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Reintroduction Programs

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This chapter outlines the conditions that make a reintroduction program using captive mammals of a threatened or endangered species an appropriate conservation strategy, and presents some basic guidelines for such an effort. IUCN (1987) also provides criteria for these and related efforts.

Reintroduction is an approach that is attractive to zoo conservationists, as well as to the general public, but such a program should be undertaken only with a clear understanding of the costs and benefits. Because reintroduction is a complex endeavor that usually involves both a long-term financial commitment and active collaboration by governmental and nongovernmental agencies and institutions, it is not a viable option for the majority of endangered species held in captivity. Indeed, attempts to reintroduce a species, if poorly conceived or implemented, may actually obscure the conservation issues that led to the decline of the species in the first place—and thus may detract from, rather than add to, a species' chances of survival (IUCN 1987).

The first step in considering a reintroduction is to define the long-term conservation goals of the program and the criteria for success. Aims vary according to (1) the status of each species in captivity and in the wild and (2) the political situation within the receiving country. Generally, major goals include increasing the size of the wild population, establishing additional wild populations, and/or preserving or enhancing available habitat. Ideally, reintroduction could also be used to enhance the demographic and genetic management of both wild and captive populations. While criteria for success vary depending upon the aims of each program, a program is likely to be judged a success if the status of a species is significantly improved by the reintroduction, even if every single released individual dies. Reintroduction solely as a solution to the problem of surplus captive animals is inappropriate; an integrated plan to promote the preservation of the species in the wild is also needed.

The success of many early attempts to reintroduce mammals into natural habitats cannot be fairly evaluated since there has been limited post-release monitoring, especially for primate reintroductions (Aveling and Mitchell 1982; Borner 1985). There have been some clear successes with ungulates, including the American bison, *Bison bison*, and the European wisent, *Bison bonasus* (Conway 1980; Campbell 1980), although those efforts also involved minimal monitoring.

In the remainder of this chapter I will concentrate on outlining those factors that should be considered in planning and implementing a reintroduction program involving the release of threatened or endangered captive mammals. There have been many more reintroduction programs for bird species (Campbell 1980), although they are neither less complicated nor less expensive than reintroduction programs for mammals. Long (1981) estimated, in a review of translocations, reintroductions, and introductions, that approximately half of the attempts failed. Cade (1986), Wemmer and Derrickson (1987), Kleiman (1989), Stanley Price (1989), Gipps (1991), and Beck et al. (1994) provide reviews and bibliographies on reintroduction programs for captive birds and mammals.

A description of a release of animals into a natural habitat needs to specify (1) whether the release occurs within the species' original geographic range, (2) whether there is a preexisting free-ranging population at the release site, and (3) the history of the specimens released (i.e., wild- or captive-born, currently in the wild or in captivity, previous experience in the wild). There are differences among authors in their use of terms (Konstant and Mittermeier 1982; IUCN 1987; Stanley Price 1989). I am defining *reintroduction* here as the release of either captive-born or wild-caught animals into an area within their original range where populations have declined or disappeared. Reintroductions may involve moving *(translocating)* wild-caught animals or releasing naive captive animals (both wild- and captive-born), and may have a conservation or an economic purpose. Goals may include improving the status of the wild population by increasing numbers (sometimes termed *restocking*) or changing the population's genetic makeup. The latter goal may be appropriate when the species exists in small groups in insular habitats that preclude outbreeding.

WHEN IS REINTRODUCTION APPROPRIATE?

Reintroduction may be appropriate when the demography and genetics of the wild population suggest that a species could go extinct and that a boost in population size or genetic diversity would protect its future. Such a judgment must be based on a thorough knowledge of the species' biology, distribution, and ecological requirements, as well as an understanding of the original factors causing the population decline.

With the condition of the wild population ascertained, there must exist a viable, self-sustaining captive population with broad genetic representation. The captive population must be sufficiently robust to sustain the loss of many animals for a prolonged period while reintroduction techniques are perfected. Animals chosen for a release program must be surplus to the future needs of the captive population and able to interbreed with animals in the wild population. There are numerous species, such as owl monkeys, *Aotus trivirgatus*, in which distinct populations appear morphologically identical, but are so different genetically that individuals cannot interbreed (Ma et al. 1976). Shields (1982) has suggested that outbreeding depression may be a more common problem than expected.

Another requirement is the existence of suitable habitat with sufficient carrying capacity (Brambell 1977) to sustain the growth of the reintroduced population. Habitat suitability can be assessed only by detailed studies of the habitat preferences, movements, shelter requirements, and foraging and feeding behavior of free-ranging wild-born animals. Critical resources may not always be self-evident. Coimbra-Filho and Mittermeier (1978) correctly identified tree holes for sleeping as a critical resource for the golden lion tamarin, *Leontopithecus rosalia*. We preceded reintroductions of this species with an evaluation of the numbers of trees with sufficient girth to provide tree holes for nocturnal nesting (J. M. Dietz, D. G. Kleiman, and B. B. Beck, unpub.). Preferred habitat should have no, or a very reduced, resident population, but be within the natural range of the species.

Since habitat loss and alteration are the paramount causes of the decline of most species, the lack of suitable protected habitat is the major ecological reason to reject proposals for a reintroduction program. Thus, a prerequisite for a reintroduction program is the existence of legally protected areas, such as national parks or equivalent reserves, with real and effective protection (Campbell 1980; U.S. Fish and Wildlife Service 1982; Aveling and Mitchell 1982; Borner 1985; Oliver 1985). There must also be the expectation that the protected areas will survive intact into the future. Without a long-term commitment, there will be a constant (and probably losing) battle to protect not only the animals but also the habitat. For example, difficulty in finding a politically safe habitat for releasing red wolves, *Canis rufus*, has been one of the major obstacles to the Red Wolf Recovery Plan (U.S. Fish and Wildlife Service 1982; Parker 1986), as it has been for the release of sea otters, *Enhydra lutris* (K. Ralls, pers. comm.).

Currently, one of the most impressive reintroduction programs involves the release of captive-born Arabian oryx, *Oryx leucoryx*, in Oman (Fitter 1984; Stanley Price 1989). The Sultan of Oman has personally taken an interest in the program and is supporting it financially and providing equipment. Furthermore, individuals from local tribes are employed by the project, and thus directly benefit from it (Stanley Price 1986, 1989). This effort is likely to be successful, as long as the support remains at the level of government policy and the local citizenry is kept aware and involved.

While sufficient protected habitat is of paramount importance for the development of a reintroduction program, other reasons for a species' decline must also be identified and eliminated prior to the release of captive-bred animals (Brambell 1977). Hunting or poaching for food, fur, trophies, or other body parts has been a major factor in many species' decline, especially for birds and the large charismatic mammals. In other cases, species have declined or been lost due to predation, food competition, or habitat destruction caused by the introduction of nonnative species, including domestic cats, dogs, rats, rabbits, goats, and snakes. Birds and reptiles endemic to islands have suffered greatly from these causes.

Diseases that can rapidly wipe out a population (and a species, if it already exists in small numbers) may also be introduced through other carriers. Kear (1975) describes several cases in which avian species have been decimated through accidentally introduced viruses.

Free-ranging animals should not be present in an area targeted for a reintroduction if the wild population is severely endangered. It is not usually appropriate to intermix the wild and captive populations unless the species' future survival absolutely depends upon an "injection" from the captive gene pool. First, the captives may carry disease agents to which they, but not the wild individuals, are immune, a problem pointed out by many authors (Brambell 1977; Caldecott and Kavanagh 1983; Aveling and Mitchell 1982). The wild population can be protected by first releasing captives in habitats that are devoid of free-ranging animals. Alternatively, captives can be shipped to the country of destination and quarantined. Prior to release, selected free-ranging individuals can be introduced to the quarantined captives and act as "guinea pigs" to test for the presence of possible disease vectors. Prerelease screening by veterinarians of the captives' blood, urine, feces, and ectoparasites, followed by appropriate treatment, may also reduce the potential for disease transmission. However, veterinary evaluations of specimens destined for release is necessary regardless of the existence of overt health problems or the likelihood of contact between a reintroduced and a wild population.

