Chapter 10
Reintroduction of Woodrats: Concepts and Applications

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Introduction

The movement of wild animals for restoration purposes has become a necessary and
more common aspect of modern conservation practices. The International Union for
the Conservation of Nature and Natural Resources (IUCN 1998) defines translo-
cation as the movement of living organisms from one area to another. Reintro-
ductions and restockings (hereafter supplementations) are forms of translocations
(Griffin et al. 1989, Kleiman 1989, IUCN 1998). A reintroduction is the intentional
release of an organism into a portion of its historic range to restore populations
extirpated because of human activities. In contrast, supplementation is the release of
an organism to parts of its historic range where a remnant population of conspecifics
exists and is usually undertaken to provide genetic or numeric enrichment to small,
isolated populations. For these reasons post-reintroduction supplementations may
be a planned component of reintroduction projects or an adaptive component deter-
dined appropriate from ongoing assessments and perceived benefits to a reintro-
duced population. Supplementations generally are recommended to be avoided
when the small, remnant populations are the result of deteriorating habitat condi-
tions. Similarly, post-reintroduction supplementations should not be undertaken if
monitoring of the reintroduced populations reveals unforeseen conditions at release
sites that may preclude the re-establishment of viable populations, regardless of the
addition of new individuals.

Early reintroduction projects in the United States were undertaken primarily
to restore wildlife that had been severely depleted during the 1800s through the
early 1900s by unregulated hunting and trapping. These projects focused on species
considered economically or recreationally important such as beaver (Castor
canadensis), white-tailed deer (Odocoileus virginianus), and wild turkeys (Meleag-
gris gallopavo). The attention given to restoring these species is understandable

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given that the origins and original missions of state wildlife agencies primarily were embedded in a need to reverse declines in wildlife populations caused by overharvest (Trefethen 1975). Gradually, however, state wildlife agencies have been adopting a more holistic approach as demonstrated by increasing attention to the conservation of both game and nongame (those not traditionally harvested) wildlife. The remedies for reversing declines in populations of nongame species and some game species typically are much more complicated to identify and address than those related to harvest management. Landscape-level perturbations associated with ongoing growth of human populations have continuously evolved into new, more insidious threats to wildlife (e.g., fragmentation of forested landscapes and pollution of aquatic habitats). Negative consequences of extensive landscape-level changes in habitat conditions are imparted on a greater variety of species than those that were imposed by unregulated harvest, and have contributed to an expanding number of species, both game and nongame, requiring conservation attention—in some cases warranting the implementation of reintroduction projects.

During the last 30 years, numerous successful wildlife reintroduction projects—often involving charismatic species (i.e., species with traits that generate high levels of public attention)—have been initiated in the United States. Examples include American martens (Martes americana), bald eagles (Haliaeetus leucocephalus), black-footed ferrets (Mustela nigripes), California condor (Gymnogyps californianus), fishers (Martes pennanti), gray wolves (Canis lupus), ospreys (Pandion haliaetus), peregrine falcons (Falco peregrinus), and river otters (Lutra canadensis). Nongame species have been well represented among these more recent reintroduction projects, but typically involved larger, better known species—those that generally can be characterized biologically as having relatively low levels of reproduction and high rates of survival (K-selected species).

Substantial population declines experienced by many species of Neotoma have prompted increasing attention for development of active conservation plans for the species of greatest conservation concern (e.g., Ford et al. 2006, McCleery et al. 2006, Feldhamer and Poole Chapter 11). Central among considerations for more active management is the conservation value that can be derived by initiating reintroduction projects, particularly for the Allegheny woodrat (Neotoma magister). Unfortunately, as is the case for most r-selected species, there are no comprehensive procedures and only a few published case studies with direct application for guiding the overall process of reintroducing woodrats. In this chapter, I review some past unsuccessful Allegheny woodrat reintroduction efforts and provide a theoretical and practical framework for planning more successful programs for this and similar species.

Woodrat reintroduction projects have taken place in four states and all have involved the Allegheny woodrat, where it had become extirpated in northern portions of the range. These reintroductions included the release of 44 woodrats from Ohio and Kentucky at a site in Ohio during 1983 and 1984 (Schlie 1985, Schlie and Bookhout 1985); 29 woodrats from West Virginia at two sites in New York during 1991 (McGowan 1993); 42 woodrats from Kentucky and West Virginia at four sites in New Jersey during 1996 (LoGiudice 2003); and 10 woodrats
from one site to another in Pennsylvania (source population was about 20 km from the release site) during 1997 (Wright 1998). Radiotelemetry studies were conducted to monitor fates of woodrats at all reintroduction sites, with outcomes indicating that the reintroductions did not contribute to the establishment of self-sustaining populations because of low survival and reproduction. The failures of the aforementioned projects demonstrate the challenges involved in restoring mammals with *r*-selected characteristics (in this case Allegheny woodrats) and the need to further develop and refine protocols for reintroduction projects involving this group of animals.

The IUCN’s Reintroduction Specialist Group (RSG) provides excellent, general guidelines for developing and implementing reintroduction projects (IUCN 1998). Nonetheless, the various components of a project ideally should be adapted for the particular needs of the species being reintroduced—although similar approaches typically can be applied among species possessing comparable life-history traits. The proportionally large variety of *K*-selected species reintroduced has contributed to the establishment of reasonably well-defined protocols for guiding approaches in future projects involving similarly adapted species (Fritts et al. 1997, Griffin et al. 1989, Kleiman 1989, Serfass et al. 2003). In contrast, few reintroduction projects have been conducted involving small, short-lived species with high reproductive and mortality rates (*r*-selected). Consequently, there are few examples available to guide reintroductions of *r*-selected species (Jordan 2003).

The reintroduction process would benefit both small and larger mammals if the general guidelines prescribed by the IUCN-RSG are followed. However, the reintroduction of small mammals poses a variety of different challenges—many related to their relatively low survivorship in comparison to large mammals. The additional attention now being devoted to nongame species has contributed to the awareness that an increasing number of small mammal species are becoming of conservation concern and may require more active management, sometimes including the implementation of reintroduction projects, to ensure maintenance of diverse, viable populations.

