Translocation as a Species Conservation Tool: Status and Strategy

BRAD GRIFFITH, J. MICHAEL SCOTT, JAMES W. CARPENTER, CHRISTINE REED

Surveys of recent (1973 to 1986) intentional releases of native birds and mammals to the wild in Australia, Canada, Hawaii, New Zealand, and the United States were conducted to document current activities, identify factors associated with success, and suggest guidelines for enhancing future work. Nearly 700 translocations were conducted each year. Native game species constituted 90 percent of translocations and were more successful (86 percent) than were translocations of threatened, endangered, or sensitive species (46 percent). Knowledge of habitat quality, location of release area within the species range, number of animals released, program length, and reproductive traits allowed correct classification of 81 percent of observed translocations as successful or not.

A TRANSLOCATION IS THE INTENTIONAL RELEASE OF ANImals to the wild in an attempt to establish, reestablish, or augment a population (1) and may consist of more than one release. To date, translocations have been used to establish populations of nonnative species and restore native species extirpated by hunting. An increasing perception of the value of biological diversity has focused attention on translocations of rare native species. These latter translocations are expensive (2, 3) and are subject to intense public scrutiny (4). They have varied goals (3) that include bolstering genetic heterogeneity of small populations (5–7), establishing satellite populations to reduce the risk of species loss due to catastrophes (8, 9), and speeding recovery of species after their habitats have been restored or recovered from the negative effects of environmental toxicants (2) or other limiting factors.

In the face of increasing species extinction rates (10–12) and impending reduction in overall biological diversity (12), translocation of rare species may become an increasingly important conservation technique. If current patterns of habitat loss continue, natural communities may become restricted to disjunct habitat fragments and intervening development may disrupt dispersal and interchange mechanisms (2). Increased rates of extinction may be expected in small fragmented habitats (13) and translocation may be required to maintain community composition, especially for species with limited dispersal abilities.

The immediacy of reduction in biodiversity (14) demands a rigorous analysis of translocation methodology, results, and strategy. We need to know how well it works, what factors are associated with success, and what strategies suggest greatest potential success.

We conducted three surveys of contemporary (1973 to 1986) translocations of native birds and mammals in Australia, Canada, Hawaii, New Zealand, and the United States (15). In the first survey, we obtained general information on the number of programs completed by various organizations. In the later surveys, we sought detailed information on translocations of (i) threatened, endangered, or sensitive species and (ii) native game birds and mammals.

Current Status

At least 93 species of native birds and mammals were translocated between 1973, the year the Endangered Species Act became law, and 1986. Most (90%) translocations were of game species; threatened, endangered, or sensitive species accounted for 7%. Ungulates (39%), gallinaceous birds (43%), and waterfowl (12%) dominated translocations of game species; raptors (28%) and marsupials (22%) dominated threatened, endangered, or sensitive species translocations.

A typical translocation consisted of six releases over the course of 3 years. Many (46%) released 30 or fewer animals and most (72%) released 75 or fewer animals.

The average number of translocations per reporting organization doubled from 1974 (5.5) to 1981 (10.6) suggesting contemporary totals of 700 translocations per year. Most (98%) of these were conducted in the United States and Canada. Effort was not uniformly distributed; 21% of North American agencies conducted 71% of North American translocations. Only 27% of reporting organizations had protocols that specified the types of information to be recorded during translocation programs.

Theoretical Considerations

A translocation is a success if it results in a self-sustaining population; conversely, the founder group may become extinct. Theoretical considerations predict that population persistence is more likely when the number of founders is large, the rate of population increase is high, and the effect of competition is low (13). Low variance in rate of increase (16), presence of refugia (9), reduced environmental variation (16), herbivorous food habits (17), and high genetic diversity among founders (18) may also enhance persistence. Suitable, protected, and maintained habitat, control of limiting factors, and proper care and training of captive reared

B. Griffith was in the Department of Fisheries and Wildlife Resources, University of Idaho, Moscow, ID 83843, and is currently assistant leader, U.S. Fish and Wildlife Service (USFWS), Cooperative Fish and Wildlife Research Unit (CFWRU), University of Maine, Orono, ME 04469. J. M. Scott is leader, USFWS, CFWRU, University of Idaho, Moscow, ID 83843. J. W. Carpenter is a research veterinarian, USFWS, Patuxent Wildlife Research Center, Laurel, MD 20708. C. Reed is a Conservation Officer, Department of Conservation, Twizel, New Zealand.

animals (3, 19) are also considered prerequisites of a successful translocation.

