

Role of reproductive technologies and genetic resource banks in animal conservation

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In combination with modern reproductive technologies, there is potential to use frozen and stored germplasm (genetic resource banks) to support conservation measures for the maintenance of genetic diversity in threatened species. However, turning this idea into reality is a complex process, requiring interdisciplinary collaboration and clearly defined goals. As the number of species deserving the attention of conservation scientists is overwhelmingly large, yet detailed knowledge of reproductive physiology is restricted to relatively few of them, choosing which species to conserve is one of the most difficult issues to be tackled. Besides the direct application of technologically advanced reproductive procedures, modern approaches to non-invasive endocrine monitoring play an important role in optimizing the success of natural breeding programmes. Through the analysis of urine and faecal samples, this type of technology provides invaluable management information about the reproductive status of diverse species. For example, it is possible to diagnose pregnancy and monitor oestrous cycles in elephants and rhinos without causing stress through restraint for sample collection. In this review, we identify the potential contribution of reproductive biology and genetic resource banks to animal conservation, but also highlight the complexity of issues determining the extent to which this potential can be achieved.

In recent years, concern for the future well-being of the global environment has grown to an unprecedented level. Among the major worries is the possibility that many species will be forced into extinction by unnatural causes, rather than through the slower evolutionary processes. Factors that contribute to artificially accelerated population decreases include large-scale farming, over-fishing, mining, forestry, schemes for the extraction, diversion and storage of water, industrialization, road building and urbanization. The deleterious consequences of these activities may be leading to major climatic changes through the increased emission of greenhouse gases, and are difficult to reverse.

On a more local scale, these processes also cause problems such as the fragmentation of habitats and environmental pollution, which impinge more directly on the survival of species by interfering with their ability to reproduce successfully. Habitat fragmentation, perhaps caused by the construction of roads and other barriers or the development of agricultural initiatives, restricts the natural ranges of animal species, thereby limiting their ability to find mates. As a consequence, inbreeding may become more common and, for some species at least, this is likely to cause a loss of genetic diversity within the population. Inbreeding increases the risk of genetically inherited diseases, congenital defects, susceptibility to infections and, hence, reduces the ability of individuals to survive. While some consequences of inbreeding are not sufficiently life-threatening to be regarded as diseases, they still result in the impairment of physiological functions, such as the production of fertile spermatozoa and the ability to sustain normal pregnancies. Clearly these effects can severely compromise the fitness and survival

of whole animal populations, the classic example being the Florida Panther (*Felis concolor coryi*), which has shown evidence of inbreeding-related defects of testis development and descent, with consequent infertility (Barone *et al.*, 1994; Fig. 1). While examples of this severity may remain relatively rare in nature, the data from which we draw these conclusions are difficult to obtain and the problem may be more widespread than is currently appreciated.

The presence of environmental contaminants and by-products of modern manufacturing processes can also affect reproduction adversely. Many man-made chemicals in the environment have weak oestrogenic or anti-androgenic activity, and may exert subtle deleterious effects on endocrine functions in many animal species. Most current attention in this respect is focused upon the possibility that these chemicals affect human spermatogenesis adversely. A number of clinical studies have reported that sperm production is becoming less efficient, with lowered sperm concentrations in semen. Although still contentious, there seems no reason to suppose that other species would be able to avoid these effects, which may then act synergistically with inbreeding to reduce animal fertility to below sustainability. Increasing numbers of studies are reporting adverse effects of environmental contamination by, for example, heavy metals on wildlife. To date, these have tended to concentrate on aquatic organisms, ranging from crustacea to fish, waterfowl and marine mammals; the possibility that similar problems are being experienced by terrestrial and air-borne organisms has yet to be confirmed. Those wild animals that are struggling to survive this harsh situation represent at least part of the variety of species on earth encompassed by the term 'biodiversity'.