The objective of any reintroduction project should be to establish a biologically meaningful population that contributes to the long-term conservation goals established for the species. The ensuing discussion focuses on developing a general set of procedures that can be applied for guiding and enhancing the process of reintroducing woodrats. The approach generally follows those prescribed by the IUCN-RSG, but applies added emphasis on specific considerations that should be applied for the reintroduction of *r*-selected species and, when possible, integrating appropriate conservation and biological information pertaining specifically to woodrats.

**Preliminary Assessments**

Reintroduction projects are inherently complex, involving an array of biological and social issues. Consequently, a variety of preliminary assessments should be undertaken as a basis for establishing justifications and protocols prior to initiating the reintroduction process. Presumably, for a species to be regarded as a candidate
for reintroduction, evidence exists suggesting that its current range has undergone substantial declines in comparison to the historic range. Nonetheless, foremost among the preliminary assessments is a thorough review of documentation pertaining to the historic and current distributions of the species.

In the case of the Allegheny woodrat, declines in portions of the range are now well-documented, but initial awareness of the decline largely was based on anecdotal observations (Wright Chapter 1). For cryptic species like woodrats, the most definitive evidence of historic range is specimen records in museum collections (Wright Chapter 1). Unfortunately, for many nongame species, data on current distribution are not routinely collected to compare with historic museum specimens, so even this preliminary step may require launching a field survey of historic sites. Surveys of this type can be a substantial undertaking (Mengak et al. Chapter 7) and have yet to be accomplished for all states within the historic range of the Allegheny woodrat (Wright Chapter 1). If the review supports the presumption that the species’ distribution has declined to an extent warranting conservation concern, then a feasibility study should be undertaken to more formally assess justifications, implications, and logistical and biological considerations for implementing a reintroduction project.

The primary aim of a feasibility study should be to put forth clear and concise rationales, based on a thorough assessment of the best available information, for use by decision makers in determining the justification and conservation value of implementing a reintroduction project (IUCN 1998). The feasibility study should also elucidate important procedural components of a reintroduction project based on biological requirements and ecological relationships of the species being assessed. Finally, the assessment must identify resources (e.g., cost and expertise) anticipated to be necessary for proper support of all phases of the reintroduction project.

The outcome (final product) of a well-conceived feasibility study should provide:

(1) A complete review of the literature pertaining to the basic biology, taxonomy, ecological associations, and techniques applicable to the conservation of the species (e.g., best methodologies for capture and handling). An outcome of this process should be the compilation of a well-organized library of pertinent readings and an associated annotated bibliography. A recent literature review for the Allegheny woodrat (Castleberry et al. 2006) and the chapters of this book provide a comprehensive, up-to-date literature survey and will serve as an excellent basis for establishing such a library.

(2) A comprehensive reassessment of existing information about the distribution of wild populations for use in determining if additional surveys are needed in portions or throughout the species’ range. For the Allegheny woodrat, systematic field surveys have been conducted in Indiana, Maryland, New Jersey, New York, Ohio, Pennsylvania, and Virginia, and are part of the Wildlife Action Plans of some other states, but no comprehensive, integrated assessment has been conducted throughout the species’ range (Wright Chapter 1, Peles and Wright Chapter 12).
(3) An assessment of the best available information, including literature and opinions of experts, to determine the most plausible causes for the species’ decline. Inherent to this process is assessing if causalities for the decline have been remedied to an extent that warrants proceeding with the reintroduction project. Likely causes for extirpation or declines of some woodrat populations are beginning to emerge and form a basis for this type of assessment (LoGiudice 2006, Chapter 2).

(4) The identification of general areas within the species’ historic range and geopolitical region of conservation jurisdiction (unless a federally endangered or threatened species, the maximum extent of this delineation typically will be defined by state boundaries) warranting consideration as a reintroduction site.

(5) A list of criteria to be applied for identifying preferred sources of individuals for use in the reintroduction, including an assessment of the conservation status, and a review of the genetic and phenotypic characteristics of individuals comprising a prospective source population.

(6) The identification of collaborators and stakeholders with appropriate levels of expertise, interest, and resources for contributing to the reintroduction project.

(7) A list of conservation authorities and their respective jurisdictions legally responsible for authorizing and supporting the various aspects of a reintroduction project. Essential to this process is being aware that permits (and, typically, other forms of formal approval) are required to legally capture and handle wildlife (ASM Animal Care and Use Committee 1998).

(8) An itemized budget of anticipated costs, and an associated review of potential sources of funding and other support.

(9) A general timeline for implementing and completing various phases of the project.

Implementation

Implementation of a reintroduction project follows satisfactory completion and interpretation of preliminary assessments, and presumes that the outcome of the feasibility study warrants initiating a project. The implementation of a well-conceived reintroduction project should comprise pre-translocation, translocation, and post-translocation phases. Although often portrayed as being discreetly situated within the project, the various phases inherently are interdependent and often overlap considerably during the reintroduction process.

Pre-translocation Phase

The primary components of the pre-translocation phase of a reintroduction project consist of: (1) selection of reintroduction sites; (2) selection of sources of animals for translocation; and (3) preparation and implementation of an outreach program (human dimensions). During this phase of the project guidelines established in the
feasibility study are applied and further refined for the process of selecting reintroduction sites, identifying sources of animals, and establishing interactions with collaborators, stakeholders, and the public at reintroduction areas.

**Reintroduction Site Selection**

A suitable release site must be within the historic range and possess habitat qualities presumed important for sustaining a population of the species being reintroduced. Although specific habitat components differ among the various species of woodrats, generally most are associated with readily discernable macro-features (e.g., talus slopes on ridges; Balcom and Yahner 1996, Ford et al. 2006) distributed as isolated units within the landscape. The advent and refinement of geographic information system (GIS) technology has considerably enhanced the capabilities for efficiently assessing and displaying the dispersion and connectivity of macro-habitat components within the landscape (Kiester et al. 1996). These capabilities are particularly appealing for application in selecting reintroduction sites for species using habitats in a coarse-grained manner (Wiens 1976), such as Allegheny woodrats, which necessitates detection and assessment of relatively rare habitat components discretely structured within the landscape. The process of selecting reintroduction sites should proceed in a hierarchical fashion, from coarse- through fine-level GIS assessments to onsite visits of prospective sites.