We found that several factors were associated with success of translocations (Table 1). Native game species were more likely to be successfully translocated than were threatened, endangered, or sensitive species. Increased habitat quality was associated with greater success. Translocations into the core of species historical ranges were more successful than were those on the periphery of or outside historical ranges. Herbivores were more likely to be successfully translocated than either carnivores or omnivores. Translocations into areas with potential competitors of similar life form were less successful than translocations into areas without competitors or areas with a congeneric potential competitor. Early breeders with large clutches were slightly more likely to be successfully translocated than were species that bred late and had small clutches.

Translocations of exclusively wild-caught animals were more likely to succeed than were those of exclusively captive-reared animals (Table 1). Among translocations of exclusively wild-caught animals, success depended ($P \leq 0.10$) on whether the source population density was high (77% success, $n = 109$), medium (78%, $n = 37$), or low (37%, $n = 8$). Success of translocations of wild-caught animals was also associated ($P \leq 0.10$) with whether the source population was increasing (83% success, $n = 93$), stable (63%, $n = 49$), or declining (44%, $n = 9$). Successful translocations released more animals than unsuccessful translocations (160 compared to 54, respectively; $P = 0.024$).

Our results are consistent with analyses of naturally invading or colonizing species that show (i) larger founder populations are more successful (20, 21), (ii) that habitat suitability is important (21), and (iii) increased number and size of clutches enhances successful invasion (22). Our data also support the hypothesis that herbivores are more successful invaders than carnivores (17) and the conclusion that, for birds, morphologically similar species have a greater depressing effect on successful invasion than do congeneric species (23).

We found no consistent association of translocation success with number of releases, habitat improvement, whether the release was hard (no food and shelter provided on site) or soft, immediate or delayed release on site, or average physical condition of animals at release. We were unable to directly evaluate genetic heterogeneity, sex and age composition, or specific rearing and handling procedures for released animals because of inadequate response to survey questions.

Evaluating Alternative Strategies

Analyses of individual factors associated with translocation success do not adequately reflect the multivariate nature of actual translocations. To overcome this problem, we used stepwise logistic regression (24, 25) to develop preliminary predictive equations for estimating the success of translocations (Table 2). An expanded data set or independent sample would probably yield different regression coefficients and estimates of success than we report. As a result, extrapolation to conditions much different than those represented by our data and applications to individual species are discouraged.

The coefficients from Table 2 can be used to plot predicted success of different kinds of translocations as a function of continuous variables such as the number released. We present an example for a threatened, endangered, or sensitive bird (Fig. 1).

This exercise (Fig. 1) illustrates that the increase in success associated with releasing larger numbers of organisms quickly becomes asymptotic. Releases larger than 80 to 120 birds do little to increase the chances that a translocation will be successful for this particular set of conditions. The asymptotic property is consistent across other classifications of the data but the inflection point varies. For large native game mammals the asymptote is reached at releases of 20 to 40 animals with a concurrently higher predicted success.

The asymptotic property of the association of translocation success and number released (Fig. 1) is consistent with theoretical predictions (13) and analytical treatments (26) that suggest a threshold population size below which extinction is likely, primarily due to chance events affecting birth and death of individuals. The existence of the inflection (Fig. 1) is also consistent with the prediction of a threshold density below which population social interactions and mating success are disrupted (27), again leading to diminished population viability.

The coefficients from Table 2 and relationships presented in Fig. 1 can be used to assess alternative strategies. Suppose 300 threatened and endangered birds are available for a translocation program and they must be released during a 3-year time frame. Further suppose that two potential translocation areas are available within the core of the species historical range. If the goal of the translocation is to establish at least one geographically disjunct population to reduce the risk of catastrophic loss of the species, how should the birds be distributed between the two potential translocation areas to minimize the probability that both translocations will fail?

If both release areas have excellent habitat quality, and the areas are independent, the answer is obvious. The birds should be divided between the areas. The coefficients from Table 2 allow us to estimate the probability that a single release of 300 birds will fail (1.0 minus probability of success) is 0.257. Two releases of 150 birds each have individual probabilities of failure of 0.312. The probability that both will fail is $0.312 \times 0.312 = 0.097$; substantial gain is achieved by splitting the birds between areas.