Another reason for reducing contact between reintroduced captive-born animals and the wild population is to protect the genetic integrity of either or both populations. For example, the red wolf is currently considered extinct in the wild due to extensive crossing with the coyote, *Canis latrans* (U.S. Fish and Wildlife Service 1982, 1986; Parker 1986). To prevent further hybridization, the reintroduction program releases captives on islands or in areas known to be devoid of coyotes and hybrids.

Releasing animals into a saturated stable natural population is known to cause social disruption and stress (Brewer

TABLE 29.1. Decision Making Concerning the Reintroduction of Lion Tamarins (*Leontopithecus*): Do the Necessary Conditions Exist?

	Leontopithecus		
	rosalia	*chrysomelas*	*chrysopygus*
1. The reasons for the reduction in species numbers have been eliminated (e.g., hunting, deforestation, commerce)	?	No	No
2. Sufficient habitat is protected and secure	Yes?	No	Yes
3. Available habitat exists with low densities of or without native animals	Yes	Yes?	?
4. It is certain that the release of animals will not jeopardize the existing wild population	No	No	No
5. Sufficient information exists about the species' biology in the wild to evaluate whether the program is a success	5	1.5	3
6. Conservation education exists	5	2	4
7. The population in captivity is secure, well managed, and has surplus animals	Yes	No	No
8. Knowledge of the techniques of reintroduction exists	3	3	3
9. Resources for postrelease monitoring are available	Yes	No	No
10. There is a need to augment the size/genetic diversity of the wild population	Yes	No	Yes?
IS REINTRODUCTION RECOMMENDED?	YES	NO	NO

Source: Based on material provided by C. and S. Padua, A. Rylands, C. Alves, J. and L. A. Dietz, J. Ballou, F. Simon, B. Beck, and J. Mallinson at the *Leontopithecus* Management Workshop, Belo Horizonte, Brazil, June 19–23, 1990.
Note: Scale: 5, best; 0, worst.

1978; Carter 1981; Aveling and Mitchell 1982; McGrew 1983; Borner 1985; Harcourt, in press). For newly released animals (as singletons or groups) unacquainted with an area and without established home ranges or territories, a confrontation with adapted wild animals in natural social groups may result, at best, in flight and dispersal to a marginal habitat. At worst, the native animals may attack and seriously wound or kill the newcomers (Harcourt, in press; McGrew 1983). There are several documented cases in which young chimpanzees, *Pan troglodytes*, have been attacked after release into the territory of an established group (Brewer 1978; Carter 1981; Borner 1985).

Captives may also be unacquainted with the etiquette of social interactions in natural habitats, and may overreact upon meeting a wild conspecific. For example, groups of wild golden lion tamarins regularly interact at territorial boundaries. Although the interactions have aggressive components, they rarely result in injuries (Peres 1986; pers. obs.). However, groups of newly released captive-born tamarins were very aggressive toward each other during their first conspecific encounters, resulting in the flight and loss of some individuals (D. G. Kleiman, J. M. Dietz, and B. B. Beck, unpub.).

Decision Making: A Concrete Example

This section (see also Kleiman 1990) provides a concrete example of how to decide whether the appropriate conditions exist to recommend (or argue against) reintroductions of captive-born animals or translocations of wild individuals or groups.

The lion tamarins (genus *Leontopithecus*) derive from the Atlantic Coastal rainforests of Brazil. All species are endangered, mainly due to habitat destruction and alteration. There are captive populations of three species, each at different levels of development.

Table 29.1 lists ten conditions that should be met in order to recommend a reintroduction/translocation program. Additionally, it evaluates the position of the three lion tamarin forms with respect to each condition. Finally, a general recommendation is presented concerning whether a program of reintroduction is warranted for each of the three forms (this material was prepared in 1990).

The major reason for the decline of the lion tamarins has been deforestation. There has also been a thriving commerce in these forms because they are favored as pets. The reasons for the decline of *L. chrysopygus* and *L. chrysomelas* have not been eliminated, thus dictating against a reintroduction at this time. It is questionable whether or not the reasons for the decline of *L. rosalia* are now fully under control.

There is likely sufficient protected habitat available for *L. chrysopygus*, but not for *L. chrysomelas*. Protected habitat exists for *L. rosalia*, although in insufficient quantities for its future survival.

To prevent social disruption and disease transmission, it is preferable to use areas that have small or no populations of wild tamarins. This condition exists for *L. rosalia*, and probably for *L. chrysomelas*. There are many available confiscated *L. chrysomelas* that cannot be absorbed easily into the captive population; reintroduction may be a viable option for this small subset of wild-born animals. The situation for *L. chrysopygus* is unknown at this time.

Reintroductions should be encouraged only when there is some certainty that the release of animals from other regions (both captive and wild-born) will not jeopardize the existing native population through transmission of disease or social disruption. We do not have this confidence for the three forms of lion tamarins at this time due to our limited knowledge of their biology and status.

The evaluation of the success of a reintroduction can be accomplished only by long-term monitoring and must be based on a thorough knowledge of a species' biology, distribution, and ecological requirements. On a scale of 1–5, with 5 being the best-case scenario, I suggest that there is sufficient information available for *L. rosalia*, and totally insufficient information available for *L. chrysomelas*, with *L. chrysopygus* somewhere in between.

A conservation education program in conjunction with a reintroduction can attract and inform the local populace and may well result in greater community support for the effort. Both *L. rosalia* and *L. chrysopygus* conservation programs have strong educational components. The education program for *L. chrysomelas* is developing.

A prerequisite to the reintroduction of animals currently in captivity (whether captive or wild-born) is a secure, well-managed captive population with a long-term Masterplan and available surplus animals. This condition is met in *L. rosalia*, but not yet in *L. chrysomelas* and *L. chrysopygus*.

We have much still to learn about the methodologies of preparation, adaptation, and release of lion tamarins. With so many unanswered questions about the techniques that will ensure success—for example, for the injection of single animals into established reproductive groups—I suggest that we still consider reintroduction an experimental approach.

Access to the resources necessary to monitor the activities and survivorship of released animals is essential for a reintroduction effort, especially since we have not yet perfected our preparation and release techniques. The conservation programs for *L. chrysomelas* and *L. chrysopygus* are not yet sufficiently developed, with respect to financial support and the necessary infrastructure, to warrant a reintroduction effort. The *L. rosalia* program has a well-developed infrastructure and considerable resources to monitor the activities of released animals.

One major purpose of a reintroduction program is to augment the numbers or genetic diversity of a population. *L. rosalia* currently needs such augmentation, while the situation for *L. chrysomelas* and *L. chrysopygus* is not clear at this time.

Weighing the degree to which the necessary conditions are met for each species suggests that while reintroduction efforts may be appropriate for *L. rosalia*, they are not yet appropriate for *L. chrysomelas* or *L. chrysopygus*.

HOW DO YOU START?

Negotiations

Most reintroductions start with individual interests but ultimately involve multiple organizations, both governmental and nongovernmental, local, national, and multinational. The first step is to obtain the support and involvement of the appropriate governmental agencies, especially those that provide permits for the movements of threatened and endangered species. Collaboration should also be sought from the staffs of zoos, local universities, and conservation organizations in as well as outside the host country.

Continued success depends upon having the program eventually involve local people rather than outsiders, regardless of its location. There should be obvious benefits to the community, or support will be half-hearted or nonexistent. An abstract benefit, such as saving a species from extinction, is often not a compelling argument to a government official without resources who is under pressure from starving landless peasants. Economic benefits are obviously a strong incentive for cooperation. In Oman, local tribes are employed in the monitoring program for the Arabian oryx (Stanley Price 1986, 1989). Educational benefits (e.g., providing advanced training abroad) and the transfer of technology are additional inducements that also accelerate the transfer of the management of the program into local hands.

There must be a signed document containing the aims and objectives of the program as well as the criteria for its success. The signed agreement should also state the expectations, responsibilities, and degree of authority of each party, preferably with a preliminary schedule of work. At the outset, the responsibility for decision making at each stage of the process must be made clear, and a set of guidelines for making decisions should be provided. For example, animals may die or be born after the candidates for reintroduction are chosen, but before release. The authority for changing the list of release candidates in these circumstances must remain with a single person. Similarly, only one person should decide whether to "rescue" an animal that is doing poorly after the release. Another issue that must be included in the formal agreement is the ownership of the specimens (will they continue to be owned by the provider or be transferred to the receiver?).