Fundamental to coarse-level assessment is the acquisition of GIS layers (i.e., electronic files containing specific features in the landscape, such as habitat types, geopolitical boundaries, and specific points of interest) comprising locations of active and historic woodrat sites and macro-habitat features identified as important in the area being evaluated for the reintroduction. For example, important macro-habitat features identified as important to Allegheny woodrats in the mid-Atlantic region that could be represented in GIS layers include forests, rocky outcroppings, and the distribution of public lands (Ford et al. 2006). Overlaying these features (portraying the various GIS layers simultaneously on a single projection) with the locations of active and historic population sites enables a concise depiction of the juxtaposition of important habitat components in relation to areas of known occupancy (current and past) by woodrats. A coarse-level assessment provides a basis for excluding large portions of the landscape from further consideration as potential reintroduction sites and for identifying areas with macro-habitat features worthy of finer-level consideration as prospective reintroduction sites. The development of GIS-based landscape models has been accomplished in several states for woodrat species, including *N. magister*, as part of the nationwide GAP analysis project (Scott et al. 1993, National Biological Information Infrastructure 2007). These models were based on a small suite of general habitat variables and, thus, lack specificity in identifying portions of the landscape suitable for woodrats. Nonetheless, the GAP-derived models provide a basis for guiding the development of GIS models more specific to woodrats, which has been the case in Pennsylvania (Mengak et al. Chapter 7). A spatially explicit GIS-based habitat model developed for Allegheny woodrats in the Daniel Boone National Forest, Kentucky, incorporated
a more detailed set of landscape-level variables that proved useful in predicting the location of active woodrat sites and serves as an excellent example of how this technology could be applied for remotely identifying prospective reintroduction sites (Ivanovich 2000).

Many of the general habitat features assessed at the macro-habitat scale can also be interpreted and used in fine-level assessments. As an example, a forest layer of a GIS often comprises sublayers such as forest type (i.e., deciduous, conifer, or mixed) and forest age class. Similarly, public lands usually can be further categorized by management activities (e.g., natural areas where no timber harvest is permitted or areas designated for multiple-use, where the sustainable harvest of timber is permitted). The availability of sublayers for the various general attributes provides an opportunity to more thoroughly identify specific portions of the landscape that are likely to be suitable as reintroduction sites. The GIS analysis should progress to the identification of specific sites possessing a suite of attributes likely to support a population of woodrats, and then an evaluation of the manner in which sites with these attributes are dispersed (e.g., degree of clustering or isolation) within the prescribed assessment area. The outcome of the GIS analysis should include the following:

1. Point locations for all sites possessing macro-habitat features known to be associated with woodrat population sites (hereafter these point locations are referred to as prospective sites).
2. An evaluation of specific (finer-level) attributes associated with prospective sites. Generally, however, the attributes being assessed will be related to the availability of food and cover. For example, mast producing tree species such as white oak (*Quercus alba*), are a reliable source of food (Castleberry et al. 2002a), and rocky outcroppings at ridgetops and along gorges provide important cover (Balcen and Yahner 1996, Castleberry et al. 2002c, Ford et al. 2006) for woodrats in the mid-Atlantic region and should be considered as positive attributes for a prospective reintroduction site.
3. An interpretation of habitat conditions surrounding prospective sites. Of particular importance in this assessment is the distance that forested conditions to extend beyond a prospective site and the degree to which the surrounding forest is fragmented (usually assessed within various buffered radii distances from the prospective site). The implication for this assessment is based on evidence that edge-tolerant predators will occur at higher levels in fragmented landscapes than in large, contiguous forest tracts, and that their presence is presumed to have deleterious consequences for woodrats (e.g., direct predation by great horned owls (*Bubo virginianus*) or transmission of the roundworm (*Baylisascaris procyonis*) through contact with raccoons (*Procyon lotor*) (McGowan 1993, Birch et al. 1994), as well as evidence that in some parts of the range, Allegheny woodrat population persistence is associated with a broad buffer of intact forest (Hassinger et al. Chapter 8)).
4. An assessment of conditions favorable for supporting dispersal of woodrats and the likelihood that dispersing individuals will encounter areas with habitat
conditions suitable to sustain a local population. This assessment also pertains to the discrete placement of multiple reintroduction sites in an area with the intent of establishing or maintaining a metapopulation (a population segregated into semi-isolated units connected by corridors able to facilitate some level of exchange among individuals; Opdam 1991, Wells and Richmond 1995, and Litvaitis and Villafuete 1996). An alternative but similar strategy would be the purposeful selection of a reintroduction site with the intent of enabling the eventual interaction of individuals with those from existing populations. In this case, an important goal would be to select reintroduction sites linked to other reintroduction sites or established population sites by habitat conditions appropriate to function as movement corridors. Wright (1998) identified research topics that should be addressed to enable conservationists to more effectively incorporate metapopulation concepts into strategies for reintroducing Allegheny woodrats. These strategies emphasize the importance of better understanding dispersal capabilities by age class and gender, habitat conditions contributing to successful dispersal, the extent that sites within a metapopulation are linked by dispersing individuals, and natural patterns of extirpations and recolonizations within a metapopulation.

(5) Determination of the conservation status of lands (public or private) at a prospective site, within radii of various predetermined distances buffering a prospective site, and within the boundaries of potential corridors connecting to other prospective sites or established sites. Generally, public lands or lands owned by conservation organizations should be preferred as reintroduction sites because of the prospect for maintaining the long-term integrity of habitats in these areas (i.e., development is less likely than on private lands) and greater opportunity to manage portions of the landscape for the conservation of woodrats.

