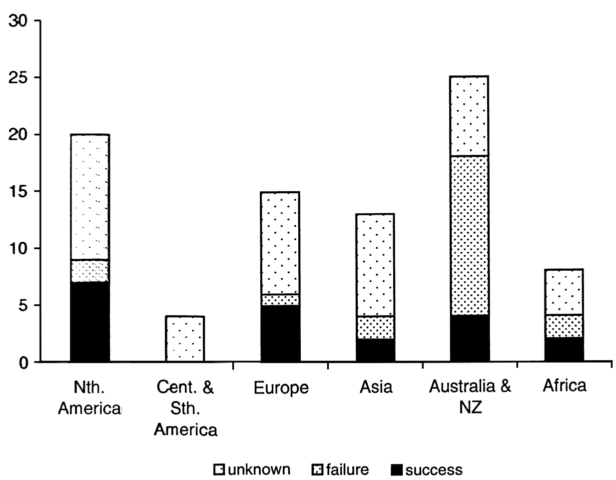

Fig. 2. Re-introduction success throughout the world (87 re-introductions conducted only for conservation purposes).

3.6. Re-introduction success in relation to number of animals released

Table 4 shows the number of animals released in the 116 re-introduction studies examined. Classes were selected to keep the number of studies per class approximately constant. The proportion of definite successes (18%) was lower than the proportion of definite failures (30%) for re-introductions with fewer than 100 individuals released (not necessarily all at the same time), while it was higher (50%) than for the proportion of failures (17%) if more than 100 animals were released.

3.7. Re-introduction success in relation to supportive measures

Of 67 mammal re-introductions, 25 were found to have employed supportive measures, while 12 employed none. In 30 cases, it was unknown whether any supportive measures were taken. The percentage of definite failures appeared to drop if supportive measures were taken (failure rate 42% without versus 12% with supportive measures). This trend was not apparent for bird re-introductions ($n=39$), with a slightly increased rate of failure if supportive measures were taken (22% without supportive measures versus 27% with supportive measures).

3.8. Re-introduction success in relation to predation — Australia vs. USA

Sixteen of 32 re-introductions in Australia involved animals being released into areas with predators. Only two of these succeeded, while 11 (69%) failed and the success of three was unknown. The presence of predators was unknown in 14 cases. Success was unknown

Table 4
Re-introduction success in relation to number of animals released

No. of individuals released	No. of case studies	No. of successes	No. of failures	No. unknown	% Definite successes	% Definite failures
Unknown	8	3	2	3	38	25
1–10	15	4	6	5	27	40
11–20	20	4	4	12	20	20
21–40	19	2	4	13	11	21
41–60	13	3	7	3	23	54
61–100	17	2	4	11	12	24
101–200	10	7	1	2	70	10
201 +	14	5	3	6	36	21
Total	116	30	31	55		

for the two re-introductions where predators were absent. In the USA, predators were present in eight of 33 re-introductions. No definite failures were reported in this category. However, for 19 of 33 re-introductions, the presence of predators was unknown.

3.9. Re-introduction success in relation to removing the cause of decline

The cause of decline was not explicitly stated in 57 of 116 re-introduction case studies (49%). In five cases (4%), the cause of decline was explicitly stated, but it was unclear whether it was addressed successfully prior to re-introduction. None of the case studies that acknowledged the cause of decline, but failed to remove it, were successful ($n=13$; 11%), although the success was uncertain in four of these 13 cases (31%). In 41 cases, the cause of decline was known, explicitly stated and effectively removed (35%). Nine of these studies were classified as successful (22%), three were classified as failures (7%), while the success for the majority of cases ($n=29$; 71%) was uncertain (Fig. 3).

4. Discussion

Our analysis of case studies showed there were three primary aims of animal relocations. These were (1) to solve human–animal conflicts, (2) to supplement game populations, and (3) conservation. This distinction has rarely been made explicitly, but is useful because the problems encountered during a relocation are likely to be fundamentally different for these three categories. We will briefly discuss the first two categories, but then focus mostly on relocations for conservation. These are our primary concern, and also the category that we assigned the majority of published case studies.