Financial Support

A reintroduction program requires the long-term commitment of many individuals, including professionals living in the field for extended periods. Substantial funding is consequently required for (1) salaries; (2) field headquarters and subsistence; (3) vehicle(s), including fuel and maintenance for transport in the area of the reintroduction; (4) animal caging and shipping costs; (5) equipment and supplies for monitoring the released animals, such as binoculars, radiotelemetry equipment (receivers, antennas, and transmitters), materials for marking animals, and traps for capturing animals; (6) travel for the principals; and (7) long-distance communication. Kleiman et al. (1991) provide examples of costs for the Golden Lion Tamarin Conservation Program, which includes a reintroduction component. Expenses mount considerably when the project involves additional components, such as a conservation education effort, habitat protection, prerelease preparation and training of animals, and extensive field studies of the status and behavioral ecology of the free-ranging wild population.

Reintroduction programs for large mammals that normally range over great distances may be prohibitively expensive, since keeping track of the released animals may require the use of aircraft for radiotelemetry (Stanley Price 1986, 1989). Cost alone can prevent reintroduction programs from being used for the preservation of most species (Brambell 1977). Wildlife protection, habitat preservation, and conservation education may be more cost-effective conservation measures than reintroduction (Borner 1985).

Field Studies and Site Selection

Initial field surveys will clarify the status of the population in the wild and the availability of suitable habitat to support the reintroduced animals *and their descendants*. Releases should cease as the carrying capacity of the habitat is reached, as may soon be the case for the orangutan, *Pongo pygmaeus*, in Malaysia and Indonesia (Aveling and Mitchell 1982), where rehabilitation centers for wild-born orphans have been operating for many years.

A suitable release site should be completely protected and accessible and should have a small (or no) resident population of the target species, unless the goal of the reintroduction is to increase genetic diversity within an insular population. Planners should know whether the reserve area can sustain a genetically viable population in the future, and of what size. Field surveys may be time-consuming and complex, especially if little is known of the behavioral ecology and habitat preferences of the species. But field surveys are crucial since they may identify the causes of a species' decline in the wild and provide information necessary to eliminate the threats. If preliminary field studies indicate that there is insufficient suitable habitat or continued major threats to the species, planners must be prepared to abandon the proposed reintroduction unless they can show that the benefits of proceeding outweigh the costs.

Regular status surveys also allow for evaluation of the potential effects of the reintroduction on the native population. Similarly, information concerning behavioral ecology allows for the immediate evaluation of habitat suitability and the eventual comparison of released and wild animals. These comparisons are absolutely critical for the continued evolution of reintroduction methodology and procedures.

Choosing Animals

The choice of specimens for release derives from the project's objectives. For example, if the intent is to release only a small quantity of "genetic material" into an inbred population, then the only selection criterion might be an individual animal's genetic background. However, since most reintroductions aim to bolster the wild population's numbers significantly, the choice of animals is usually much more complicated. Biologists must also ensure that none of the selection criteria will negatively affect the genetic or demographic composition of the captive population.

The genetic characteristics of the candidates for reintroduction should be as close as possible to those of the original wild inhabitants of the region so that genetic adaptations to particular ecological characteristics of the area will be present in the released animals (Brambell 1977). For example, Stromberg and Boyce (1986) criticize the release of swift foxes, *Vulpes velox*, from Colorado stock in Canada because they believe that hybridization between the northern and southern populations will swamp the remaining fragile population of northern foxes and that the Colorado foxes will be unable to survive the cold winters of the north. Herrero, Schroeder, and Scott-Brown (1986) provide a convincing rejoinder and review the bases for their decision.

Biologists must determine the age and sex classes most appropriate for reintroduction, as well as the size and composition of groups to be reintroduced. Previous studies of the mating system, social organization, and the spatial relationships of individuals will provide guidelines for making these decisions. For example, based on such information, the groups of Jamaican hutias, *Geocapromys brownii*, golden lion tamarins, and Arabian oryx chosen for reintroduction were stable and cohesive; the hutias and tamarins were in monogamous families and the oryx in polygynous herds (Oliver 1985; Kleiman et al. 1986; Stanley Price 1986). Red wolves have been released as mated pairs (U.S. Fish and Wildlife Service 1986; Point Defiance Zoo and Aquarium 1988), and European otters, *Lutra lutra*, as trios of a single male and two females (Jeffries et al. 1985). Except for the otters, these were all reintroductions conducted in locations devoid of the species.

In saturated areas a different strategy is necessary. For example, gorilla, *Gorilla gorilla*, ecology and social behavior suggests that adult males or adult females with young are not good choices for release due to the likelihood of aggression from established groups; adolescent and adult females are probably the best candidates (Harcourt, in press). Early experiences with chimpanzee reintroductions suggested that cohesive groups should be released in already populated areas (Borner 1985). Finally, in some cases it might be best to reintroduce captive-born animals in the company of one or more wild-born individuals, rather than in a group composed only of captives.

Other decisions include the choice of season for the release, the distance between release sites, and the timing of the release(s)—that is, whether all releases will occur simultaneously or at predetermined intervals. The season chosen for release(s) should not be one in which critical resources are unavailable. Timing of releases depends in part on social organization if the animals will ultimately be occupying territories adjacent to each other.

The choice of animals and groups for reintroduction is a complex process that may require alternative strategies and considerable experimentation. Ultimately, the aim is the combination of animals that will survive best with the least preparation and cost, since a major criterion for success is a viable, free-ranging, self-sustaining population. The research and development phases of a reintroduction program may be very costly.

Cooperating Institutions

If only a single institution is holding the captive animals scheduled for reintroduction, then animals need only be moved between that institution, a halfway house quarantine facility (if necessary), and the release site. If several zoos are holding animals to be reintroduced, then coordination is more complicated, especially when substantial prerelease preparation is planned. As the individuals constituting the captive population of an endangered species are often distributed widely to minimize extinction risks, coordination will undoubtedly be complicated. In all cases, veterinary screening and treatment prior to release is necessary and is best done at a single institution for consistency.

Cooperating zoos must obtain health and import/export permits and arrange transport well in advance of the shipment itself. Institutions at the receiving site must be fully involved in the scheduling of shipments, especially if the receiving agency needs to prepare facilities or holding cages for prerelease acclimation.

Public Relations and Education

Public education and a broad base of public support are the only long-term solutions to conservation problems in both developing and developed countries. Since the local community often contributes significantly to the decline of a species through hunting or other activities that result in habitat degradation, a strategy involving the local community as collaborators rather than as obstacles to the program is the most likely to achieve success. Carley (1981) and Dietz and Nagagata (1986) describe conservation education programs acting in conjunction with the experimental release of red wolves in South Carolina and the reintroduction of the golden lion tamarin in Brazil, respectively.

Conservationists need to be sensitive to the pressures affecting the activities of local individuals, especially government officials, so that the latter are not put in impossible or compromising positions due to the activities of the reintroduction program. Although a successful conservation program clearly requires considerable basic biological knowledge, it demands public relations and political skills even more. Harcourt (in press) suggests, and I strongly agree, that the politics of reintroductions are as important as the release methodology.

A good reintroduction program involves local collaborators with a stake in its future success. In a developing country, there should be a commitment to train a future cadre of professional biologists in zoo biology, reintroduction methodology, wildlife biology, and conservation (Kleiman et al. 1986). To this end, a percentage of the project's total budget should be allocated for student support (or other forms of professional training) (see Kleiman et al. 1991).

Habitat Protection and Management

The degradation of habitats is the chief cause of species losses. A successful reintroduction requires a secure site; therefore an active program for habitat protection must exist. In some cases, habitat protection will derive from the activities of the reintroduction program (Aveling and Mitchell 1982). Additionally, reintroduction programs may need to become involved in aggressive management of land and animals or even the restoration of destroyed habitats. This need for aggressive management derives from the islandlike quality of so many reserve areas, whose ecological balance is easily upset due to their small size. The management and restoration of habitats in the Tropics are major challenges for the future (Ehrlich and Ehrlich 1981).