Unfortunately, specific guidelines have not been developed to guide the management of habitats for woodrats at either fine or coarse scales. Existing habitat studies provide a basis for guiding the process of identifying and protecting habitats important for Allegheny woodrats (Balcom and Yahner 1996, Ivanovich 2000, Castleberry et al. 2002c, Ford et al. 2006, Castleberry Chapter 4). Hassinger et al. (Chapter 8) have proposed a habitat management plan for application in the general conservation or reintroduction of Allegheny woodrats. The plan suggests that habitat protected for Allegheny woodrats should comprise an appropriate rock habitat surrounded by a 200-m-wide foraging zone, where management actions are designed to improve production of hard mast, and then by an outer 2-km-wide landscape protection zone or nondissection buffer where commercial forest management may occur but roads, right-of-ways, and other forms of permanent fragmentation and dissection are discouraged. However, the authors acknowledge that these criteria are based on interpretation of existing habitat studies and not an empirical assessment of outcomes based on the application of guidelines that have actually been applied. Thus, the plan should be regarded as an initial, general guideline, which can be adaptively modified based on assessments of the manner in which native or reintroduced woodrat populations respond to this type of habitat management.
Assessment of the GIS analysis should yield an objective ranking of the quality of prospective sites based on biological and ecological criteria identified in the feasibility study. Ultimately, the selected sites should possess qualities that meet biological criteria for sustaining a viable woodrat population at the release location, provide conditions that facilitate opportunities for woodrats to disperse and pioneer new areas (i.e., establish a metapopulations structure or, similarly interact with other reintroduced populations or established populations in the region), and are likely to retain conditions appropriate for maintaining woodrat populations (metapopulations) in the future (i.e., changes in patterns of land use that would be detrimental to the population are unlikely based on current land-use designations).

The final selection of a reintroduction site must be determined through onsite inspections of prospective sites ranked most favorably by GIS analysis. The inspectors should include experts that have developed, through training and experience, a conceptual model of conditions appropriate for sustaining woodrats. The value of these opinions should not be underestimated and should be given serious consideration in the final determination of a reintroduction site.

Source of Animals

Various criteria have been established for selecting sources of individuals for reintroduction projects. Ideally, reintroduced animals should be obtained from areas that represent the same subspecies that occurred at the reintroduction site (IUCN 1998). To enhance the likelihood of a successful reintroduction, Meffe (1995) suggested that reintroduced animals should be obtained from nearby populations that occupy a range of environmental conditions similar to those that will be encountered at reintroduction sites. The recommendation is based on the premise that founders from local populations have evolved under selective pressures imposed by the range of environmental conditions in the region and, as such, should be best suited to adapt to conditions imposed at release sites.

In general, translocation of individuals from nearby populations should be considered the most practicable and defensible approach for obtaining animals for use in a reintroduction project. However, defining what constitutes an appropriate, nearby population often can be confounded by a variety of biological and practical issues. Inherent to this approach in defining a source of individuals for translocation is the assumption that populations geographically close to the reintroduction site are composed of individuals of similar genetic composition to that of the extirpated population. This assumption can be compromised somewhat by organisms, such as Allegheny woodrats, that exist as disjunct aggregations among suitable habitats dispersed throughout the landscape (Balcom and Yahner 1996, Ford et al. 2006). The natural isolation of populations through discrete use of the landscape and limited ability for juvenile woodrats to disperse through suboptimal habitats undoubtedly contributed to genetic uniqueness among populations—even those occupying the same general region. For example, analysis of genetic variability among Allegheny woodrats in West Virginia demonstrated considerable differentiation among subpopulations separated by as little as 3 km (Castleberry et al. 2002b).
Consequently, identifying historic patterns of gene flow is a challenge for interpreting the degree of genetic similarity that existed among extant and extirpated populations. The genetic issue is complicated further by changes (declines and isolation) in woodrat populations that have been brought about by anthropogenic alterations to the landscape (Balcom and Yahner 1996, Ford et al. 2006, Smyser and Rhodes Chapter 9). These types of changes in the characteristics of a population can contribute to substantial reduction in genetic variation through bottlenecks (rapid reduction in the size of a population followed by some level of recovery; Bonnell and Selander 1974, O’Brien et al. 1983), or through genetic drift (Gilpin and Soule 1986), which is most pronounced in small, isolated populations. Therefore, selecting a nearby, apparently viable population as the primary source of animals for the reintroduction (regardless of the current size of the population) may be contributing only a portion of the original levels of genetic diversity contained within woodrat populations from the region. The situation is further confounded by the likelihood that only a portion of the genetic diversity contained within the source population will be sampled among translocated individuals (best thought of as a type of sampling error). Following this scenario, the reintroduced population may have considerably lower levels of genetic diversity than would be considered desirable for the long-term sustainability of the population. Smyser and Rhodes (Chapter 9) discuss in detail the complexities of choosing a genetically appropriate source population for a proposed reintroduction of Allegheny woodrats in Indiana.

Basic to any reintroduction project is the identification of source populations capable of supporting the sustained removal of sufficient numbers of individuals to meet biological and practical components of the project. This criterion has implications related directly to the conservation of source populations (i.e., removal of individuals will not adversely impact the long-term sustainability of genetic integrity of the population) and for realistically meeting projected timelines for completing the translocation phase of the project (i.e., a sufficient number on individuals will be available to sustain a meaningful reintroduction).

Coordinators of reintroduction projects should be aware that identifying the best source (or sources) of individuals for use in a reintroduction project often is subject to various interpretations—regardless of the quality of biological and conservation information available for the species to be reintroduced. Consequently, disagreements as to what constitutes an appropriate source population are not unusual and should be anticipated (Serfass 1998), especially given the complexity of integrating the various biological and management criteria into a cogent plan for conducting a reintroduction project.