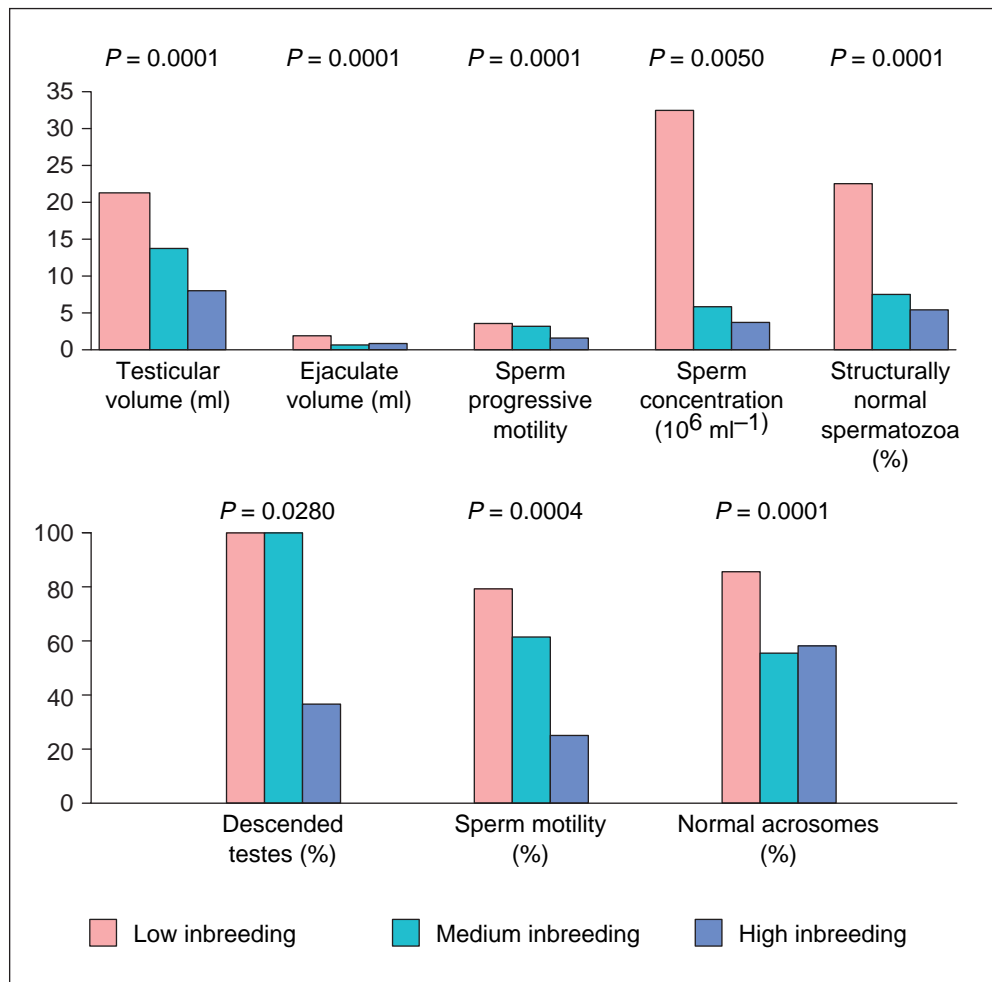


Fig. 1. Effects of inbreeding on the testicular and semen characteristics of animals with Florida panther (*Felis concolor coryi*) ancestry. Individuals from three different sub-populations (wild-caught and captive) known to exhibit different degrees of inbreeding were compared during a 12 year investigation. Probability values show overall differences among groups. (Data from Barone *et al.*, 1994).

Reproductive technology can have only a very limited role in the conservation of biodiversity if the primary aim is simply to preserve species. Estimates of the number of species currently in existence vary between 10 million and 100 million and, if it can be argued that the 15 000–30 000 extinctions estimated to occur annually are, in fact, insignificant (Kellert, 1996), then conserving a single species by any method cannot be worthy of consideration. Most of these disappearing species are obscure and unknown invertebrates, the existence of which is somehow credited with much less value than that of their larger vertebrate counterparts. An argument such as this not only casts doubt on the value of reproductive technology as a conservation tool, but also impugns the value of conservation itself.

However, supporters of conservation argue that functional ecosystems, which depend on biodiversity, are important for providing a number of environmental services for the good of the planet (Wildt, 1997). Considered in this way, the aims of conservation can be understood in terms of ensuring the

survival and evolutionary development of species and populations of animals, plants and micro-organisms in their native habitats. Therefore, reproductive biology as a discipline has valuable contributions to make towards the broad aims of conservation when so defined. It provides insight into the many reproductive specialities and adaptations of different species, and is crucial for understanding the novel factors that deleteriously affect the survival of populations. In so doing, it also provides information for making strategic management decisions aimed at alleviating these threats to survival. However, as Wildt *et al.* (1995) have pointed out, there is still a paucity of information about the reproductive biology of most animal species, and the realization that this is true of a particular species of interest often comes when the population is in decline and difficult to study. Hence, there is a strong case for gathering basic information about any species, whether threatened or not, as the opportunities arise.