THE REINTRODUCTION

Preparation of Animals

We have very little experience in reintroducing captive mammals into their native habitats. No general guidelines exist for preparing species from the various taxa for reintroduction. However, there are at least six major areas of behavior to consider in the development of any preparation scheme. To survive, candidates for reintroduction must be able to (1) avoid predators; (2) acquire and process food; (3) interact socially with conspecifics; (4) find or construct shelters and nests; (5) locomote on complex terrain; and (6) orient and navigate in a complex environment. Preparation also may involve acclimatization of release candidates to the habitat and climatic conditions at the release site for some time prior to the reintroduction.

Species differences in the amount of prerelease conditioning required are likely to be significant. Herbivores may need little training in food acquisition and processing, while omnivores and carnivores may require extensive training. Species that normally live in herds or are solitary in the wild may need less preparation in the rules of social etiquette than forms that live in groups with a complex social structure. Arboreal species may need more preparation in locomotion and orientation than terrestrial forms. Migratory species or those with large home ranges may need to learn how to navigate and develop routes through natural habitats; territorial forms may need to learn how to define the limits of their ranges. We do not know which of these behaviors are learned and thus require training, and which are genetically hard-wired. Examples of different approaches to preparation (both recommended and tested) are given by Kleiman et al. (1986); Beck et al. (1991); Beck et al. (in press); Box (1991); Miller et al. (1990a, 1990b); Stanley Price (1986, 1989); Oliver (1985); Oliver et al. (1986); Parker (1986); Harcourt (in press); Rijksen (1974); Scott-Brown, Herrero, and Mamo (1986); and U.S. Fish and Wildlife Service (1982).

To prepare golden lion tamarins to forage and feed, Beck developed a feeding protocol that involved the gradual replacement of a single bowl of food with food that was distributed in different locations and hidden in "puzzle boxes," thereby forcing the animals not only to search for food, but to work to extract it. To improve locomotor ability and spatial orientation, animals were exposed to exceedingly complex three-dimensional environments that were regularly dismantled and rebuilt. The overall survival rates of prepared and unprepared tamarins did not differ (Beck et al. 1991; Beck et al., in press). Living for several months in a free-ranging condition on the zoo grounds, however, seemed to confer an advantage on tamarins after release, especially with extensive post-release support through provisioning and post-release training (Beck et al. 1991).

Red wolves have been preadapted to hunting by exposing them first to carcasses and then to live prey before reintroduction (U.S. Fish and Wildlife Service 1982). Miller et al. (1990a, 1990b) conducted one of the very few experiments to test the effects of training protocols on the behavior of captive animals with the ultimate aim of applying the techniques to the preparation of endangered black-footed ferrets, *Mustela nigripes*, for reintroduction. They used nonendangered Siberian polecats, *Mustela eversmannii*, as a model species to examine the development of predator avoidance and prey location skills in naive captives. The captives in general spent more time in surface activity than in burrows when searching for food. They also showed little evidence of a capacity for long-term memory of a negative experience with a potential predator.

For many species, social preparation is of considerable importance. Castro et al. (in press) have noted that the auditory communication skills of captive-born golden lion tamarins differ from those of wild tamarins, which could affect the ability of released captive-born individuals to interact properly with wild conspecifics.

For great ape reintroductions (and introductions), the major preparation has been social, in that candidates have been housed with conspecifics prior to release (Wilson and Elicker 1976; Pfeiffer and Koebner 1978) after being housed alone for long periods. Great ape releases have also often involved providing animals with exposure to a natural environment while still keeping them under human care. Hannah and McGrew (1991) summarize great ape rehabilitation projects, including some preparation techniques.

Incorporating preparation techniques into the normal zoo environment might result in more naturalistic and complex habitats for captive animals. At the National Zoological Park, tamarin groups scheduled for reintroduction are now released on zoo grounds during the spring and summer months. They are free-ranging for several months prior to shipment (Bronikowski, Beck, and Power 1989).

Beck (1991) points out that our attitudes toward animal welfare may be an obstacle to providing an enriched environment that would prepare captive-borns for survival in the wild. Real preparation would include exposure to food shortages, parasites and disease, predators, dramatic fluctuations in ambient conditions, and dangerous objects. To most keepers and veterinarians, such practices would simply be unacceptable.

Preparation has not generally been considered an essential element in most reintroduction programs, possibly because the training technology is not yet available. An alternative to prerelease training may be the pairing of captive-born animals with experienced wild-caught individuals prior to release, with or without post-release training.

Release and Monitoring

The reintroduction of captive-born animals into the wild signifies a change in the relationship between the animals and the animal manager, even if each specimen is outfitted with a transmitter and followed for 24 hours each day. Captive animals are the total responsibility of their caretakers; their diets, shelters, companions—indeed, most aspects of their environment—are controlled and controllable. Once the release occurs, this control is lost. Project personnel must decide whether and under what conditions to intervene if an animal begins to fail. The decision depends upon many factors, such as the political situation (can animals be allowed to die with everyone's full knowledge?); the value of the individual animal to the project because of its social, experiential, or genetic background; the perceived reason for the animal's problem (e.g., disease, predation, social conflict, human error); and the availability of captive housing for rescued individuals. If guidelines governing the rescue of reintroduced animals are clearly spelled out before the release, project personnel can avoid making a rushed decision in a confused and possibly emotionally charged climate.

The long-term monitoring of released animals is a crucial component of any reintroduction program. The zoos providing the animals for reintroduction have a special interest in the results of monitoring since it is important for them to keep their constituencies informed about the progress of individuals from their collections that have been reintroduced. Intensive monitoring can also facilitate the collection of carcasses for pathological study and thus clarify causes of death of released animals. A monitoring program will indicate how and when the behavioral repertoire of captive-born animals becomes comparable to that of wild specimens. All of this information can then be fed back into the management of the captive population.

Most reintroduction programs have included the provision of essential resources such as food, water, and shelter, both to provide support for the animals and to control their movements. Golden lion tamarins, Jamaican hutias, and Arabian oryx were all released from enclosures with shelters, with the hope that the animals would remain in the vicinity (Kleiman et al. 1986; Oliver et al. 1986; Stanley Price 1986, 1989). Sites where food and shelter are provided can be used for trapping and examining the specimens.

When to eliminate support is a major decision. It is extremely important to challenge the animals, but is also easier to control their movements if critical resources like food are provided. Achieving a wild state may mean developing fear and avoidance responses to humans, a condition that most animal managers find difficult to promote in their "charges." For each reintroduction, because of species differences and differences in goals, there will be complex decisions to be made for which there are no clear guidelines. To what extent and for how long should food supplementation continue? To what extent and for how long should humans be an important part of the lives of the released specimens? How much intensive monitoring is necessary, and how long should it continue? A common thread and a common problem will be reducing the human-animal contacts and encouraging the animals to avoid people, all while the project personnel continue to monitor the animals.

Defining Success

There are no established criteria for calling any given reintroduction a success. Griffith et al. (1989) evaluated those variables that led to the success of intentional introductions and reintroductions of native birds and mammals (not all endangered or threatened) to the wild in Australia, New Zealand, Canada, and the United States (including Hawaii) between 1973 and 1986. Greater success was associated with releasing larger numbers of individuals; extending the program duration; releasing animals into excellent habitat and into the core of their historical range; using wild-caught individuals; releasing herbivores rather than omnivores or carnivores; and releasing animals into areas without competitors. Stanley Price (1989) discusses the characteristics that make animals the most reintroducible: large animals living in cohesive groups, explorer species, nocturnal species, and species tolerant of habitat change or extreme environmental variation.

Beck et al. (1994) suggest that a reintroduction project should be counted as successful if the wild population reaches 500 individuals that are free of provisioning or other human support, or if a formal genetic/demographic analysis predicts that the population will be self-sustaining. By these stringent criteria, they found that only 16 (11%) of 145 animal reintroductions were successful. However, many of these projects are ongoing, and their success or failure cannot yet be evaluated. Also, a reintroduction attempt can have indirect, longer-term conservation benefits, such as increased public awareness, professional training, and enhanced habitat protection (Beck et al. 1994).

Beck et al. (1994) noted that the successful programs (by their definition) were longer and released more animals than the unsuccessful programs (as did Griffith et al. 1989). They also provided local employment and had community education programs. Finally, the successful projects used medical screening and post-release provisioning *less* than unsuccessful projects, a counterintuitive result.

One issue requires clarification. All reintroduced animals will eventually die, as will all captive animals. The success or failure of a program should not be measured by the mortality of the original reintroduced cohort. More important is the number and genetic variation of the surviving descendants of the released animals and the degree to which their genetic material is integrated with that of the original wild population.