**Number of Animals**

Reintroduction programs need to incorporate minimum viable population (MVP) criteria when considering the number of animals needed to be released to establish and maintain a population. MVP considerations include loss of genetic diversity, demographic stochasticity, and environmental stochasticity (Gilpin and Soule 1986). Meeting MVP criteria in reintroduction projects is dependent on the number of
animals released, demographics and post-release survival of reintroduced individuals, and genetic composition of the source populations. Unfortunately, identifying the number of individuals necessary to ensure the establishment of a viable, self-sustaining population is fraught with uncertainties related to the responses of translocated individuals to conditions at the reintroduction site (e.g., post-release survival rates and levels of reproduction).

The low survival rates characteristic of r-selected organisms adds further complications in determining the number of animals needed for release. As an example, the Allegheny woodrat in Pennsylvania has annual survival and mean life expectancies estimated at only 0.46 and 1.3 years, respectively (J. Hassinger unpublished data), and does not readily breed during the winter. Reintroduction efforts must take into account potential low over-winter survival while planning for the number of animals to be released.

There are few examples for small mammals (or specifically woodrats) to guide the determination of what constitutes an adequate number of woodrats to be released at a reintroduction site. Jordan (2003) suggested that release of at least 30–50 individuals (sometimes higher) is normal among the few reintroduction projects that have involved small mammals. Unfortunately, woodrats are territorial and tend to naturally maintain relatively small population units. For example, the typical population size for Allegheny woodrats is less than 20 individuals—even for healthy, self-sustaining populations (Mengak et al. Chapter 7). A population of this size is unlikely to be able to adequately buffer against stochastic fluctuation and catastrophes. Historically, populations of Allegheny woodrats likely have been subjected to episodic bouts of extirpation and subsequent recolonization by dispersing individuals from surrounding populations. Attempts to reintroduce the number of woodrats at a site within the natural size of a typical population might be predisposed to failure because of initial stochastic processes (e.g., differential survival by gender or loss of genetic diversity if a few individuals contribute disproportionately to breeding). Release of a larger group of individuals (e.g., > 20 individuals) to overcome could contribute to social stress because of the innate territoriality of woodrats (Kinsey 1977, Peles and Wright Chapter 5).

These aspects of Allegheny woodrat biology confound decision-making regarding the appropriate number of individuals that should be released to enhance the likelihood of establishing a population. Considering that Allegheny woodrats have short life expectancies and naturally fluctuating small populations, including bouts of extirpations and natural recolonizations, a strategy of pulsed releases (supplementations) over time may be necessary to provide numeric and genetic enrichment to sustain a reintroduced population. Such a strategy could be designed to emulate interactions among woodrat populations typically facilitated by dispersing individuals. Although much remains to be learned about natural dispersal of Allegheny woodrats, apparently, adult woodrats of both sexes are potential dispersers (Wood Chapter 3). Supplementations would be continued until dispersing individuals from the reintroduction site pioneered suitable habitats in the region, thus contributing to the establishment of interacting populations typical of self-sustaining woodrat populations. Alternatively, a similar outcome might be achieved
by releasing individuals among several clustered reintroduction sites in a manner intended to enable eventual dispersal among populations. At the least, protocols should be in place to supplement reintroduced populations if evidence from monitoring indicates a need because of unexpectedly high levels of post-mortality or the dispersal of a large number of individuals to locations distant enough whereby they are functionally no longer part of the reintroduced population.

Application of population viability analysis (PVA) has considerable value for establishing a basis of what constitutes an adequate number and demographic composition of individuals to be released, and for assessing temporal and spatial strategies for releases (White 2000). PVA can help ensure, with reasonable certainty, that the reintroduced population will be large enough to avoid adverse consequences from short-term demographic stochasticity, long-term genetic stochasticity, and will develop into a sustainable MVP (Shafer 1981). McCleery et al. (2005) provided an excellent example of the application of PVA simulations for anticipating outcomes of translocation projects—in this case, for determining the likelihood that the Key Largo woodrat (N. floridana smalli) population would derive long-term benefit by supplemental stockings. The simulations indicated a high probability that the Key Largo woodrat population would become extinct unless management activities were implemented to mitigate deleterious impacts of limiting factors—habitat alterations, black rats (Rattus rattus), fire ants, and feral cats have been suggested plausible reasons for declines in the population. However, the trajectory of the population decline was reduced when supplemental releases were included in the model, and simulations that included a scenario of ongoing supplementations substantially reduced the likelihood of extinction.

Releasing enough individuals to ensure adequate levels of genetic diversity within a released population should be an important goal of a reintroduction project. Leberg (1990) applied population genetic principles developed by Wright (1969) to demonstrate that loss of heterozygosity in founding populations is small if the population consists of 10 or more individuals of equal sex ratios. However, the adequacy of reintroducing this few individuals presumes high survival among founding individuals, and that all or most contribute to breeding and production of offspring. These presumptions are likely to be unrealistic, and the release of this few animals may be insufficient to establish a self-sustaining population, especially for species having high mortality rates (r-selected species), such as woodrats.

Designing release strategies to facilitate the establishment of a metapopulation structure through the release of animals at two or more spatially disjunct areas connected by corridors is likely advantageous for the long-term persistence of the reintroduced population and could serve as an alternative or be integrated with supplementations. The strategy has various advantages, including the recreation of more natural processes whereby numeric and genetic enrichments are facilitated by dispersal of individuals among units of the metapopulation.

**Human Dimensions**

Another component that needs to be considered at the start of a reintroduction project is the development of a well-conceived public relations program. Project
coordinators must recognize that a successful reintroduction requires more than making appropriate decisions regarding the biological and ecologically requirements of the species. Engendering support and interest for the species with the public (particularly, but not exclusively at the reintroduction area) is important for enhancing the likelihood of positive interactions and support during all phases of the reintroduction project. Coordinators of successful reintroduction projects also embrace opportunities for collaboration with professionals responsible for conservation activities at or near the reintroduction site.

Public Relations

Outreach, with the goal of building public support, arguably represents the most viable approach for achieving positive, long-term outcomes for important conservation issues, including the re-establishment of species by reintroduction (Kleiman 1989, Kleiman et al. 1996). Unfortunately, conservation professionals too often neglect or are unaware of the positive benefits that can be derived from such efforts.