Such arguments imply that reproductive biologists can only fulfil a passive role in conservation, rather like bystanders

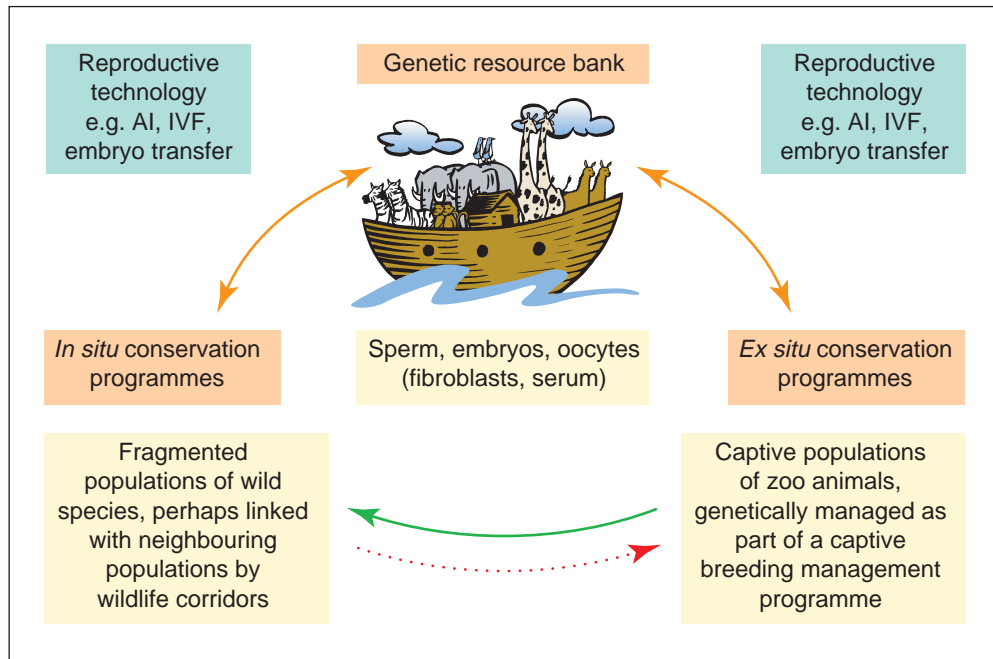


Fig. 2. Schematic illustrating the potential for a genetic resource bank to act as an interface between captive breeding programmes (*ex situ* conservation) and field-based conservation programmes (*in situ* conservation). Transfer of the genetic material from the resource bank to either the wild or captive live population requires a basic understanding of the physiology of the species in question for the application of reproductive technologies. Nevertheless, concurrent storage of related tissues and sera can also contribute significantly to practical conservation efforts by allowing genotyping or epidemiological studies of the stored material at a future date, should the need arise.

at the scene of an accident who forget to treat the injured or call an ambulance. Even cursory examination of the literature reveals that this is not a view held by reproductive biologists with interests in conservation. While recognizing the force of the argument that protecting individual species may strictly be of limited global value, nevertheless there is a moral imperative to help prevent the decline of vulnerable species towards extinction. One way of doing this is by helping to ensure that inappropriate inbreeding depression in small and fragmented populations is avoided if possible. If the small populations in question are no longer represented in their natural habitats, there may be long-term plans for their reintroduction. Ideally, the future of the reintroduced animals should not be jeopardized through inbreeding if this can be avoided.

The genetic resource bank concept

A number of approaches to attempt to slow and halt the rate of species decline have been mooted. One suggestion is to undertake a programme aimed at preserving genetic material, specifically spermatozoa, oocytes and embryos, from endangered and threatened species. Often termed a 'genetic resource bank' (GRB) or 'genome bank', in this context GRBs are intended for use as repositories of germplasm, which is available for use in procedures such as artificial insemination or embryo transfer when required, and as an interface between *ex situ* and *in situ* conservation programmes. Genetic resource

banks differ fundamentally from a bank of stored cells and tissues available only as a resource for genetic research. At face value, the goal of GRB programmes is simple and directly useful (Fig. 2); it effectively lengthens the 'genetic lifespan' of valuable individuals, who can continue being part of managed breeding programmes even after their death. As the aim of managed breeding programmes for endangered species is the maintenance of the maximum genetic diversity, it is clear that GRBs contribute directly to the broad objectives of conservation. The importance of the GRB concept has been recognized by organizations such as the Conservation Breeding Specialist Group (CBSG), who have recently commenced a GRB programme for the Amur or Siberian tiger (*Panthera tigris altaica*).