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WILD MAMMALS IN CAPTIVITY

Principles and Techniques

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30

The Role of Conservation and Survival Centers in Wildlife Conservation

CHRISTEN WEMMER, SCOTT DERRICKSON, AND LARRY COLLINS

Humans have invented institutions to sustain wildlife since the beginning of urbanization and the decline of wilderness. The menagerie and the hunting preserve were among the oldest of these institutions, and the differences between them were substantial (Loisel 1912). While menageries catered to the amusement of the urban middle class, hunting preserves reserved wildlife for the elite as a symbol of aristocratic power and privilege. Menageries presented wild animals to the common people in artificial containment, whereas the hunting preserve protected wildlife in its natural environment for the exclusive use of a privileged few. National parks, biosphere reserves, wildlife refuges, conservation centers, and a variety of similar institutions have been developed more recently (cf. McNeely and Miller 1984; Carr 1989; Bildstein and Brisbin 1990; Boza 1993; Curtin 1993). Despite their diversity, their origins can all be traced to human recreation in its various manifestations. Their principal differences lie in their means of support and form of management.

This chapter deals with the role of propagation centers in the conservation of endangered wildlife. We use the adjective "propagation" rather than "breeding" to identify those centers whose management is motivated by the long-term conservation of gene pools, as opposed to production for human consumption (i.e., ranching), in which retention of wild traits is not a primary concern. This concern reflects the rapid changes taking place in zoo philosophy and objectives as a result of the present global extinction crisis. It is fair to say that zoos are in the midst of a significant reformation, and that the driving force behind this change is a growing awareness of their potential contributions to conserving wildlife through active programs in endangered species propagation, research, education, and training (Conway 1986, 1988; Seal 1988; Rudran, Wemmer, and Singh 1990; Wemmer, Pickett, and Teare 1990; Wemmer et al. 1993).

Zoos and reserves differ in many ways, but their raisons d'être are converging, and they are becoming more similar in other ways. This convergence stems primarily from the rapid and unceasing fragmentation of vast natural landscapes into an archipelago of small habitat islands whose ecological systems must be increasingly maintained by human inputs. With limited possibilities for dispersal and emigration, species inhabiting these islands exist in a situation that closely approximates that of their zoo counterparts: they are captives in a closed system that requires human intervention for its continued survival. Zoos now attempt to mimic the natural settings of the animals they keep (Hediger 1969; Hutchins, Hancocks, and Crockett 1984; Polakowski 1987), and wildlife in reserves must be managed attentively to ensure their continued survival. However, these are considerations of husbandry and management, and political factors are often more compelling determinants of institutional character. Ultimately, the survival of wildlife depends on the ability of responsible institutions to remain relevant to society and endure in a rapidly changing world.

The conservation or survival center is only one of many types of institutions that preserve wildlife. In the following paragraphs we (1) compare conservation centers and game ranches; (2) discuss some of the immediate challenges of managing wildlife in conservation centers; and (3) discuss the broader role of conservation centers in the context of mammal conservation.

THE SCOPE OF CONSERVATION CENTERS AND GAME RANCHES

Interest in wildlife management and conservation has brought about a range of methods and institutions for preserving wild animal populations. Because conservation centers and game ranches are superficially similar, it is particularly worthwhile to examine the characteristics and objectives of these institutions, and enumerate their similarities and differences.

Conservation or Survival Centers

The invention of the conservation or survival center (we use the terms interchangeably) took place in the early 1970s. These centers differ from traditional zoos in that their primary function is the breeding of rare and endangered wildlife as opposed to public exhibition and education. Consequently, their animal collections normally encompass larger populations of a smaller selection of species than those in traditional zoos. Table 30.1 summarizes pertinent information on conservation centers. Some centers specialize; examples are the Institute for Herpetological Research in Stanford, California, the Duke University Primate Center in Durham, North Carolina, and the Duiker Research and Breeding Center in Chipangali, Zimbabwe (Pinchin 1993). Breeding programs at conservation centers emphasize the preservation of genetic variability and adaptations to the natural conditions in which species evolved. These programs typically incorporate specific genetic, demographic, and behavioral management protocols in order to minimize artificial selection and progressive domestication (Foose and Ballou 1988; Frankham et al. 1986). Such programmatic objectives differ from those of most private and commercial breeders of wildlife, whose institutions might be more appropriately called game ranches or breeding farms. Conservation centers can bridge the gap between the historically artificial environment of the urban zoo and that of the national park. Often, they are closed to the public, and research and training are normally fundamental components of their programs.

Animals in conservation centers may be jointly owned by several zoos, with the ownership of offspring determined by legal documents known as breeding loan agreements (see Block and Perkins, appendix 5, this volume). In other instances, ownership may reside solely with the single institution responsible for the species' recovery and reestablishment in the wild. All black-footed ferrets, *Mustela nigripes*, for example, are owned by the state of Wyoming.

Game Ranches

In many parts of the world, native or exotic wildlife is maintained on private lands for commercial exploitation. Following Geist (1988), we use the term "game ranch" to denote those commercial enterprises that gain supplemental income through the sale of breeding stock, meat and byproducts, and/or the sale of viewing or hunting privileges and associated accommodations. As currently practiced in North America, New Zealand, and southern Africa, game ranching encompasses a wide spectrum of enterprises, ranging from simple culling operations involving the harvesting of wild animals (Geist 1985) to extremely large-scale operations involving intensive husbandry and domestication (Haigh and Hudson 1993). The rapid expansion of game ranching in the past several decades is traceable to both aesthetic and financial considerations. In North America, small zoos, private breeders, seasonal amusement parks, traveling carnivals, the pet trade, and the public are all significant consumers or paying users of wildlife produced and maintained by game ranches. Private land ownership is the key to this industry, and in countries in which most of the land is privately owned, game ranching can potentially provide economic incentives promoting both species and habitat conservation (Luxmoore 1985). Unfortunately, however, game ranching can also have a number of adverse effects on conservation, such as the elimination of predators and other species, domestication, hybridization, exposure of wildlife to exotic diseases, habitat degradation, development of illegal markets in wildlife products, the social and economic monopolization of wildlife, and the privatization of public lands (Luxmoore 1985; Geist 1985, 1988). Furthermore, because commerce in selected native or exotic species is the primary concern of game ranching, no serious effort is usually made to maintain the composition of the area's original flora and fauna unless the operation secures its principal income from the public viewing of wildlife in natural habitat.

CONSERVATION OR SURVIVAL CENTERS: GOALS AND COMMITMENT

General Goals

Sustained reproduction of wildlife is the primary objective of most conservation centers. Biological research on wildlife species in captivity and in the field is an equally important goal that is also normally pursued. Ideally, a conservation center should support multidimensional programs that promote the conservation of selected species through captive propagation and research. A well-rounded program might include several of the following elements:

1. captive propagation with participation in cooperatively organized programs
2. compilation of a detailed husbandry manual for the species
3. collection of blood or tissue for reproductive and genetic research
4. documentation of life history characteristics through research and/or collaborative compilation of data from multiple institutions
5. investigations of reintroduction methods
6. surveys of species distribution and status in the wild
7. implementation of education and training programs in the native range of the species

Though a conservation center may assume a leading role by initiating several such activities, a successful species-oriented program will kindle the desire of other zoological organizations to participate. Conservation of endangered wildlife is far more likely to succeed when it is conducted as a cooperative scientific program rather than as an independent effort, no matter how well the activity is endowed.

Conservation centers should not focus all of their resources on captive propagation of endangered species. Many taxa will disappear before their biological characteristics are known, and short-term investigations of little-known or rare taxa can make significant contributions to our biological knowledge and understanding, as well as benefiting conservation.

