POPULATIONS TRANSLOCATION EVENTS AND IMPACT ON NATURAL HABITATS

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Summary

Translocations of wild-caught or captive-reared animals are playing an increasing role in conservation of rare and endangered species and are used to establish new populations, to reintroduce a species to unoccupied portions of its historic range, or to augment populations that are critically small and in danger of imminent extinction. Translocations include establishing of new populations or re-establishing by both the artificial movement of individuals between natural populations and the release of (often captive-reared) animals to reintroduce or augment small populations of native individuals. But thorough precautions must be taken because introduction of native species to areas outside their natural distribution can have detrimental impacts: these include introduction of disease organisms and disturbance of ecosystems. In addition, introduction may result in loss of genetic diversity when separate stocks of the same species are mixed. A translocated population may be considered viable and conserved only after showing promise of sustaining itself over ecological time measured in tens to thousands of years! Population genetics and demography determine the success of the introduction: specifically, the number of founders, the quality of habitats, and the historical distribution are variables that have been associated with translocation success. Because small populations are more subject to extinction due to inbreeding and demographic accidents than larger ones, information on the influence of translocation practices on genetic diversity and postrelease reproductive success would be of great value in designing reintroduction programs.

It is recognized that translocation is a valuable conservation tool, both in terms of restoration communities and assessing the extent of ecosystem dysfunction. Nevertheless, there are potential risks with translocation conservation strategies. For example, disease transmission and impact of other endemic populations may result.

Up to the early 1990s, the success and effect of translocation programs were not well evaluated because there was rarely appreciable monitoring after release. Since 1995, the monitoring programs following translocations are carefully developed and documented in order to gain knowledge from strategies that succeeded or failed. Information on the effects of translocations on translocations of animal and plant species and their environment are more and more available.

1. Introduction

The principle aim of any reintroduction should be to establish a viable, free-ranging population in the wild, of a species, subspecies or race, which became globally or locally extinct, or extirpated, in the wild. It should be reintroduced within the species' former natural habitat and range and should require minimal long-term management.

The objectives of reintroductions may include: to enhance the long-term survival of a species; to re-establish a keystone species (in the ecological or cultural sense) in an ecosystem; to maintain and/or restore natural biodiversity; to provide long-term economic benefits to the local and/or national economy; to promote conservation awareness; or a combination of the these objectives.

Captive propagation, introduction, and translocation programs for many animals have been undertaken by federal, state, and private agencies for more than 20 years. These programs help aid the recovery of endangered and threatened species, reestablish lost species, augment declining populations, increase recreational opportunities, reduce nuisance species, and introduced non-native species. It is now recognized that translocation is a valuable conservation tool, both as a component of successful early restorations of animal communities and for assessing the extent of ecosystem dysfunction. This can be done with little threat to existing stocks, even of threatened species, but it seems important that certain criteria are taken into account in relation to any translocation proposal. It is why an IUCN (i.e., the World Conservation Union) statement describes the advantageous uses of translocations but states that there are potential risks with translocation strategies and that precautions are needed to avoid the disastrous consequences of poorly planned translocations. The principal dangers are disease transmission and impacts on endemic populations. Diseases or parasites have frequently been spread throughout the world by species translocation. Pathogens (not endemic to a particular region) are frequently more dangerous to the new hosts (endemic species) than the original carrier. Even the translocation of native species within their natural range poses the risk of spreading taxon-specific pathogens. Supposedly taxon-specific (species-specific) diseases have been shown to be capable of infecting other nonrelated species.

There are also ecological and genetic impacts of introduced and translocated species: genetic subdivision of a species indicates the potential for local adaptation and the genetic differences among populations are key components of genetic diversity. Where there is a deep genetic structure, indicating substantial evolutionary independence of sets of populations, translocations may threaten basic components of genetic diversity.