Although the GRB concept is simple to understand and, in principle, should be easy to implement, many technical and logistical factors need to be considered to avoid the risk of establishing a 'cemetery' of frozen cells. These factors have been reviewed in detail by Holt *et al.* (1996a), but it is worth emphasizing that there is a considerable difference between the planned collection of samples for a GRB and their casual accumulation by chance over a prolonged period. Planned collections need to take account of the genetic and disease status of individual sample donors; these factors are important, but can easily be overlooked. Extreme cases, in which species identification is a problem, could be resolved in future, provided adequate background information and spare samples are available. For example, cases of cryptic speciation are now being

identified, in which morphologically similar species are shown subsequently by DNA analysis to be substantially different (for example, Pipistrelle bats (*Pipistrellus pipistrellus*); Barratt *et al.*, 1997). Similarly, the risks of disease transmission from samples to animals must be open to assessment, which requires that serum be available for future serotyping or virus detection, should the need arise. In parallel with a germplasm bank, a collection of associated cells and sera would provide helpful, even essential, backup. Indeed, any conservation programme would benefit from such a collection. Cells such as fibroblasts, which are easily obtained from small skin or muscle samples, would be available for DNA and protein analysis when needed. Since fibroblasts can be cultured from a small number of cells, and the cultures themselves cryopreserved and multiplied, any future DNA analysis would not involve destruction of the germplasm stocks.

Genetic resource banking in practice

At present, procedures for the use of cryopreserved germplasm are not well developed for wild species. This situation is, in part, a reflection of the variety of reproductive characteristics of diverse species, in which, for example, differences in female anatomy and physiology affect the timing of ovulation, the site of insemination or the number of spermatozoa required for conception. As sperm function and survival is affected deleteriously by cryopreservation, these factors affect the success of artificial insemination procedures. A properly organized GRB programme can only function when basic knowledge of the reproductive biology of the species in question is available, once again distinguishing the planned programme from the *ad hoc* collection of sperm, eggs and embryos. In turn, the need for basic information introduces the concepts of selectivity and targeting the programmes at species of particular interest, in which the investment needed to gain the requisite background knowledge is considered justified.

This necessary amount of scientific and financial commitment means that no individual researcher, or even research group, has the resources to support GRB programmes in more than a limited number of species. Collaboration and skill sharing among groups are helpful, but the popularly held belief that any single centre could maintain a huge stock of frozen germplasm from multiple species, 'the frozen zoo', is almost certainly unrealistic. It is more reasonable to expect that GRB programmes in different countries will focus upon species of special, or local interest. Marsupial conservation in Australia provides a clear example of such focused efforts; the Australian scientific community has recently formed a consortium of research groups with an interest in reproductive technologies, The Animal Gene Storage and Resource Centre of Australia, the aim of which is to direct and encourage research into these issues. Other countries or continents can identify their own research priorities. There is a practical as well as an intellectual benefit to sharing research and priorities in this way; if frozen germplasm is stored locally, it may minimize the need for international transport when it is required for use. Use of the material within its natural environment will reduce the risk of transmitting exotic diseases to the recipients.

To date, few GRBs worthy of the name have been initiated for threatened species and, where efforts to implement such

GRBs have been undertaken, they have concentrated on the storage of frozen semen, for example, in bison (*Bison bonasus*) (Sipko *et al.*, 1997), tigers (*Panthera tigris*) (Wildt *et al.*, 1995) and gazelles (*Gazella dama mhorr*) (Holt *et al.*, 1996a). This situation is mainly a reflection of the technical limitations in embryo and oocyte cryopreservation in most species. However, GRB programmes have been developed by various organizations interested in domestic livestock (for example, rare breeds of cattle) or medical research (inbred mouse strains stored in frozen embryo banks and, more recently, sperm banks) and these can provide helpful examples for day to day logistics and organization. A further practical point is that since GRBs require long-term care and financial support, it would be wise, where possible, to place their care and maintenance in the hands of professional organizations, such as the European Centre for Animal Cell Cultures (ECACC) in the UK, the sole purpose of which is the storing of cell lines and tissues for research. There are similar organizations in other countries. Some zoos express reservations over the policy of handing over samples of spermatozoa or embryos to an outside organization, concerned that they will somehow lose control of their material. However, organizations such as ECACC do not assume ownership of the samples, merely custodianship, and these reservations are more than outweighed by the security provided.