Table 1. Percentage success of intentional introductions or reintroductions (translocations) of native birds and mammals to the wild in Australia, Canada, Hawaii, New Zealand, and the United States between 1973 and 1986. Data were obtained from a survey conducted in 1987 (15). The data include 134 translocations of birds and 64 translocations of mammals. For all variables listed, χ^2 was statistically significant ($P \leq 0.10$), implying true differences in the percentages of successful translocations among the categories. Animals that first give birth at age 2 or less with average clutch size of three or more are considered early breeders with large clutches; all others are late breeders with small clutches.

Variable	Translocations (n)	Success (%)
Threatened, endangered, or sensitive species	80	44
Native game	118	86
Release area habitat		
Excellent	63	84
Good	98	69
Fair or poor	32	38
Location of release		
Core of historic range	133	76
Periphery or outside	54	48
Wild-caught	163	75
Captive-reared	34	38
Adult food habit		
Carnivore	40	48
Herbivore	145	77
Omnivore	13	38
Early breeder, large clutch	102	75
Late breeder, small clutch	96	62
Potential competitors		
Congeneric	39	72
Similar	48	52
Neither	105	75

If we complicate the picture and say that one potential area has excellent habitat quality and the other has only good habitat quality; we see that it remains slightly advantageous to split the birds between areas. Predicted probabilities of failure are 0.312 for excellent and 0.698 for good habitat, respectively. The probability that both translocations will fail is $0.312 \times 0.698 = 0.218$ compared to 0.257 for putting all birds in a single excellent habitat quality area. In this example, slight advantage to splitting the translocated birds between areas is maintained down to a total release of 40 birds. However, with so few birds released the probability that both translocations will fail is increased to about 0.42.

The model coefficients in Table 2 may be used to evaluate other scenarios. For example, given two alternatives, should a given number of birds be released in good habitat quality in the core of the historical species range or in excellent habitat quality on the periphery or outside the historical range? Good habitat quality in the core of the range is the better choice regardless of the number of birds released. This suggests that the physiological amplitude of a species may influence local population viability.

Enhancing the Chances of Success

Without high habitat quality, translocations have low chances of success regardless of how many organisms are released or how well they are prepared for the release. Active management is required. Limiting factors must be identified and controlled and assurances of maintenance of habitat quality obtained prior to translocation.

Identification and retention of adequate habitat will require a combined species and ecosystem approach. Ecological information will be necessary to identify critical life history traits, factors determining habitat quality, species interactions, and minimum
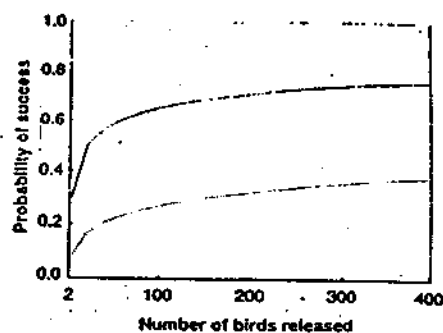

Fig. 1. Predicted probability of successful translocation as a function of the number of animals released during a 3-year period in the core of the historic species range in either excellent (solid line) or good (dashed line) habitat quality for a threatened, endangered, or sensitive bird species that first breeds at 2 years of age or more with average clutch size of three or less. Probabilities are based on stepwise logistic regression model coefficients (Table 2).

habitat fragment size (28). Regional approaches to maintaining diversity (29) will be essential to ensure that existing species and habitat assemblages are identified, their interactions are understood, and remnant habitats are protected. The latter approach may ultimately reduce the number of species that require translocation if it enhances understanding of the effects of habitat fragmentation on persistence of multiple disjunct populations.

We may reduce the need for and increase the success of translocations if we can improve our ability to identify potentially tenuous situations and act before we are faced with a rescue. Simulation modeling (28, 32) of the behavior of small populations of species or of groups of species with similar reproductive strategies can provide guidance for establishing minimum population and vital rate goals. Simulations will be most productive if set in a regional context that addresses the interaction among metapopulations and the spatial relation among reserves or potential release sites (28).