Translocations have been widely proposed for, or utilized in conservation programs to alleviate, the detrimental effects of inbreeding depression and demographic stochasticity. Several criteria have been associated with successful translocation. These include habitat quality, where species are released relative to the extent of their range, and whether animals were wild caught or captive reared. In general, translocations have been variable in their success. Generally it is focused on the potential effects of gene flow as an underlying mechanism in failed translocations. Translocated populations can hybridize with native populations of the same species or closely related species, consequently impacting the genetic purity of each species. An example is the introduction of the Sika deer to Western Europe: Sika deer readily interbreed with native red deer and now there are no pure red deer remaining in Great Britain. Translocations can also have detrimental consequences for population fitness: for example, hybridizing populations from different latitudes can result in a suboptimal breeding time with the consequent birth of offspring when resources are scarce. This is the case with the translocation of feral goats from the Mediterranean to Wales: crossing populations with different photoperiods has lead to reduced offspring survival. Other translocations have reduced resident population fitness due to introgression of poorly adapted gene complexes. For example, Bobwhite Quail were translocated from the southern USA to augment the Ontario, Canada game population. However, the hybrid quail were less able to survive the northern winter and the population declined. Translocated populations may simply not be well adapted to the area in which they are introduced. Translocated animals died because of a dramatic shifts in climate conditions. Translocations can also result in the transmission of disease. Without a readily usable protocol for the diagnosis of infestation, translocation of a species may result in reduced population fitness, rather than the goal of augmenting populations. For example, diseases or parasites have frequently been spread throughout the world by the translocation of fish. Pathogens not endemic to a particular region are frequently more dangerous to the new hosts (the endemic fish) than the original carrier. Even the translocation of native species within their natural range poses the risk of spreading taxon-specific pathogens. Supposedly taxon-specific (species-specific) diseases have been shown to be capable of infecting other nonrelated species. Several additional pathogens have been introduced to native species from exotic species. It was underlined the importance of overcoming disease problems to have a successful reintroduction program and provided documented incidents of disease introduction into new environments via animal translocation. These diseases have substantial effects on wildlife, domestic animals, and humans.

Species translocated	**Source†**	**Disease or agent**	**Release area**	**Species affected**
Desert tortoise	Pet shops w/c	*Mycoplasma*	Mojave Desert	Desert tortoise
Whooping crane	MD, c/b	Avian tuberculosis	ID	Whooping crane
Waterfowl	Various, c/b	Duck plague	Various	Waterfowl
Wild turkey	Various, w/c, c/b	*Mycoplasma*	Various	Wild turkey
Parrot	Central Am., S. Am., w/c	Newcastle disease	CA	Domestic poultry Pet birds
Raccoon	FL, w/c TX, w/c	Rabies Parvovirus	VA WV	Raccoon, 6 other spp. Skunk, raccoon
Red fox	OH, other states	Echinococcus multilocularis	SC	Unknown
Bighorn sheep	Los Angeles, Co., CA, w/c ID, w/c	Contagious ecthyma (Orf) Scabies (mange mites)	Ventura Co., CA OR	Human Human
Tule elk	CA, w/c	Paratuberculosis	Pt. Reyes CA	Tule elk (from contact with domestic cattle)
Elk, caribou	Various, w/c	Brainworm	Various, w/c	Elk, caribou (from contact with wild white-tailed deer)

† w/c, wild caught; c/b, captive bred.

Table 1. Some diseases transmitted by or to translocated animals in the USA

Translocations may result in dystocia or difficult parturition in some species. Dystocia can be caused by crossing animals that are different in size or in proportion: for this reason, it is important to introduce animals that are similarly sized to native animals.

Consequently, a reintroduction requires a multidisciplinary approach involving a team of persons drawn from a variety of backgrounds. As well as government personnel, they may include persons from governmental natural resource management agencies, nongovernmental organizations, funding bodies, universities, veterinary institutions, zoos (and private animal breeders), and/or botanic gardens, with a full range of suitable expertise. Team leaders should be responsible for coordination between the various bodies and provision should be made for publicity and public education about the project.

2. Different Types of Translocation

2.1. Translocation by Introduction

Introduction refers to movement of nonendemic species into an area where they did not formerly exist. Such introductions have been required by hunting, fishing, economic development, and as biological control agents. In the past, introduction of many exotic species has been disastrous and it seems important to recognise that translocation of endemic species may also lead to similar undesirable outcomes. Therefore, caution should be exhibited when translocating endemic as well exotic species.

To reduce the damaging impact of introductions on the balance of natural systems, governments should provide the legal authority and administrative support that will promote implementation of the following approach:

- Introduction of an alien species should only be considered (a) if clear and well-defined benefits to human or natural communities can be foreseen, and (b) if no native species is considered suitable for the purpose for which introduction is being made.
- No alien species should be deliberately introduced into any natural habitat, island, lake, sea, ocean, whether within or beyond the limits of national jurisdiction. Such area should be surrounded by a buffer zone sufficiently large to prevent unaided spread of alien species from nearby areas.
- No alien species should be introduced into a seminatural habitat unless there are exceptional reasons to do so, and only when the action has been comprehensively investigated and carefully planned in advance.