Given the limitations outlined above, the most sensible approach to genetic resource banking is to ensure that the goals are well defined before the necessarily long-term business of collecting and storing sperm, eggs and embryos is begun. These goals are best achieved in the context of well-planned captive breeding programmes, in which information about the status of the extant population is available. If suitable germplasm cryopreservation procedures for the species in question have not been perfected, a degree of judgement is required as to whether or not the best action would be to initiate research aimed at technique refinement. The pragmatic decision may be that a GRB programme is not yet realistic.

Current research and the development of genetic resource banks

The principle of using reproductive technologies to assist the conservation of threatened mammalian species is not new, and a number of examples can be cited to illustrate their successful application. These include artificial insemination in blackbuck (*Antelope cervicapra*) (Holt *et al.*, 1988) and Mohor gazelle (Holt *et al.*, 1996b), giant panda (*Ailuropoda melanoleuca*) (Moore *et al.*, 1984), black-footed ferret (*Mustela putrius furo*) (Howard *et al.*, 1991), Siberian tiger (Donoghue *et al.*, 1992), puma (*Felis Puma concolor*) (Moore *et al.*, 1981), scimitar-horned oryx (*Oryx dammah*) (Garland, 1989) and various species of deer (Dott and Utsi, 1973; Haigh *et al.*, 1984; Fennessy *et al.*, 1990; Jabbour *et al.*, 1993); for further information, see reviews by Watson (1990) and Holt (1992). A number of successful embryo transfers have also been reported, sometimes using similar, but different, species as surrogate mothers (for review, see Rott, 1996). Strenuous efforts are being made to develop artificial insemination methodologies for other mammalian species, such as elephants (*Loxodonta africana* and *Elephas maximus*), in which the problems are less with semen freezing (Jones, 1973;

Howard *et al.*, 1986) than with the delivery of semen into the female tract at the appropriate time of the oestrous cycle.

The development of non-invasive endocrine monitoring procedures, by the measurement of steroid hormone metabolite concentrations in excreta, has facilitated increased success in the manipulation of reproduction in exotic species. Characterization of ovarian and testicular function, and the diagnosis of pregnancy or reproductive failure are now possible in circumstances in which frequent blood sampling or long-term behavioural monitoring are impractical or inappropriate. With such information available, other procedures, such as artificial insemination or embryo transfer, can be timed more accurately, and reproduction can be manipulated through the use of exogenous hormones, thus increasing the probability that these techniques will be successful.

Hormones have been measured non-invasively in captive animals using urine (for review, see Heistermann *et al.*, 1995) and saliva (Digiano *et al.*, 1992; Czekala and Callison, 1996; Thorne *et al.*, 1998) but, for practical reasons, the analysis of faecal matter has been most extensively used in recent years. The development of faecal monitoring procedures has extended this technique to monitor free-roaming animals within their natural habitat (Curtis *et al.*, 1999; Garnier *et al.*, 1999) and may, in future, provide valuable insight into differences in fertility or seasonal breeding between populations of wild and captive individuals. Nevertheless, there are inter-specific differences in the profiles of hormone metabolites excreted, even in closely related species, such as the black, white and Asian rhinoceroses (*Diceros bicornis*, *Ceratotherium simum* and *Dicerorhinus sumatrensis*). Thus, chemical or immunological characterization of the hormone metabolites is required before routine procedures can be established for a species not investigated previously. High-throughput, field-orientated technologies for reproductive monitoring have yet to be developed, but these would be a major advantage for the management of endangered species, as current procedures only allow retrospective analysis of the reproductive status of a few individuals.