The value of public education has been demonstrated in various reintroduction projects, most notably those involving larger species of wildlife, such as wolves (Fritts et al. 1997) and river otters (Serfass 1998, Serfass et al. 2003), that are considered appealing to the general public. Admittedly, the public typically is less familiar and generally uninformed about woodrats and other smaller animals. However, the Allegheny woodrat possesses many characteristics that can be used to garner interest in the species (including unique behaviors, such as the creation of middens), and thus is a good candidate on which to focus public education events (e.g., slide shows about its natural history and conservation status to school groups or conservation groups). Also, the inherent message associated with a reintroduction project—a species has become imperiled and an effort is underway to restore it—is likely to attract the public’s attention, and thereby provide another opportunity to convey an important conservation message. For the woodrat, this message should include discussions about human-induced changes in the landscape that have contributed to its decline. Ultimately, the quality of the message will depend upon the creativity of the conservationists conducting the reintroduction project.

Development of the outreach program should coincide and integrate with the initial planning of the reintroduction project and include the following steps:

1. **Identify the audience**—The intended audience for reintroduction projects is generally the population living around the release site. However, conservation organizations, groups, civic leaders, and school conservation clubs (among others) should be informed about the project and included in educational events. The process should also seek to identify any individuals or groups that may have concerns (or express concerns) about the reintroduction project.

2. **Identify the purpose and specific messages to be portrayed**—The initial message typically will be about various aspects of the project (justifications, objectives, and goals) and the biology and natural history of the animal to be reintroduced. The message must emphasize that Allegheny woodrats, unlike Norway rats
(Rattus norvegicus), are a native species and will not become a pest species. Specific messages should be developed to coincide with different phases of the reintroduction project. At times, a message may need to be developed in an adaptive manner to communicate unexpected events or to address a particular concern or question posed by the public.

(3) Determine the best mechanisms available for communicating the message—Typically, an initial message can be delivered to communities near reintroduction areas through local media (i.e., newspapers, radio, and television). Preparation of press releases and media packet is useful in guiding interviews with reporters and ensuring that important facts about the project are appropriately portrayed. Activities involving capture, handling, and release of animals provide unique opportunities for participating media to obtain images of animals being reintroduced and a more intimate understanding of the reintroduction process. The public relations program should be ongoing and designed to inform the public about progress and important events associated with the various phases of the project.

Professional Interactions

Reintroductions are multi-faceted efforts requiring various levels of interaction among a variety of conservation professionals. Procedures for disseminating information among members of the reintroduction team and to other professionals associated with the project should be established early in the program (prior to initiating trapping and translocations). Depending on the conservation status of the species, state and/or federal permits will be required for capture, handling, and translocation. In many cases, reintroductions take place on public lands or lands owned and managed by private conservation organizations (see Site Selection). Consequently, members of the reintroduction team should anticipate frequent interactions with professionals responsible for management of the lands at the reintroduction site. In some cases there may be formal expectations regarding the reporting of activities associated with the reintroduction to agency representatives responsible for managing the lands. Regardless, professional courtesy warrants effective and frequent communication with others directly or indirectly associated with the project.

Translocation Phase

Capture and Handling

High survival rates among founding individuals (with respect to what would be anticipated for the species being reintroduced) are essential for enhancing the likelihood of a successful reintroduction program. The prospects for high levels of survival during stressful, post-release acclimation periods likely will be enhanced when reintroduced animals are in good physical condition, which is influenced
by protocols implemented during capture and handling (e.g., removing from trap, tagging, transport, and captive care).

Animals are subjected to stress and potential injury when captured and handled, with clinical consequences manifested as a complex sequence of conditions, including external trauma (e.g., trap-related injury) and skeletal muscle necrosis (Serfass et al. 1993, Hartup et al. 1999). The degree of stress and frequency of injuries can be mitigated by following the best available guidelines for the capture, handling, and care of the species (i.e., from review of literature and consultation with experts; ASM 1998). Regardless, responses of animals to capture and handling can be unpredictable and some level of stress or the occurrence of injuries should be anticipated. Mechanisms should be in place to assess an animal's condition through the various phases of the translocation process. Ideally, animals should receive an immediate, post-capture physical exam to identify injuries in need of veterinary care, and to serve as an assessment of capture and handling procedures.

Following completion of physical exams, animals should be transported to captive facilities for a period of confinement to facilitate veterinary evaluation and, if necessary, receive treatment for injuries or disease prior to being released. Protocols for transport and captive management will vary by species and should be developed in collaboration with veterinarians participating with the reintroduction project. The type (e.g., size of caging and level of quarantine) and duration of confinement initially will be defined by goals of the project (e.g., if the intention is to simultaneously release a large group of animals, some individuals may require a long period of captivity until the desired number of animals is attained), and initial assessments of captive requirements for the species and responses of individuals to captive environment (e.g., some species may respond poorly to extensive periods in captivity, whereas others may thrive in captivity), and subsequently refined through ongoing assessments and interpretations of individual responses to captive conditions. Allegheny woodrats generally appear to adapt readily to captive conditions and do not require elaborate housing (Poole 1940, Kinsey 1976). However, adults must be confined individually to prevent aggressive interactions, which can result in severe injuries or deaths.

The benefits and justifications for incorporating a captive management program generally are well recognized and typically recommended to be incorporated into the design of reintroduction projects (Hoover et al. 1984, Kleiman 1989, Dodd and Seigel 1991, IUCN 1998). The primary objectives of confining animals prior to reintroduction should be to identify and treat injuries, diseases, and other forms of general pathology, and to enhance the general condition of animals by feeding a nutritionally complete diet—the ultimate intention being to promote the release of healthy, vigorous animals that have a high probability of survival (Serfass et al. 1993). The potential for spreading infectious disease and parasites is a particularly important issue for the translocation of wild animals, further justifying the implementation of a captive management program to facilitate health evaluations (Viggers et al. 1993, Serfass et al. 1995). In the western United States, woodrats occasionally harbor Lyme disease and hantavirus pathogens (Lane and Brown 1991, Dearing et al. 1998). Allegheny woodrats could be susceptible to these diseases, but there
are no documented reports. The susceptibility of Allegheny woodrats to raccoon roundworm is, however, well established (LoGiudice 2000). Although direct transmission of *B. procyonis* from woodrat to woodrat does not appear feasible, translocation of an infected woodrat and its subsequent ingestion by a raccoon could spread this parasite to new areas (LoGiudice 2000). Finally, holding animals in captivity provides opportunities to schedule releases to coincide with favorable environmental conditions.