Essential features of investigation and planning must consist of (a) an assessment phase culminating in a decision on the desirability of the introduction; (b) an experiment by controlled trial; and (c) a monitoring subsequent to the introduction phase.

2.2 Translocation by Reintroduction

This means the release of a species into an area in which it was indigenous before extermination by human activities or natural catastrophe. Reintroduction is thus a particularly useful tool for restoring a species in its original habitat where it has become extinct due to human persecution, overcollecting, overharvesting, or habitat deterioration, but where these factors can at present be controlled. It should be reintroduced within the species' former natural habitat and range and should require minimal long-term management.

The objectives of a reintroduction may include enhancing the long-term survival of a species, to reestablish a keystone species in an ecosystem, to maintain and/or restore natural biodiversity, to provide long-term economic benefits to the local and/or national economy, and to promote conservation awareness.

Reintroduction should only take place where the original causes of extinction have been removed and where the habitat requirements of the species are satisfied. The basic program for reintroduction should consist of several steps. First, a feasibility study should be undertaken. This should be an ecological study to assess the previous relationship of the species with the future habitat in conjunction with education of the local people, emphasizing the benefits to them of the reintroduction. The closest available race or type to the original stock should be identified and used for the reintroduciton (see genetic status). Next is a preparation phase. Preliminary knowledge of the biological needs of the species must be required—both the needs of the species and ecological dynamics of the area of reintroduction. In the release or introduction phases, the determination of the age of reintroduced individuals, genetic status, sex ratio, season, and the freedom of both the species and the area from disease and parasite should be ascertained. Finally, in the follow-up phase, the released species should be monitoring of to determine the rate of adaptation and dispersal, the need for further releases, and identification of the reasons for success or failure of the program.

2.3. Translocation by Restocking

Restocking is the release of a species into an area in which it is already present. Thus, restocking may be a useful tool where it is feared that a small reduced population is becoming dangerously inbred, or a population has dropped below critical levels and recovery by natural growth will be dangerously slow, or where artificial exchange and artificially high rates of immigration are required to maintain outbreeding between small isolated populations or biogeographical islands.

Thus, attention should be paid to the genetic constitution of stocks used for restocking. Genetic manipulation of wild stocks should be kept to a minimum as it may affect the ability of a species to survive. Genetically impoverished stocks should not be used to restock populations, as their ability to survive would be limited by their genetic homogeneity. The species being used for restocking must be of the same race. Where a species has an extensive natural range and restocking has the aim of conserving a dangerously reduced population at the climatic or ecological edge of its range, care should be taken that only individuals from a similar climatic or ecological zone are used since interbreeding with individuals from an area with a milder climate can interfere with resistant and hardy genotypes on the population’s edge. Introduction of stock from zoos may be appropriate, but the breeding history and origin of the animals should be known and followed as closely as possible. The danger of introducing new diseases into wild populations must be avoided. Where restocking corresponds to release or to rehabilitate captive animals, it is safer to perform such release.

2.4. Gene Flow and Endangered-Species Translocations

If only a small number of individuals establishes a population, genetic variation will be lost. Such losses can affect the growth rates of newly established populations. Because small populations are more subject to extinction due to inbreeding and demographic accidents than larger ones, information on the influence of translocation practices on genetic diversity and postrelease reproductive success would be of great value in designing reintroduction programs. Theoretical consideration indicate that 500 individuals represent a minimum population level (effective population size) that would contain sufficient genetic variation to enable that population to evolve and respond to the constraints imposed by their natural habitat. Recognizing the genetic diversity that exists among migrants seems essential when constructing policies for the reintroduction or the restocking of declining populations of important species. An understanding of the evolutionary role of gene flow or of the migration of individuals and of the subsequent transfer of genes among populations seems pivotal to the management of endangered species. Moderate to high rates of gene flow among populations help prevent subpopulations isolation, thereby maintaining genetic variation and avoiding inbreeding depression. Habitat fragmentation can restrict gene flow, which can result in the loss of genetic variation. This can have serious consequences, reducing survival, growth, and decreasing the ability of individuals in the population to adapt to a changing environment. The loss of genetic diversity is a central topic in conservation genetics. Conservation biologists are concerned that declines in genetic variation may inhibit the future ability of an organism to adapt to environmental change. Translocation of individuals from larger populations can be used to increase gene flow and supplement genetic variation in small populations, thereby reducing the possibility of inbreeding depression and the loss of genetic variation. In other words, to alleviate these problems, artificial gene flow has been initiated for some species by translocating individuals between isolated populations, which can restore the genetic variability of small populations to the levels found in larger populations. In order to avoid outbreeding depression and to preserve historic gene flow patterns, information about population differentiation and genetic distances between populations is required before translocations are conducted. As a result, management strategies often include translocations among populations or captive breeding and release of individuals into natural populations. Implicit in these management designs is the assumption that gene flow will have positive effects by acting as a creative evolutionary force in maintaining genetic variation and/or introducing favorable migrants (i.e., well-adapted individuals with high fitness). However, gene flow can also act as a force that constraints local adaptation. Genetic mixture of populations that are adapted to different local conditions can result in outbreeding depression, the reduction of fitness caused by the breakdown of coadapted gene complexes.