Most of the successes of reproductive technology that can be cited have been based on the cryopreservation of spermatozoa, which is the most practical means of storing germplasm. However, some major gaps can be identified in the success of semen freezing technologies, caused by lack of success when efforts have been made, but also by the relative infrequency of investigations. Examples here include marsupials as a group, in which research efforts in semen physiology and technology only commenced recently (Rodger, 1990), and rodents, in which semen preservation studies have been almost exclusively directed towards laboratory mice (for example, see Sztejn *et al.*, 1992; Nakagata, 1993). As the poultry industry uses artificial insemination for the commercial breeding of turkeys and chickens, a basis exists for the development of semen freezing technologies for wild and threatened bird species. Non-domesticated avian species that have been bred by artificial insemination include budgerigars (*Melopsittacus undulatus*) (Samour *et al.*, 1988) and Houbara bustards (*Chlamydotis undulata undulata*) (Hartley *et al.*, 1999). Although cryopreservation of fish spermatozoa is well-developed for commercially important species, particularly salmon and trout, very little work has been directed specifically towards the development of techniques that may be useful in fish conservation.

One of the interesting and surprising observations to have emerged from marsupial sperm cryopreservation studies is the high tolerance to glycerol, a cryoprotectant, exhibited by some of these species. Preliminary investigations of koala (*Phascolarctos cinereus*) spermatozoa indicated that they tolerated glycerol concentrations of > 14% (Johnston *et al.*, 1993), and some recent experiments with kangaroo (*Macropus giganteus*) semen indicated that cryopreservation may only succeed if these high concentrations are used (W. V. Holt and L. Penfold, unpublished). As the cellular basis of glycerol tolerance is poorly understood (Hammerstedt *et al.*, 1990), it is not possible to interpret these observations, which contrast markedly with the extremely low glycerol tolerances (< 1.5%) of pig and mouse spermatozoa. It is clear that unifying hypotheses are required so that determinants of sperm cryosurvival can be sought and identified in an effort to guide the development of appropriate cryopreservation methods. For more detailed reviews of cryopreservation methods and principles, see Hammerstedt *et al.* (1990), Holt (1997) and Watson (1995).

Declining trends in human fertility and the possible impacts of global change on reproductive systems and function in a diversity of species (for example, marine molluscs, freshwater fish and reptiles) have prompted investigators to question the extent to which species are under threat from the accumulation of synthetic chemicals in the environment (for review, see Turner and Sharpe, 1997). Efforts to define the true impact of such chemicals upon wild species would be enhanced considerably if banks of stored semen had been established many years ago. Combined with intracytoplasmic sperm injection (ICSI), the genomic integrity of spermatozoa could be investigated at both chromosomal and nucleic acid resolutions. Studies have shown that individual human spermatozoa differ in the extent to which their genomic DNA is damaged as a result of environmental stress, and yet spermatozoa exhibiting a significant degree of DNA fragmentation are still capable of fertilization (Aitken *et al.*, 1998). The scale of this problem, its recent history and its variability among species cannot now be investigated retrospectively; however, the establishment of GRBs would enable such investigations to be performed in future. This argument is an additional, but compelling, reason to regard collections of gametic, haploid genomic materials as a fundamentally different research resource from that provided by the more routine collections of somatic tissues and DNA.

New biotechnologies and genetic resource banks

There have been a number of recent, well-publicized developments in biotechnology that may have direct relevance to genetic resource banking. These include the cloning of mammalian embryos, ICSI and spermatogonial transfer from one species to another.

Embryo cloning in sheep was achieved by a group working at the BBSRC Roslin laboratories (Campbell *et al.*, 1996; Wilmut *et al.*, 1997) in Scotland. The technique involved the initial production of totipotent cell lines that originated from either a single sheep embryo or adult mammary tissue. The embryos were produced from these totipotent cells by removing all chromosomal material from a series of sheep oocytes, then using cell nuclei (that is, material containing chromosomes) from the cell line to replace the extracted oocyte chromosomes.