The asymptotic nature of the relation between translocation success and number of animals released emphasizes the point that releasing large numbers of animals does little to increase the success of translocations. Lack of demonstrated success after translocating large numbers of animals is cause for reevaluating other variables associated with success.

The asymptotic levels do suggest that there is a minimum number of animals that should be released. Because longer translocation programs are more successful (Table 2), the minimum number may be released over several years if insufficient animals are available for a single release. Captive rearing programs that are focused on translocation should have the goal of establishing multiple self-sustaining populations so they can provide sufficient animals over a number of years and increase the success of these expensive (2, 3) programs.

Those planning translocations should adopt rigorous data recording procedures (19, 30). Details of translocation attempts should be assembled in a database. It is critical that both failures and successes be adequately documented. Permit-granting agencies may need to assume the role of ensuring that adequate records are kept so the database can be increased and predictability of success enhanced.

Because of the low success of translocations of small numbers of endangered, threatened, or sensitive species, even in excellent habitat quality, it is clear that translocation must be considered long before it becomes a last resort for these species—before density has become low and populations are in decline. Both these traits are associated with low chances of successful translocation. In addition, obtaining sufficient numbers of animals to achieve reasonable chances of success may be impossible. The greatest potential for establishing satellite populations may occur when a candidate population is expanding and numbers are moderate to high. These conditions are the ones that tend to make endangered species biologists relax; our analysis suggests that these conditions may point out the time for action.

Table 2. Stepwise logistic regression (24) model coefficients for predicting probability $[P = 1/(1 + e^{-x})]$ of success of intentional introductions or reintroductions (translocations) of native birds and mammals in Australia, Canada, Hawaii, New Zealand, and the United States between 1973 and 1986; x is the sum of applicable coefficients for categorical variables plus the applicable coefficient times the value of continuous variables. The model is based on 155 translocations; 100 were of birds and 55 were of mammals. Data were obtained from a survey conducted in 1987 (15). The stepwise procedure was run at the $\alpha = 0.10$ level for entry of terms and the $\alpha = 0.15$ level for removal of terms. Probability of larger test statistics for the model were χ^2, $P = 0.90$ (24); Hosmer-Lemeshow χ^2, $P = 0.121$ (24); Brown's χ^2, $P = 0.537$ (24). The model correctly classified 81.3% of observed translocations based on a cutpoint of 0.50 in predicted probability of success.

Variable	Coefficient (SE)
Threatened, endangered, or sensitive species	−1.418 (0.738) −0.972 (0.253)[1]*
Native game	0.972 (0.253)[1]
Birds	−0.919 (0.374)[6]
Mammals	0.919 (0.374)[6]
Release area habitat	
Excellent	1.681 (0.438)[2]
Good	0.053 (0.314)[2]
Fair or poor	−1.734 (0.450)[2]
Release area	
Core of historic range	1.028 (0.267)[3]
Periphery or outside	−1.028 (0.267)[3]
Early breeder, large clutch	1.080 (0.355)[5]
Late breeder, large clutch	−1.080 (0.355)[5]
Log(number released)	0.887 (0.405)[7]
Program length (years)	0.181 (0.074)[4]

*Numbers in brackets represent order of entry.