Effects of species translocations focus on the translocation of individuals between existing natural populations and captive breeding programs, including either reintroductions of populations into regions from which they have been extirpated, or restocking of existing wild populations to bolster both effective population size and genetic variability. The degree of isolation and consequent independence of populations are important in both ecological and evolutionary contexts, and are highly relevant for the management and conservation of natural populations.

A review of the literature on genetic assessments of translocations was recently made and reveals several insights into the effectiveness of this important management activity. Examination of variation within and among translocated populations tends to support the expectation that large numbers of individuals must be released to ensure that most of the variation present in the source population will be represented in recipient populations. However, losses of genetic diversity and genetic drift have been reported in cases when hundreds of individuals have been released, suggesting that in at least some translocations, many of the released individuals make little or no genetic contributions to the population they are released to establish. Some cases also suggest that translocated individuals often, but not always, contribute genetic material to native populations they were intended to augment. Studies of deer and turkeys suggest that the contributions of released individuals to population recovery may be largely limited to the populations close to the release sites, but it is not clear if this result can be extended to other taxa.

Inbreeding is known to lead to decreased survival and reproduction in captive populations; it is thus also important to know whether inbreeding has deleterious effects in natural habitats. For example, an experimental study reveals that inbreeding has a detrimental effect on the survivorship of mice reintroduced into a natural habitat and that the effect is more severe than those effects observed in laboratory studies of the same population.

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Biographical Sketches

Catherine Souty-Grosset was born in La Rochelle (France) on 23 January, 1954. She has been a research scientist in CNRS (Centre National de la Recherche Scientifique) since October 1980, working in a joint research laboratory named UMR CNRS 6556 "Génétique et Biologie des Populations de Crustacés" (University of Poitiers) as the coordinator of Population Genetics Research. She received her PhD degree from the University of Poitiers in 1978 and obtained State Doctor es Sciences in 1984 (vitellogenesis in terrestrial and marine isopods); she obtained HDR (empowered to supervise research) in 1985. From 1984 to 1992, research was devoted to ecophysiology in terrestrial and marine isopods. Since 1992, her scientific interest has been directed to population genetics of isopods, penaeids, and conservation genetics of a native European crayfish. She coordinates all projects on conservation biology of *Austropotamobius pallipes* that are financed by Higher Fisheries Council, Region, Ministry of Environment, CNRS/MAE/Enterprise, Republic of Ireland. She organized the Erasmus Winterschool lab session on Cell signalling, mitochondrial genomes, and evolutionary biology in 1993. She was coordinator and editorial committee member of three special issues devoted to native European crayfish in BFPP (Bulletin Français de la Pêche et de la Pisciculture; translated, "knowledge and management of aquatic systems"). She wrote a book review for the American Zoologist on the biology of terrestrial isopods (1996) and wrote a chapter "vitellogenin synthesis in marine invertebrates" in *Marine Biotechnology* (1997: ed. M. Fingerman, Tulane University, Louisiana). She is the author of more than seventy papers and more than sixty oral presentations at invited conferences and seminars. Recently she organized an Euroconference entitled "Knowledge-Based Management of Native European Crayfishes" (Poitiers, France, 13–15 September 2001).

Frédéric Grandjean was born in Epinal (France) on 12 March, 1967. He has been a lecturer since October 1998 in the same joint research laboratory named UMR CNRS 6556 "Génétique et Biologie des Populations de Crustacés" (University of Poitiers). He obtained a PhD in 1997 on " Morphometric and genetic variability of populations in *Austropotamobius pallipes*: biogeographical implications" (under the direction of C. Souty-Grosset). He is lecturer in aquatic ecology and population genetics and researcher in all crayfish projects of the UMR CNRS 6556 and has written 12 papers on the subject.