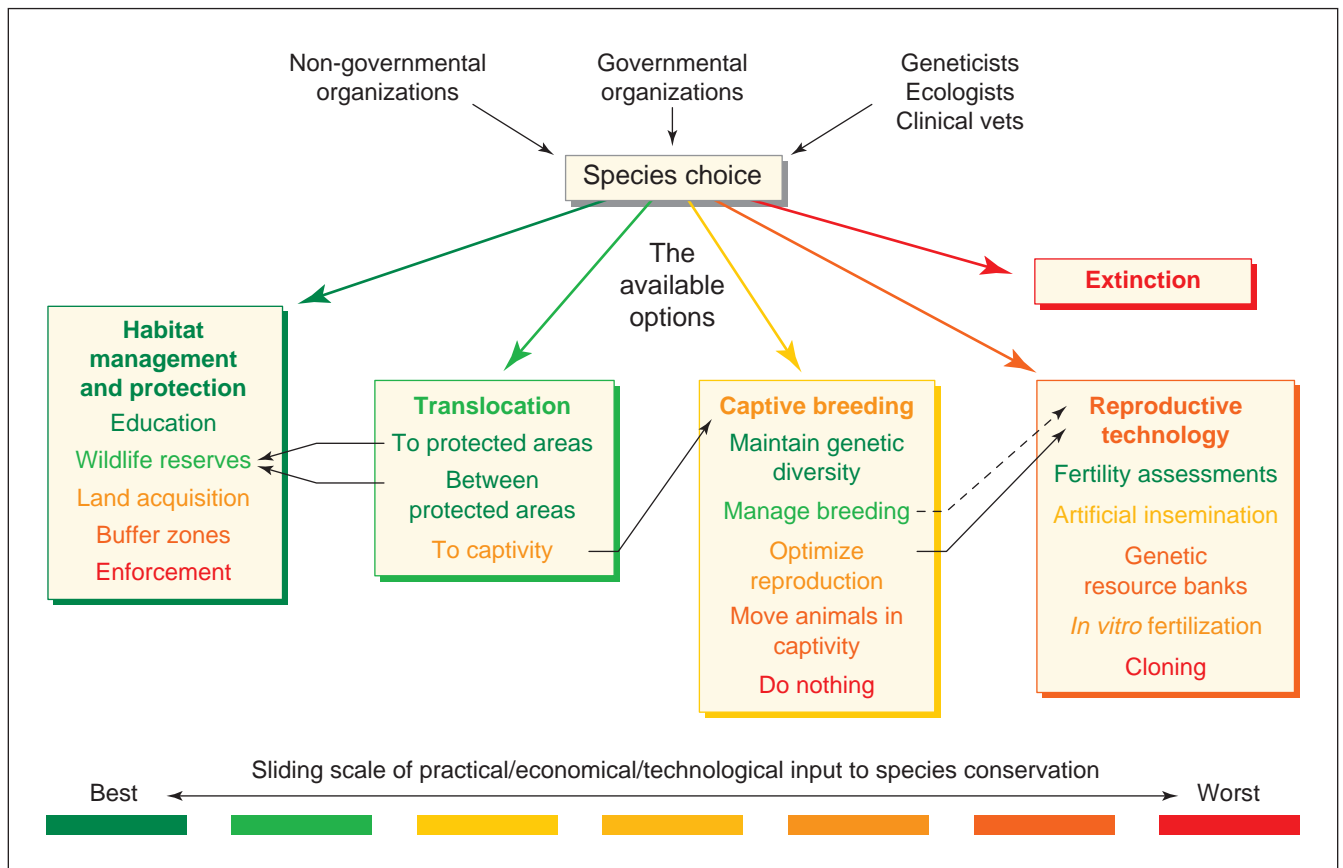


Fig. 3. Overview of potential approaches to species conservation and their economic and technological costs. Species choice is a central issue, influenced by various governmental bodies and other organizations, with widely diverse interests (for example, economics and tourism, scientific value, cultural and emblematic importance). Extinction is an option that may sometimes be inevitable. Final decisions are often outside the control of biologists, but expert opinion on the viability and sustainability of populations requires interdisciplinary scientific input. A range of options for species protection, maintenance and management is open to conservationists; these vary in cost and the degree of intervention required. Reproductive biology can make useful contributions to the support of species viability at several levels, and with various degrees of technical intervention.

Embryos were then cultured *in vitro*, and those that developed to the morula-blastocyst stage (that is, after multiple cell divisions) were transferred to the uteri of ewes. Several lambs were born and have grown and reproduced normally. The extension of this technology to wild animals would be a major undertaking, requiring intensive effort and concentration upon one species, or a least a restricted group of species. At first sight, this technique seems to have little value for conservation, as any offspring would be genetically identical. However, as the technique develops, it may become more realistic to consider the production of offspring from stored tissue samples, such as those that are, at present, stored exclusively for genetic research purposes.