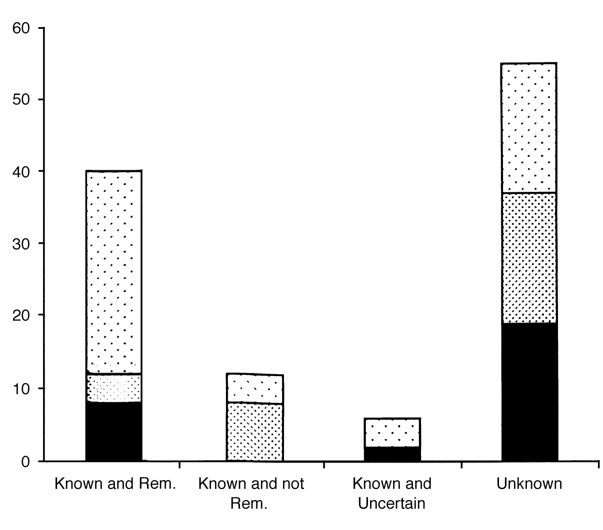

Fig. 3. Effect of knowing and effectively removing the initial cause of decline on re-introduction success. "Known and Uncertain" refers to cases where the initial cause of decline was known, but it was uncertain whether this was effectively removed.

4.1. Relocations to solve human–animal conflicts

Translocations seemed to be a commonly employed management tool to solve human–animal conflict situations, but were often unsuccessful. In the majority of cases reported, the stated aim clearly failed. For example, suburban common brushtail possums (*Trichosurus vulpecula*) in Melbourne, Australia, frequently died from predation after being translocated into a non-urban environment (Pietsch, 1994). Similarly, a large proportion of metropolitan white-tailed deer (*Odocoileus virginianus*) in Illinois, USA, died after translocation to a non-urban environment (Jones and Witham, 1990).

Other problems frequently limiting the success of human–animal conflict translocations were extensive movements of relocated animals and homing behaviour. Translocation of gray wolves (*Canis lupus*) did not successfully reduce the problem of livestock predation, and homing was reported for animals released too close to the initial capture site (Fritts et al., 1984). Similar problems occurred with Alaskan brown bears (*Ursus arctos*) (Miller and Ballard, 1982), saltwater crocodiles (*Crocodylus porosus*) in the Northern Territory, Australia (Walsh and Whitehead, 1993), and the translocation of elephants (*Elephas maximus*) in Malaysia (Stüwe et al., 1998). Our findings were consistent with the findings of Linnell et al. (1997) who reviewed the feasibility of carnivore translocations as a management tool to solve human–animal conflict situations.

4.2. Relocations to supplement game populations

Relocations to supplement game populations are frequently conducted in North America. In their mailing survey, Griffith et al. (1989) found that more than 90% of relocations dealt with game species. While the sources we examined mostly dealt with relocations for conservation, the relevance of game species relocations in North America was evident in the relatively high proportion of supplementations completed for reasons other than conservation. This trend applied in particular to birds whose populations were frequently supplemented for reasons other than conservation.

4.3. Relocations for conservation

Most case studies examined in this study dealt with relocations for conservation. This illustrates the popularity and potential value of relocations as a management tool.

4.3.1. Taxonomic groups

A total of 93% of all case studies focused on mammals and birds. Mammals alone accounted for more than 50% of all relocation studies. This may indicate that re-introductions are a particularly suitable conservation strategy for mammals. Given that mammals only account for 0.25% of species globally (Rahbek, 1993), these trends may also indicate that mammals receive disproportionate attention in conservation efforts.

Due to a lack of detail for specific case studies, a number of review articles could not be included in the data base for case studies. These articles dealt mostly with mammals (Anderson, 1986; Zurowski and Kasperczyk, 1988; Bergerud and Mercer, 1989), but also with fish (Simons et al., 1989), amphibians and reptiles (Dodd and Seigel, 1991; Denton et al., 1997), and invertebrates (New, 1994). This suggests that relocation strategies may be a useful conservation tool for a range of taxa.