**Considerations for Capture and Restraint**

Various box and cage-type traps have been used successfully to capture woodrats. The use of Sherman traps (model PCLF15; H. B. Sherman Traps, Inc., Tallahassee) and Tomahawk live traps (model TL201; Tomahawk Live Trap, Tomahawk, Wisconsin, USA) has been reported for woodrats (McCleery et al. 2006, Parker 2006, Mengak et al. Chapter 7). For restraint during handling, Frase and Van Vuren (1989) and Parker (2006) assessed the use of ketamine hydrochloride and isoflurane, respectively. Unfortunately, there have been no published studies comparing the efficacy of various traps, restraints, transport techniques, or captive management procedures for woodrats. However, numerous general models exist for the handling and care of small mammals (Kleiman et al. 1996), which can serve as initial guides in developing or enhancing procedures for woodrats.

Ideally, trapping should be avoided during primary periods of primary reproductive activity (spring) and of low food production (i.e., late fall through early spring). First litters of Allegheny woodrats typically are born in mid-spring, and most live-trapping programs are designed to avoid the peak in lactation during this period (Mengak et al. Chapter 7). However, breeding has been documented throughout summer and into fall (Castleberry et al. 2006) and, consequently, trapping during some periods of the reproductive season is unavoidable if woodrats are to be obtained for release when natural foods are most available at reintroduction sites.

**Release Strategies**

Plans to reintroduce animals should consider factors such as the time of year (implications related to the availability of food and opportunities to prepare a winter food cache) and behavioral characteristics of the species. Seasonal variation in the availability of food will be more pronounced for species occupying northern portions of the woodrat’s distribution. Woodrats begin assembling a winter food cache in mid-summer and typically do not change dens after early fall (Peles and Wright Chapter 5), so the chance to accumulate a sufficient cache to survive the winter is likely to diminish as release periods extend into later summer and fall. The optimum period for capture and release may thus be mid-summer, unless released individuals are provided with over-winter food supplements.

Survival of Allegheny woodrats reintroduced in Ohio was higher in summer (after leaf-out) than during spring (prior to leaf-out), presumably because of increased vegetative cover, which provided better avoidance from predators (Schlie
1985). However, interpretation of this outcome is confounded because of different release strategies used for the two seasons—"direct" releases (animals released directly at the release site 2–3 days post-capture) were used during spring and "gentle" releases (animals held in cages at release site for ≥7 days post-capture and supplemental food was provided following release) in summer. McGowan (1993) demonstrated that territorial behavior of woodrats should be considered in release strategies. In this case, a phased-release strategy (animals not simultaneously released at the site) appeared to contribute to greater dispersal (and associated higher mortality) than that observed when individuals were released simultaneously. Presumably, the greater movement and lower survival among individuals in the phased-release group was related to agonistic encounters between established woodrats (those released earliest in the project typically established territories near the release site) and individuals released later in the project, which typically dispersed furthest from the release site. However, further study is needed before concluding that release strategy was the primary casual mechanism for the observed movement patterns.

An important consideration is the implementation of hard-release (i.e., animals directly transported from the capture site and released) or soft-release (i.e., animals transported from capture site to a reintroduction site where they are housed in cages for a period of adjustment until being released) strategies. The higher survival rate among woodrats released in Ohio during summer in comparison to those released during spring (Schlie 1985), which was attributed to seasonal differences in vegetative cover, could likely have been from the spring use of hard releases in comparison to summer soft releases. The simultaneous release of all (most) individuals comprising the reintroduced population has been suggested as the most appropriate strategy for releasing woodrats at a particular site (McGowan 1993), which is most easily accomplished by a soft-release. However, exclusive use of a simultaneous release strategy would prohibit the use of strategies that incorporate supplemental releases. Failure of previous efforts to successfully reintroduce Allegheny woodrats suggests that alternative strategies, including supplemental releases, may be warranted in future reintroduction projects. Clearly, additional investigation is required to determine what scenarios constitute the best strategies for releasing woodrats, including evaluations of approaches that could be used to minimize agonistic encounters between established woodrats and new individuals released to supplement the population.

**Post-translocation Phase**

**Evaluation and Monitoring**

Monitoring initial fates of translocated wildlife and subsequent long-term studies to determine if self-sustaining populations become established should be an important aspect of reintroduction projects (IUCN 1998, Serfass et al. 2003). The level of funding will dictate the type and intensity of effort that can be devoted to post-release monitoring. Regardless, monitoring should incorporate an initial, post-release (short-term) and ensuing long-term phase.
Short-Term Phase

The primary goals of short-term monitoring are to determine survival rates, movement patterns, and levels of interaction among translocated individuals. Minimally, some mechanism should be applied that enables identification of each reintroduced individual. Numerous techniques have been devised that are applicable for marking small mammals, including ear-tagging, toe-clipping, implantable (subcutaneous) transponder chips, and developing a genetic profile for each individual from tissues collected during capture and handling (Paetkau 2004, Peakall et al. 2006). Typically, metal ear tags or ear tattoos have been used to identify individual woodrats (Mengak et al. Chapter 7).