REFERENCES AND NOTES

1. International Union for Conservation of Nature and Natural Resources (IUCN), "Position Statement on the Translocation of Living Organisms: Introductions, Re-introductions, and Re-stocking" (IUCN Council, Gland, Switzerland, 4 September 1987).
2. T. J. Cade, in (12), pp. 279–288.
3. D. G. Kleiman, BioScience 39, 152 (1989).
4. W. Booth, Science 241, 156 (1988).
5. T. J. Foose, in Genetics and Conservation, C. M. Schoenwald-Cox et al., Eds. (Benjamin-Cummings, London, 1983), pp. 374–401.
6. J. C. Greig, S. Afr. J. Wildl. Res. 9, 57 (1979).
7. S. Conant, BioScience 38, 254 (1988).
8. W. J. Ewens et al., in Viable Populations for Conservation, M. E. Soulé, Ed. (Cambridge Univ. Press, Cambridge, 1987), pp. 59–68.
9. D. Goodman, Conserv. Biol. 1, 59 (1987).
10. P. R. Ehrlich, in (12), pp. 21–27.
11. _____ and A. H. Ehrlich, Extinction: The Causes and Consequences of the Disappearance of Species (Random House, New York, 1981).
12. E. O. Wilson, Ed., Biodiversity (National Academy Press, Washington, DC, 1988).
13. R. H. MacArthur and E. O. Wilson, The Theory of Island Biogeography (Princeton Univ. Press, Princeton, NJ, 1967).
14. T. E. Lovejoy, Keynote Address, 39th American Institute of Biological Sciences Plenary Session, University of California, Davis, 14 August 1988.
15. We used standard procedures (31). The general survey covered 3 years selected randomly (1974, 1979, 1981) and asked for the total number of translocations by group (such as game birds or nongame birds). It was sent to the heads of wildlife management in conservation organizations; 93% of 81 distributed questionnaires were usable. The two detailed surveys asked 52 questions about specific translocations. These were sent to conservation organizations and to curators of zoos. The threatened, endangered, and sensitive species survey was intended to census all work between 1973 and 1986 and was sent to 350 people; 85% replied. The native game survey obtained a random sample of translocations conducted in 1983 and 1984 and was sent to 65 organizations in North America; 94% replied. In both cases, some respondents reported that no translocations were conducted. A total of 240 detailed surveys describing 72 threatened, endangered, or sensitive species and 176 surveys on 18 native game species were received. Of these, 198 were classed as successful (self-sustaining population established) or not (translocated animals declined and disappeared or declined but were still present) by respondents and could be used in contingency table analyses; 155 were useable for multivariate analyses.
16. E. G. Leigh, Jr., J. Theor. Biol. 90, 213 (1981).
17. M. J. Crawley, Philos. Trans. R. Soc. London Ser. B 314, 711 (1986).
18. V. Geist, Can. J. Zool. 65, 1067 (1987).
19. J. M. Scott and J. W. Carpenter, Auk 104, 544 (1987).
20. G. Bump, J. Wildl. Manage. 27, 855 (1963).
21. A. E. Newsome and I. R. Noble, in Ecology of Biological Invasions, R. H. Groves and J. J. Burdon, Eds. (Cambridge Univ. Press, New York, 1986), pp. 1–20.
22. R. J. O'Connor, Philos. Trans. R. Soc. London Ser. B 314, 583 (1986).
23. M. P. Moulton and S. L. Pimm, in Community Ecology, J. Diamond and T. J. Case, Eds. (Harper & Row, New York, 1986), pp. 80–97.
24. L. Engelman, in BMDP Statistical Software, W. J. Dixon, Ed. (Univ. of California Press, Berkeley, 1983), pp. 330–344.
25. Potential species bias in results of analyses was evaluated by deleting the dominant (30% of observations) species (wild turkey, Meleagris gallopavo) and reanalyzing. Only 1 of 11 univariate analyses (reproductive traits) changed because of the deletion. For multivariate analyses, the model without turkeys included the exact same set of variables as the all species case, the sign of coefficients remained the same, and the magnitude of coefficients was comparable.
26. N. Richter-Dyn and N. S. Goel, Theor. Pop. Biol. 3, 406 (1972).
27. R. Lande, Science 241, 1455 (1989).
28. D. Simberloff, Annu. Rev. Ecol. Syst. 19, 473 (1988).
29. J. M. Scott, B. Csuti, J. D. Jacobi, J. E. Estes, BioScience 37, 782 (1987).
30. W. Conway, Conserv. Biol. 2, 132 (1988).
31. D. A. Dillman, Mail and Telephone Surveys: The Total Design Method (Wiley, New York, 1981).
32. M. Shaffer, BioScience 31, 131 (1981).
33. This work would not have been possible without the voluntary efforts of cooperators who responded to our survey. We thank S. I. Batten, S. Hill, and L. J. Miller for assistance in the project and T. J. Cade, S. H. Fritts, J. Hatfield, H. R. Perry, Jr., K. Ralls, D. P. Scott, and T. G. Shoemaker for comments on the manuscript. Conducted under the auspices of the Idaho Cooperative Fish and Wildlife Research Unit, which is funded and supported by Idaho Department of Fish and Game, University of Idaho, U.S. Fish and Wildlife Service, and the Wildlife Management Institute; contribution number 465 from the University of Idaho Forest, Wildlife, and Range Experiment Station.