A novel series of experiments has established the possibility of propagating mice testicular cells from one individual in another of either the same or a different species. The experiments involved injecting mixtures of testicular germ cells taken from one individual into the testicular tubules of another individual. Clouthier *et al.* (1996) showed that rat spermatogonia could be transferred to immunodeficient mice, in which

they underwent cell division culminating in the production of rat spermatozoa. When this work was reported, it was claimed that the technique had potential implications for animal conservation. Immunodeficient mice could be used as a sort of propagation system for the production of spermatozoa that could be used for ICSI or IVF. The potential of this approach is unpredictable; current indications are that spermatogonia could be recovered without much difficulty. Spermatogonial cryopreservation is known to be possible, and may actually be easier than sperm cryopreservation, thus allowing the storage of testicular material from a wide range of species in which it is, at present, impossible. The conservation community needs to decide whether to pursue this approach to germplasm cryopreservation, as it offers a novel means of propagating species.

Direct microinjection of spermatozoa into oocytes has become very popular as a way of overcoming human male infertility. Many clinics are now offering ICSI as an alternative to IVF, despite the extra skill resource needed to perform the technique. As fertilization does not occur in the normal way

through the zona pellucida, the spermatozoa do not undergo any selection process whatever. Some practitioners choose the spermatozoa on the basis of 'normal' head shape, but there is no evidence to support the validity of this practice. Others choose the more highly motile spermatozoa and claim that this leads to superior embryo development. ICSI offers some interesting advantages for genetic resource banking because the full fertilization qualities of the spermatozoa are not needed. This means that poorly preserved spermatozoa could still be used. The small number of spermatozoa needed for embryo production also means that sperm cryopreservation could be carried out on a smaller scale, perhaps preserving hundreds, tens or even a single spermatozoon instead of the millions needed at present.

However, these approaches to reproductive technology, albeit 'hi-tech' and glamorous, may be less useful in achieving the goal of providing genetic support for threatened populations than the more mundane techniques. Technical support needs to be easy to perform and routinely successful for it to be of use. This is the position of artificial insemination in the context of the pig and cattle breeding industries, in which reliability is taken for granted and there is no special cause for celebration when a procedure actually works. For the time being, alternatives to techniques such as cloning, which has a success rate of <1% in even highly characterized species such as sheep, should be considered for species conservation wherever possible. In the time taken to develop highly technological procedures for the conservation of a small, endangered wild population, it is likely that the species would have become extinct before the procedure was adequately efficient, and the removal of individuals from that population for research purposes would most likely contribute to that extinction. The financial investment would be better directed at more practical ways of prolonging the survival of the species and to assist its re-establishment.

Conclusions

Much has been published about the principles and practice of genetic resource banks, including some theoretical modelling of the best ways to integrate sample usage with genetic goals (Johnston and Lacy, 1995); this article merely highlights some of the main benefits to be gained from developing the concept. Genetic resource bank plans need to be integrated into existing species management plans and must provide some contextual background to justify the consideration of reproductive technology as a *bona fide* part of modern conservation. Potential approaches to species conservation and their economic and technological costs are summarized (Fig. 3).

Genetic resource bank programmes should not be undertaken lightly; indeed, the CBSG suggest that the justification, the requisite techniques, and the various types of expertise needed should be written out in detail as an action plan before a GRB is implemented. The CBSG itself produced such an action plan for tiger conservation (Wildt *et al.*, 1993). Undertaking such an exercise has the added bonus of focusing future directions for research.

In this article, the principle that establishing GRBs can be economically useful to humankind has been understated or ignored. This is not out of awkwardness, but because these

arguments, though powerful, have been discussed at length by other reviewers (for example, see Oldfield, 1989; Wildt, 1997). Furthermore, it is difficult to apply the utilitarian principle indiscriminately on the off-chance that a species will one day become vitally important to agriculture or industry. Is the value of a species dependent only upon its ability to provide the material basis of human life, in terms of foods, raw materials for manufacturing and pharmaceuticals? Perhaps the term 'genetic resource bank' is inappropriate because 'utilization' is implicit therein; a resource that is of no practical use is a contradiction in terms. Conservation seems to abound with ethical dilemmas such as this, in which different interests can come into conflict. At this stage, while the opportunities to protect and support species are still being created, we cannot easily dictate to others the policies for prioritizing species. Indeed it is questionable whether GRBs for a species such as the black footed ferret would ever be established if 'utility to humankind' were the overriding principle. The utilitarian argument, expressed by some Montana farmers and ranchers (see, Kellert, 1996), implacably opposes the conservation of this species on the basis that the ferrets have neither ecological nor practical value, and, furthermore, no moral right to be protected. However, the establishment of GRBs, in which gametes and embryos are stored with the intention of future use in breeding programmes, is considerably more valuable than a database of gene sequences or a collection of frozen tissue samples for analysis.

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