TABLE 30.1. A Listing of Selected Conservation Centers

Institution/ address	Date established	Status and affiliations	Annual budget	No. of employees	Acres	Animal collection	Specialties
Bamberger Ranch 7714 Redbird Valley San Antonio, TX 78229	1969	Privately owned (J. David Bamberger); AAZPA-SSP participant (1 sp.)	$30K	3	640	Mammals: 1 sp. (88)	Propagation of endangered ungulates
Bell Ranch c/o Chicago Zoological Park 3300 Golf Rd. Brookfield, IL 60513	1987	Owned by Lane Industries; associated with Chicago Zoological Park; AAZPA-SSP participant (2 spp.)	$6K	2	1,050	Mammals: 2 spp. (10)	Propagation of large ungulates; field conservation research
St. Catherine's Island Survival Center Rt 1, Box 207-Z Midway, GA 31320	1974	Owned and managed by New York Zoological Society; AAZPA-SSP participant (10 spp.)	$400K	8	200	Mammals: 13 spp. (144) Birds: 19 spp. (154) Reptiles: 2 spp. (64)	Propagation and research on endangered mammals, birds, and reptiles
Cincinnati Zoo Breeding Center c/o Cincinnati Zoo 3400 Vine St. Cincinnati, OH 45220	1989	Owned and managed by the Cincinnati Zoo; AAZPA-SSP participant (5 spp.)	$40K	1	108	Mammals: 3 spp. (31) Birds: 4 spp. (19)	Off-site breeding facility for zoo
Conservation and Research Center National Zoological Park Rt. 522 South Front Royal, VA 22630	1975	Owned and managed by the Smithsonian Institution as a department of the National Zoological Park; AAZPA-SSP participant (12 spp.)	$1.1M	45	3,150	Mammals: 19 spp. (494) Birds: 22 spp. (547)	Captive propagation and research on endangered species; conservation training of developing country nationals
Duke University Primate Center 3705 Erwin Road Durham, NC 27705	1968	Owned and managed by Duke University; AAZPA-SSP participant (2 spp.)	$900K	11	55	Mammals: 24 spp. (604)	Biological studies and captive propagation of prosimian primates
Fossil Rim Wildlife Center Rt. 1, Box 210 Glen Rose, TX 76043	1984	Owned by Jim Jackson and Christine Jurzykowski in cooperation with the Fossil Rim Foundation; AAZPA-SSP participant (8 spp.)	$1.1M	74	3,000	Mammals: 33 spp. (872) Birds: 4 spp. (55)	Captive propagation and research on mammals and birds; conservation education in the developing world
The Wilds 85 E. Gay St., Suite 603 Columbus, OH 43215	1984	Owned by the International Center for the Preservation of Wild Animals, Inc., a nonprofit corporation; AAZPA-SSP participant (2 spp.)	$450K	10	9,154	Mammals: 8 spp. (75)	Captive propagation and research on threatened and endangered species
International Crane Foundation E-11376 Shady Lane Road Baraboo, WI 53913	1973	Owned by the ICF, a nonprofit corporation; AAZPA-SSP participant (5 spp.)	$1.2M	5	160	Birds: 15 spp. (140)	Captive propagation and research on cranes; international training in crane conservation techniques, wetland conservation, education
Institute for Herpetological Research P.O. Box 2227 Stanford, CA 94305	1973	Owned by a nonprofit research organization; AAZPA-SSP participant (1 sp.)	$30K	2	.25	Reptiles: 32 spp. (200)	Captive propagation of reptiles; reptile husbandry and disease research

The Lubee Foundation 18401 NW County Rd. #231 Gainesville, FL 32609	1985	A private nonprofit foundation; AAZPA-SSP participant (5 spp.)	$200K	9	90	Mammals: 32 spp. (315) Birds: 11 spp. (44)	Endangered species propagation and research (mammals and birds)
Patuxent Wildlife Research Center Laurel, MD 20708	1936	Owned and managed by the U.S. Fish and Wildlife Service; not an AAZPA-SSP participant	$2M	172	600	Birds: 13 spp. (2,188)	Captive propagation and research on selected North American mammals and birds
Point Defiance Zoo Red Wolf Facility c/o Point Defiance Zoo 5400 North Pearl St. Tacoma, WA 98407	1975	Owned and managed by the Point Defiance Zoo in cooperation with the U.S. Fish and Wildlife Service; AAZPA-SSP participant (1 sp.)	$175K	2	5	Mammals: 1 spp. (60)	Captive propagation and research on red wolves
San Diego Wild Animal Park[a] 15500 San Pasqual Valley Rd. Escondido, CA 92027	1972	Owned by city and managed by Zoological Society of San Diego; AAZPA-SSP participant (24 spp.)	$21.8M	415	1,840	Mammals: 127 spp. (1,644) Birds: 293 spp. (1,528) Reptiles: 3 spp. (3)	Captive propagation of birds and ungulates
Sedgwick County Zoo off-site breeding facility c/o Sedgwick County Zoo 5555 Zoo Blvd. Wichita, KS 67212	1976	Owned and managed by the Sedgwick County Zoological Society; AAZPA-SSP participant (1 sp.)	$70K	2	40	Mammals: 8 spp. (46) Birds: 10 spp. (40)	Off-site breeding facility for zoo
Sybille Wildlife Research Center c/o Wyoming Dept. of Fish & Game Box 3312 University Station Laramie, WY 82071	1952	Owned and managed by the Wyoming Dept. of Fish and Game; AAZPA-SSP participant (1 sp.)	$100K	8	15	Mammals: 11 spp. (314) Amphibs: 1 sp. (16)	Research on diseases of North American ungulates; captive propagation of black-footed ferrets
Topeka Zoo off-site breeding facility c/o Topeka Zoological Park 635 S.W. Gage Blvd. Topeka, KS 66606-2066	1987	Owned and managed by the Topeka Zoological Park; AAZPA-SSP participant (1 sp.)	$1.3M[b]	1	160	Mammals: 1 sp. (9)	Captive propagation of the Asian wild horse
Vogelpark Walsrode off-site breeding facility Mallorca	1985	Owned and managed by the Vogelpark Walsrode; AAZPA-SSP participant (4 spp.)	$560K	12	50	Birds: 350 spp. (2,000)	Holding and breeding facility for the bird park at Walsrode
Vogelpark Walsrode off-site facility Dominican Republic	1981	Owned and managed by the Vogelpark Walsrode; AAZPA-SSP participant (7 spp.)	$31K	3	12	Birds: 10 spp. (60)	Breeding facility for endangered South American and Caribbean parrots
White Oak Plantation 726 Owens Road Yulee, FL 32097	1975	Owned by the Gilman Paper Company; AAZPA-SSP participant (15 spp.)	$850K	16	400	Mammals: 25 spp. (350) Birds: 32 spp. (220) Reptiles: 1 sp. (8)	Research and propagation of selected endangered species
Wild Animal Habitat[a] 6300 Kings Island Drive Kings Island, OH 45034	1972	Owned by American Financial Corporation; AAZPA-SSP participant (9 spp.)	$900K	12	125	Mammals: 26 spp. (313) Birds: 8 spp. (47)	Captive propagation/reproductive research. Educational tours, Wildlife Discovery Days

[a]Facility open to the public.
[b]Not separate from zoo budget.

R·nge of Conservation Activities

·ecies Selection. The selection of species at any single ·ervation center is guided by several criteria, but the degree of *endangerment* is normally a primary consideration. William Conway (1974) has cogently addressed this factor: "Only one systematic method of selecting species . . . has received general attention. It is called "triage," a strategy adopted by World War I French surgeons for dealing with more casualties than they could handle. Doctors divided wounded soldiers into three groups: those who could probably recover without immediate attention, those who would probably die even with attention, and those where surgical treatment seemed likely to make the difference between life and death." Ideally, conservation centers should focus their resources primarily on species that require captive breeding. Because species conservation is best served through methods associated with habitat, community, and ecosystem preservation, the highest priority should always be given to breeding programs that are closely integrated with in situ management and recovery efforts.

The potential for cooperation with other institutions is also a critical consideration in species selection. Formally coordinated propagation programs involving several institutions have the advantage of reducing risks of loss from epidemics and accidents and of maximizing available facilities and involved personnel (Neesham 1990).

The opportunity for research is also an important factor in species selection. In some instances, nonendangered spe·s can be used as surrogates in investigations of pertinent ·ects of behavior or biology that can be directly applied ·closely related endangered species. For example, at the Conservation and Research Center, the Siberian polecat, *Mustela eversmannii*, was used as a surrogate to investigate methods of maximizing the survival of captive-bred black-footed ferrets, *M. nigripes*, reintroduced into the wild (Miller et al. 1990a, 1990b).