4.3.2. Use of surrogates

Several studies released a non-endangered related species as a surrogate for the actual target species (e.g. Wallace and Temple, 1987; Zwank and Wilson, 1987; Belden and Hagedorn, 1993; Diefenbach et al., 1993; Powell and Cuthbert, 1993). This approach may be useful to identify some key problems that may affect the related target species in later relocation attempts. For example, disease and predation have been identified as key issues for re-introduction attempts of Hawaiian birds (Kuehler et al., 1996). The limitation of this approach lies in the fact that no two species react in the same way to the same environmental conditions. Furthermore, pilot studies of this kind often release very small groups of animals (e.g. Kuehler et al., 1996) which may in some cases be unlikely to establish a viable population (but see e.g. Pierre 1999). Therefore, they may only give a partial picture of what is needed for a successful relocation. Carefully assessing the similarity of surrogate and target species is an important preliminary step in any relocation programme (Powell and Cuthbert, 1993).

4.3.3. Re-introduction success

It is likely that the results presented here, although they did not reveal particularly high success rates, still over-estimate re-introduction success. This is because authors may be more likely to publish their results if they are able to report a "success". The same is true for empirical studies based on mailing surveys (e.g. Griffith et al., 1989; Wolf et al., 1996; Reading et al., 1997). This fact, combined with the large number of "uncertain" outcomes obtained from our extensive assessment of the literature, made it difficult to draw general conclusions about the value of relocations as a conservation tool. However, we identified several factors which can increase the chances of success.

Similar to Griffith et al. (1989), we found an overall increase in success with a larger number of animals released. The methodology we employed did not discriminate between one or several releases through time, and our choice of class location and width may bias the success rates of classes. However, it appeared that releasing approximately 100 individuals led to a higher chance of success than releasing fewer individuals (Table 4).

We also found empirical evidence that the initial cause of decline needs to be removed effectively for a successful re-introduction (see also Kleiman, 1989; Dodd and Seigel, 1991). Some of the most striking examples come from Australia. Feral predators are widely regarded as a major factor linked to the decline of many native mammals, yet re-introduction attempts frequently occurred in areas where these predators had not been effectively eliminated (Short et al., 1992; Short and Smith, 1994).

There are a range of other factors influencing re-introduction success discussed in the literature, but up to now no effective summary of these factors exists. These may be ecological factors, such as habitat quality (Burgman and Lindenmayer, 1998), genetics (Jiménez et al., 1994; Lacy, 1994; Pray et al., 1994), or competition (Burgman and Lindenmayer, 1998). In addition, a number of non-ecological factors may affect re-introduction success. These include public relations and education (Kleiman, 1989; Maguire and Servheen, 1992; Reading and Kellert, 1993), good team management (Clark and Westrum, 1989), social and valuational factors (Reading et al., 1997), legal considerations and litigation costs (Morris, 1986; Minckley, 1995; Bangs and Fritts, 1996), and long-term commitment to the re-introduction project (Rahbek, 1993).

4.4. Strategies to improve relocations as a conservation tool

Animal relocations are one of the main options available to conservation biologists seeking to restore populations. They have the potential to attract considerable publicity (Dodd and Seigel, 1991), and especially when combined with captive breeding programmes in zoos, have the additional benefit of promoting conservation, raising public awareness, educating the public (Stuart, 1991; Lindburg, 1992; Mitchell, 1992; Rahbek, 1993; Wiese et al., 1996) and raising funds (Snyder et al., 1996; Wiese et al., 1996). All these factors make relocations an attractive option for biodiversity conservation. However, the effectiveness of relocations both ecologically and as a publicity tool could be enhanced through a more uniform and rigorous approach to the design and reporting of relocations. In particular, we identified five broad areas of concern that can help improve the approach.