Although expensive in time, labor, and equipment, radiotelemetry is the most effective method for determining the fates of reintroduced individuals and has been used in all Allegheny woodrat reintroduction efforts. Success of the reintroduction project depends on a sufficient number of interacting individuals persisting at the reintroduction location to achieve reproductive success. Thus, information about post-release survival and movements is essential for informed decision making about the short-term prospects for a successful reintroduction and determining if there is a need to adjust the reintroduction process. Radiotelemetry is the only mechanism for reliably assessing important demographic and behavioral characteristics of a species, such as survival, reproduction, movement patterns, interactions with conspecifics, and determining causes of deaths. Also, if supplemental releases occur during the project, radiotelemetry would be an ideal method for assessing if survival and movement of newly released animals is influenced by agonistic encounters with resident animals.

Long-Term Phase

The general intent of long-term monitoring will be to determine if the reintroduction results in the establishment of a self-sustaining population. Therefore, long-term monitoring ideally should continue until a definitive status is determined for the population (e.g., the area is judged unsuitable for sustaining a viable population or, alternatively, the population is considered secure). A properly designed live-trapping effort conducted at five-year intervals would likely yield sufficient information to determine the general status of the population (e.g., evidence of persistence and demographics), but would be unlikely to provide information adequate for a meaningful assessment of population trends or a valid interpretation of factors contributing to those trends (e.g., unexpectedly high fecundity or, conversely, mortality). Also, researchers involved in long-term assessments must be aware that multi-year studies of natural Allegheny woodrat populations demonstrate considerable levels of stochastic fluctuation in population size among years, including extirpation and subsequent recolonization (Mengak et al. Chapter 7). Such naturally occurring population fluctuations can confound the interpretation of results derived from monitoring reintroduced populations. Consequently, monitoring must take place for a period of time sufficient for researchers to determine
if changes in the population size (increasing or decreasing) are the result of natural cycling or an indication that the reintroduction is actually succeeding (population stable or expanding) or failing (population declining).

Often overlooked in the monitoring process are opportunities for long-term assessments of the population's genetic composition. An apparently thriving reintroduced population (based on population size) may, nonetheless, have lost a substantial portion of genetic diversity, which could have unforeseen deleterious effects to the population. Elk in Pennsylvania is an excellent example of a reintroduced population that has increased in numbers, but retained very little of the genetic diversity retained in the source population (Williams et al. 2002). Useful information could be obtained by collecting samples for genetic analysis at any stage of the monitoring process. However, a preferred scenario would be to obtain samples from all individuals comprising the reintroduced population and then sequentially during various phases of the monitoring process. This approach would enable an assessment of retention or loss of genetic variability over time and, thus, enable informed decision making regarding possible conservation actions such as supplementations.

**Conservation and Management of Declining Species**

The ranges of some species of woodrats have suffered considerable declines, presumably because of the direct and indirect consequences of anthropogenic disturbances. These declines have prompted discussions about implementing more active management approaches for woodrats, including implementing reintroduction projects. Species of small mammals exhibiting *r*-selected traits have received very little active conservation attention in comparison to larger, charismatic species, and there are few examples of them being the focus of reintroduction projects for woodrats (Schlie and Bookhout 1985, McGowan 1993, Gerber et al. 2003, McCleery et al. 2005) or other *r*-selected small mammals (Jordan 2003). Consequently, there are few specific reintroduction models available to guide the process of reintroducing woodrats or for anticipating the most likely outcomes of reintroduction projects. Nonetheless, past failed attempts to reintroduce woodrats provide useful insight into the reintroduction process. For example, Schlie (1985) advocated release of woodrats after leaf-out and the use of a soft-release strategy; McGowan (1993) and LoGiudice (2003) demonstrated the importance of avoiding *B. procyonis* contamination at the release site; and Wright (1998) discussed possible social interactions that may discourage individuals from settling at a site when a pulsed release is implemented. Although these post-hoc assessments are valuable, a comprehensive approach must be developed to enhance the likelihood of successfully reintroducing woodrats. Thus, an important challenge for woodrat conservation will be the development of a coherent reintroduction strategy derived from the ongoing development, implementation, assessment, and subsequent refinement of reintroduction concepts and techniques.

The IUCN-RSG (1998) has developed useful general guidelines for reintroduction projects. However, specific components of the reintroduction process must
be designed to conform to the unique requirements of the species being reintroduced. For woodrats (and the case for most r-selected species) there have been no comprehensive reintroduction efforts from which the reintroduction process can be modeled. In this chapter, I put forth a complete conceptual model to serve as a basis for developing and refining approaches that can be applied and evaluated for the reintroduction of woodrats. Although similar in many aspects, the recommendations diverge from approaches typically applied for reintroducing larger, K-selected mammals (which represent the majoring of mammalian reintroductions) by emphasizing challenges related to reintroducing the Allegheny woodrat—an organism that occupies habitats typically dispersed as small patches within the landscape, maintains relatively low population densities among interconnected populations (metapopulations), but otherwise has r-selected characteristics, including high rates of mortality. Specifically, I recommend an approach that recognizes the obstacles of reintroducing woodrats, whose existence revolves around cyclic episodes of extirpations and recolonization from individuals dispersing from adjacent populations, as would be expected for an organism that has evolved to persist through interactions within a metapopulation. Inherent to this consideration is attempting to recreate or maintain a metapopulation as part of the reintroduction strategy. Such an approach is likely to comprise multiple scenarios, including, but not limited to: (1) reintroducing a new population in the proximity of extant populations with the intent of fortifying an existing but deteriorating metapopulation; (2) reintroducing several populations in proximity to one another with the intent of establishing a metapopulation; or (3) reintroducing a single population with ongoing supplementation of new individuals until dispersing individuals colonize new areas, resulting in the establishment of a metapopulation. Regardless of the scenario, high mortality should be anticipated and ongoing supplementations should be considered for the design of future reintroduction projects involving woodrats.

Conservationists have much to learn about the best procedures to apply for reintroducing Allegheny woodrats. Designing future woodrat reintroduction projects as series of well conceived, noninvasive experiments will facilitate objective evaluation and interpretation of the various phases of a restoration effort. Such an approach will serve as a basis for refining the reintroduction process for woodrats, as well as other similarly adapted r-selected species.

References