Finally, the availability of adequate support facilities for and expertise with specific taxa is also an important selection criterion. No animals should be acquired unless proper housing and management can be provided by staff experienced in the handling and care of related taxa.

Captive Propagation. Captive propagation programs, whether in zoos or conservation centers, must include three elements to achieve their conservation objectives. First, the basic reproductive information that results from captive propagation should be maintained in the institution's record system and should also be made available to the zoological community through registration with the International Species Inventory System (ISIS) (Flesness and Mace 1988; Seal 1988; see also Shoemaker and Flesness, appendix 4, this volume). Second, every institution with long-term experience in breeding a species in captivity has an obligation to provide its results to the zoological community through publication in professional journals. Progress cannot be achieved in the absence of communication, and the preferred medium for conveying new findings on husbandry, reproductive biology, and behavior is publication in ref·reed journals. Third, few propagation centers have the ·sources to single-handedly address the genetic and de·ographic requirements of captive populations; significant progress in breeding endangered species can be achieved only through active cooperation and collaboration with other zoological institutions.

While the breeding of exotic wildlife in captivity in itself is often mistakenly equated with conservation, efforts to breed wildlife independently of established cooperative programs do not usually contribute to the growing body of knowledge on which conservation practice is based. Today, successful captive propagation means gene pool preservation, which requires a combination of behavioral, genetic, and demographic management techniques (Conway 1980; Foose 1987; Kleiman 1980). Participation in cooperative programs should include membership in regional and national zoo associations and participation in their cooperative breeding programs. The Species Survival Plan (SSP) in North America and the Europäisches Erhaltungszucht Programm (EEP) in Europe are examples of such programs. Several important publications have set forth the principles and assumptions guiding these national and international efforts (Baker and George 1988; Bennett 1990; Foose 1989; Foose and Ballou 1988; IUCN 1987; Nogge 1989).

Research and Training. Conservation centers often have the potential to contribute to conservation in ways other than captive propagation. In many cases, their location and size and the absence of large-scale public visitation release them from the programmatic constraints of urban zoos. Conservation centers situated in rural settings can also devote some of their resources to research investigations both in the captive setting and in the field. Facilities that divide their resources among scientific research on the biology of endangered species, reintroductions, and training are perhaps most justified in being called "conservation or survival centers." All of these activities are vital to the accumulation and dissemination of the knowledge necessary for the long-term conservation and management of endangered species.

Many aspects of life history can be learned more quickly and economically in the captive setting than in the wild. Reproductive characteristics such as age of sexual maturity, reproductive life span, litter size, gestation period, and weaning age are easily acquired from breeding populations in captivity. Knowledge of these variables is still lacking or incomplete for many mammals. Aside from its inherent scientific value, such information remains essential for understanding population dynamics and ecology in the wild as well as for long-term management in captivity. Through routine record keeping, such information accumulates over time for any species bred in captivity. However, painstaking verification is required to ascertain the influence of captive management regimes on the resulting values. The existence of postpartum estrus, for example, will not be detected if males are separated from parturient females until weaning. Likewise, interbirth interval in captivity cannot be accurately determined unless it is known that males were available to females at all times during their periods of reproductive cycling. In the conservation center, or the rare large zoo capable of housing a number of breeding groups, data on life history parameters can be accumulated over a relatively short time, and under controlled conditions.

Many kinds of research cannot be easily conducted in a traditional zoo due to constraints imposed by sample size, facility requirements, and public access. Virtually all experimental studies demand isolation from the normal disturbances of public institutions. Behavioral, physiological, and nutritional research generally requires large sample sizes and standardized conditions and is best conducted where the influence of extraneous factors can be minimized or selectively controlled. Investigations of mammalian lactation, for example, which require weekly milk collections, demand nonstressful conditions for the maintenance of the mother-offspring relationship, and weekly handling of the animals must be carried out under predictable circumstances with minimal disturbance (Sadleir 1980). Noninvasive urinary and fecal sampling techniques for monitoring reproductive hormones are an alternative to traditional biomedical methods, which require physical or chemical restraint for blood sampling (Monfort et al. 1990; Monfort, Schwartz, and Wasser 1993; Wasser, Risler, and Steiner 1988). Long-term endocrine monitoring can now be carried out without animal handling. As previously mentioned, nonendangered surrogate species can often play an important role in comparative studies and technique development. The surrogate studies by Miller et al. (1990a, 1990b) on Siberian polecats clearly demonstrate how conservation centers can afford facilities and space for experimental work that most zoos cannot.

Large animal collections and a core research staff are invaluable resources for research and training, and conservation centers should encourage utilization of these resources by establishing close collaborative relationships with researchers and with educational and zoological institutions. At the Conservation and Research Center, mammal keepers from other zoos and a host of students and professionals from zoos and universities have used the collection for collaborative training, education, and/or research purposes. Additionally, the Center's staff has developed training courses in zoo biology/captive management and in wildlife conservation/applied ecology. These courses are aimed at students and professionals from developing nations, are conducted abroad as well as at the Center, and incorporate professionals from other zoos, museums, and universities as instructors (Rudran, Wemmer, and Singh 1990; Wemmer, Pickett, and Teare 1990; Wemmer et al. 1993).

DEALING WITH INTERACTIONS BETWEEN NATIVE WILDLIFE AND EXOTICS

Interactions between indigenous and exotic species at rural breeding centers present two potential problems: (1) the direct predation on or harassment of exotic animals by native wildlife or domestic species, and (2) the transmittal of parasites or disease organisms from indigenous to exotic species. These are also problems in the urban zoo, but the magnitude of the problem is often greater in a rural setting where animals are maintained under more natural, free-ranging conditions.

Predator Problems

Large mammalian predators, such as bobcats, *Lynx rufus*, coyotes, *Canis latrans*, and dogs, *C. familiaris*, can be excluded from pastures and other enclosures by utilizing a combination of fencing, overhangs, and "hot wires" or electric fencing (see Collins 1982, 155). One of the worst predation threats faced by rural breeding centers is that posed by dogs. Both domestic and feral dogs will form packs that can become deadly and efficient killing machines. Ungulate pastures and barns, as well as primate, carnivore, and small mammal facilities, must be rendered dog-proof. The elimination of resident dog packs should be accomplished with the cooperation and assistance of the local animal control warden.

Smaller mammalian predators such as foxes, *Vulpes* spp., raccoons, *Procyon lotor*, mink, *Mustela vison*, and cats, *Felis catus*, can be controlled using the devices mentioned above, but it may become necessary to protect small species from climbing predators by covering the tops of their enclosures with wire mesh. The same may hold true for protecting small mammals and the offspring of ungulates from avian predators. The possibility also exists of losing small mammals to snakes such as the black rat snake, *Elaphe obsoleta*. Predation by pythons (Pythoninae) and boa constrictors (Boinae) is not an uncommon problem for zoos in the Old and New World Tropics. This potential problem should be considered when selecting mesh size for outdoor enclosures of vulnerable species.

Diseases and Parasites

The direct or indirect transmission of diseases and parasites from indigenous or domestic species to exotics (and vice versa) can be a very serious problem. Rabies, tuberculosis, distemper, and a host of other diseases and parasites vectored by both wild and domestic species are a constant threat to exotic species.

A variety of lethal internal and external parasites can be transmitted to exotics from indigenous or domestic species. The meningeal worm, *Parelaphostrongylus tenuis* (Nematoda: Metastrongylidae), is a widespread parasite of white-tailed deer, *Odocoileus virginianus*, and other cervids in North America (Anderson 1963). The adult nematodes inhabit the central nervous systems of deer. Larvae are passed in deer feces and subsequently infect certain species of terrestrial slugs and snails, undergoing obligatory developmental stages within these molluscan secondary hosts (Lankester and Anderson 1968). Deer become infected by accidentally ingesting infected mollusks as they graze (Platt 1978). While this parasite causes little overt damage to white-tailed deer, many other native and exotic ungulates have been lost to meningeal worm infections, including moose, *Alces alces*, elk, *Cervus elaphus*, and caribou, *Rangifer tarandus* (Griffiths 1978), and sable antelope, *Hippotragus niger*, scimitar-horned oryx, *Oryx dammah*, and bongos, *Tragelaphus euryceros*. The proximity of free-ranging, infected white-tailed deer to exotic ungulate pastures appears to be a major factor in the transmission of *P. tenuis*. Mollusks that become infected in areas adjacent to fenced pastures can migrate into exotic hoofstock enclosures and be ingested inadvertently (Rowley et al. 1986). Where possible, perimeter fencing and other means of control should be used to maintain as great a distance as is feasible between exotic species and native wildlife or domestic animals, since it is often more practical to control the primary host via fencing and other means than to try to control the secondary host or disease vector.