4.4.1. Concern No. 1: rigorous checking for the appropriateness of the approach

The overviews of Griffith et al. (1989), Wolf et al. (1996), Dodd and Seigel (1991), and this paper provide useful summaries about which factors influence relocation success. These broad overviews (and more detailed studies dealing with the organism targeted for relocation) should be studied prior to the design of relocations. In addition, adverse consequences of the release of animals on the present ecosystem or humans nearby should be taken into consideration (Morris, 1986; Viggers et al., 1993; Cunningham, 1996; Yeager, 1997; Nolet and Rosell, 1998). If the overall aim is conservation, alternatives to relocation should be contemplated. Are there more effective ways to restore the population given the financial resources available?

4.4.2. *Concern No. 2: clearer definitions of success*

We identified problems with the definition of "success" of a relocation programme. From an ecological perspective, the establishment of a viable self-sustaining population is a key measure of success. Some authors chose a more pragmatic perspective, and thus perceived a re-introduction as successful if initial signs of ecological success were observed. Lohoefener and Lohmeier (1986), for example, considered the re-introduction of a tortoise was successful if it accepted a burrow that had been prepared for it in a new environment. Clearly, from a pragmatic perspective, this initial step is critical. While it is also critical from an ecological perspective, it is only one of many factors required for the establishment of a viable self-sustaining population. The timescale over which relocations prove to be successful is important (Dodd and Seigel, 1991). The re-introduction of giant land tortoises (*Geochelone gigantea)* in the Seychelles showed signs of initial success (Stoddart et al., 1982), but the population then declined (Samour et al., 1987), and only more than a decade after the initial re-introduction, the definite failure of the project was apparent (Hambler, 1994). To avoid confusion, we suggest authors clearly state their perspective and definition of re-introduction success. This, in turn, provides a yardstick against which subsequent monitoring (see below) can assess the success of a relocation programme. Ultimately, workable and effective conservation measures will have to meet both pragmatic and ecological criteria.

4.4.3. *Concern No. 3: constant monitoring of success*

We had to classify the outcome of many case studies examined as "uncertain" (Figs. 2 and 3). This was partly because it may take a long time until success can be determined (see above), but also because most studies did not seem to follow a strict population monitoring agenda. We suggest that scientists and wildlife managers conducting a relocation programme develop long-term monitoring protocols in which they gather key parameters reflecting the success of a relocation at previously specified time intervals. These parameters may be the number of animals, sex ratios, adult/juvenile ratios, population change, and a constant re-assessment of the threatening process.

4.4.4. *Concern No. 4: better financial accountability*

Very few studies reported their costs. Those that did — with the exception of Kleiman et al. (1991) — did not provide a breakdown of expenditures, and did not report the source of funding in any detail. We believe that given the scarcity of financial resources for conservation, it would be useful for the planning and fund-raising stages of any relocation programme if more information was available on the cost of such projects.

4.4.5. *Concern No. 5: publication of results*

Much of the relocation literature is not generally accessible to wildlife managers and conservation biologists. This may be why previous reviews adopted a different approach than the one employed in this study, i.e. mailing surveys (Griffith et al., 1989; Wolf et al., 1996; Reading et al., 1997). We believe that the field of relocation biology needs to make the outcomes of relocation projects better available for future wildlife managers to learn from past mistakes. Citations of "personal communications", especially when reporting previous unsuccessful re-introduction attempts (e.g. Combreau and Smith, 1998; Hendrickson and Brooks, 1991 in Minckley, 1995), can be of limited value to scientists and managers seeking additional information. Clearly, there is a need for more complete documentation of past experiences in the generally accessible literature (Stanley Price, 1991; Minckley, 1995).

5. Conclusion

Relocations are a commonly used, popular, and potentially powerful tool for the conservation of biodiversity. However, they are often carried out in an ad hoc fashion, and are not carefully monitored. In addition, most relocations are poorly documented in the published literature. Given the high publicity many relocation programmes attract, this approach has much to gain by following some simple steps to ensure that scarce conservation dollars are used in an ecologically and financially efficient way.

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