All animals should undergo a strict quarantine period, hich should include a complete health examination and treatment if needed, before entering the collection. Subsequent management practices for controlling parasites and diseases should include a thorough prevention program that integrates periodic physical and fecal examinations, diagnostic testing, prophylactic administration of parasiticides (Isaza, Courtney, and Kollias 1990), and vaccination (where possible). All mortalities should be carefully documented, and necropsy results should be reviewed on a regular basis by the curators, veterinarians, and pathologists. The long-term preservation of tissue samples should be employed as an integral part of the overall animal management program, as retrospective analyses could be important in detecting and analyzing causes of mortality.

Husbandry practices naturally affect the ease of controlling parasites. Ungulates that range in large enclosures under seminatural conditions present special difficulties in assessing parasitic infection because collecting fecal samples from known animals is time-consuming and individual dosages of vermicide are difficult to administer. "Barn-training" of ungulates entails considerable effort, especially in large enclosures, but its advantages often make it worth the effort. If animals are trained to feed in individual stalls, fecal collection, administration of medicines, close-hand examination, and capture for treatment or observation can be easily managed.

MAJOR CHALLENGES TO CONSERVATION CENTERS

Conservation centers have arisen to augment captive breeding of endangered species on the scale practiced by traditional zoos. The initial motivation for establishing conservation centers was to escape the typical collection limitation of maintaining only a few individuals of each species. In the following section we examine some of the factors that limit propagation programs.

Institutional Coordination

Even large survival centers can do little to preserve species by themselves because of size and economic limitations. Of course, there have been notable exceptions. The Duke of Bedford is the best-known example of an individual whose institution single-handedly saved a species—the Père David's deer, *Elaphurus davidianus*—from the brink of extinction. But most institutions lack the means for such institutional heroism, and it was this realization that led to efforts by zoos to coordinate their individual propagation programs for particular species.

Cooperation and scientific management of endangered species of mammals did not progress significantly until the beginning of the 1980s, when cooperative breeding programs, such as the North American SSP and European EEP programs, were formalized. These programs aspire to manage captive populations scientifically so as to minimize loss of genetic variability (see Ryder and Fleischer, chap. 25, and Ballou and Foose, chap. 26, this volume). Participating zoos are expected to abide by the recommendations of the species coordinator and the management group, and thus the organizational objectives of the program are expected to supersede the individual motives of member institutions. This coordination is perhaps the greatest challenge to the long-term success of any cooperative program.

In view of this, what role can propagation facilities play to enhance the survival of endangered species? In fact, conservation centers have little to offer by themselves. William Conway (1986) has remarked that all the world's zoos can deal with but a fraction of the diversity of threatened wildlife. The existence of more survival centers will not improve the odds greatly. The minimum viable size of the captive population required to maintain any single species is large, and is beyond the capacity of any single center. Like any other zoo, survival centers must participate in collaborative long-range programs.

Economic Challenges

Survival centers that exclude the public do not generate gate fees, and miss a significant source of income. Those that cater to public viewing require much larger budgets to accommodate the many requirements of visitors. At this time, it is fair to say that survival centers will almost always have to depend upon large zoos for their support, or finance their operations through gate fees and recreational services. The pure survival center generally is not a particularly satisfying experience for the family seeking an entertaining weekend at the zoo. Despite the ability of a few large zoos to support survival centers, species survival plans often require funds far in excess of a zoo's normal operating budget. Unfortunately, donor contributions to captive breeding programs are relatively uncommon, and recent changes in American tax laws make philanthropy an even less likely source of supplemental financial support in the future.

ZOOS AND SURVIVAL CENTERS: DIFFERENT INSTITUTIONS, DIFFERENT PROBLEMS

The nature of an institution determines the nature of its problems and challenges. Visitation by the public, animal management, and research are three interacting factors that differ between zoos and propagation centers.

Visitors

In traditional zoos, the visitor is a powerful determinant of priorities and economics, as the human needs associated with the educational and recreational experience must be catered to at all times (Hediger 1969). Food, toilets, human conveyance, resting stations, first aid, police, and information signage are all important concerns in a zoo that ministers to the urban population. These services are estimated to consume approximately 70% of the typical zoo's budget. In a conservation center in a rural setting the exclusion of visitors can greatly diminish costs. This is usually not an option, however, because when the paying public is excluded, the income of the conservation center is usually not sufficient to pay land taxes, salaries, and the costs of maintaining facilities and animals. This fact explains why the largest number of institutions in the United States holding exotic animals are privately owned; the exotics are, in a sense, gratuitous boarders. In Texas alone, numerous game ranches support viable breeding populations of approximately a dozen species, but the exotics produce supplemental income.

The public that visits the traditional zoo also affects its policy and practices. An animal that becomes a celebrity as a result of successful media coverage can also evoke a public hue and cry contrary to the best interests of a nationally managed breeding program. Management decisions may be viewed either as unjustified and insensitive to the animal's needs by an uninformed zoo public, or as a violation of the animal's "rights" by a minority of well-intentioned citizens. While some public reactions to zoo policy can be avoided by thoughtful publicity and planning, it is not possible to avoid crises completely. Managing well-intentioned but misguided public reaction occupies a definite but unmeasurable percentage of zoo managers' time. Such concerns are unlikely to develop to the same extent at a facility closed to the public.

Animal Management

A second set of biological problems is a consequence of the difference in the sizes of breeding groups maintained in traditional zoos and in conservation centers. It is generally easier to manage, monitor reproduction and health in, and treat problems in small groups of animals. In survival centers polygynous mammals are often managed in large mixed-sex herds for convenience and economy. Rarely is it possible, though, to monitor male parentage in large multimale breeding herds, and this problem greatly limits the value of the offspring in a propagation program managed under genetic and demographic guidelines. The preferred, but more costly and time-consuming, alternative is to maintain single males with small groups of females, which assures the identity of the sire and maintains higher levels of genetic mixing. With this method a large, productive population in a conservation center can have a far greater effect on the age and genetic composition of the cooperatively managed population as a whole. By virtue of the larger number of animals and the chance of larger "errors," conservation centers require more intensive population management than urban zoos.

Research

Biological investigation has become an important function of the modern zoo, but few zoos can afford to reserve special collections of exotic animals exclusively for research. In the traditional zoo, liberties cannot be taken with exhibit design purely for the sake of scientific research, unless the benefits to the animals and the public are appreciable. Absence of visitors and large numbers of animals are two important advantages that propagation centers offer to research. Research is increasingly becoming an important tool for improving the health, management, and productivity of wild animals in captivity. Zoos can no longer afford to neglect the scientific and conservation value of their collections.

LESSONS FROM ZOODOM

Zoos are commonly regarded as unique institutions having little in common with national parks and other natural areas. The settings and philosophies are different, but the needs for genetic and demographic management in natural areas are often not that different from the requirements in zoos (Neesham 1990). We have made the case elsewhere that small populations of vertebrates in isolated reserves share a number of management problems with populations in zoos (Wemmer, Smith, and Mishra 1987). In either setting, small wild populations are subject to founder effects, genetic drift, and inbreeding, and manipulating wild animals to counteract these effects is usually much more difficult than in the zoo. Imagine the skills and logistics necessary to capture a prime breeding-age male tiger and transport it from one reserve to another. We now know that most tigers born into Nepal's Chitwan tiger, *Panthera tigris*, population perish before maturity, and that genetic interchange between populations is practically impossible. Tigers coming of dispersal age (18–24 months) usually die when they move into cultivated land and kill livestock or people (Smith 1984). In captive tiger populations, demography and gene flow are more easily managed.

It is fair to say that political factors can be greater obstacles in zoos and reserves than the technical challenges of manipulating individuals within a population. Given the magnitude of the global crisis in biodiversity, however, our conservation efforts must promote cooperation and incorporate a diverse spectrum of activities, institutions, and constituencies.

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WILD MAMMALS IN CAPTIVITY

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