Avian reintroduction biology: current issues for science and management

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Reintroduction is a widespread technique for conservation of endangered species. It is highly visible and has tangible outcomes easily grasped by people in the short term. This often results in reintroduction becoming a showcase for conservation; proof that we are attempting something, and a way to generate public support and involvement.

Birds are the major taxa in reintroduction projects globally, and provide excellent examples of the significant advances and failures that reintroduction practitioners have made. However, the overall success of bird reintroduction campaigns is often poor. Reintroduction practice has evolved with little scientific rigour and poorly established monitoring and reporting protocols. The result is we often fail to learn from our mistakes.

Conservation science is increasingly addressing this issue and scientists involved in reintroduction procedures have a responsibility to coordinate and advance the expertise generated through their involvement. Of additional benefit is the wide scientific base reintroductions draw from. Yet this raises its own problems. Wildlife ecologists, population modelers, geneticists, animal husbandry professionals, and veterinarians all contribute expertise with often differing, and sometimes conflicting, goals and approaches. There remains a desperate need to coordinate our thinking across these disciplines to promote a stronger knowledge base for more efficient and successful reintroductions in the future.

The need to discuss reintroduction across broad scientific disciplines was recently met during a 2-day symposium held at the Zoological Society of London (8th and 9th May 2008). Experts from these various fields came together, presented and discussed their views about reintroduction. A central theme running through the meeting was how to create a unified reintroduction framework and importantly how scientists could contribute their expertise more successfully to reintroduction. This meeting was both positive and successful. The following abstracts are from the talks and posters presented. In addition to the authors represented here, are the additional 100 registered guests who attended the meeting and joined in discussion, many with a wealth of relevant experience.

While advances have been made, we still require dissemination of information and the development of a unified best practice approach to reintroduction. One step toward this is the publication of abstracts here in *Avian Biology Research*. In addition, the organisers of this symposium are currently editing a book covering these themes to be published within Blackwell Publishing's Conservation Science in Practice Series.

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ABSTRACTS TO SPOKEN PRESENTATIONS

Developing the science of reintroduction biology

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When the last members of a species have been lost from parts of their historical range often the only option for restoration is through reintroduction, involving the translocation and release of either captive or wild-caught individuals. High-profile programmes in the 1970s and 1980s raised awareness of reintroduction as a conservation tool and contributed to a proliferation of new management projects, many poorly planned. Subsequent low success rates of reintroductions worldwide led to calls for improved post-release monitoring.

Since 1990 there has been increased collaboration between reintroduction practitioners and researchers. This has resulted in an exponential increase in the number of peer-reviewed publications related to wildlife reintroductions, and there is now a recognisable field of reintroduction biology. However, a recent review (Seddon *et al.* (2007) *Conservation Biology*, **21**, 303–312) indicates that much of the research so far has been fragmented and *ad hoc*, consisting largely of descriptive accounts. Studies have often addressed questions retrospectively based on the available data, rather than the data being collected in organised attempts to gain reliable knowledge to improve reintroduction success.

I suggest that there is scope to improve reintroduction biology by advancing beyond simple observation and description of patterns (inductive reasoning), to formulation and testing of theory, particularly through the use of modelling approaches and well-designed experiments. There is also need for a more strategic approach whereby research and monitoring focus on questions identified *a priori* to be relevant to improving reintroduction success. I outline ten key questions that have been proposed for reintroduction biology (Armstrong and Seddon, (2008) *Trends in Ecology and Evolution*, **23**: 20–25), with different questions focusing at the population, metapopulation and ecosystem level. I conclude with a summary of five ways in which a more strategic approach to reintroduction biology can develop under the proposed framework of questions.

Historic successes and future challenges in reintroductions

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Examples of where man has deliberately established or re-established free-living bird populations are to be found throughout history and in most cultures – some dating back hundreds, if not thousands of years. Birds have been moved within and beyond natural biogeographic ranges for reasons as diverse as for food, recreation and commerce, as well as for cultural and aesthetic purposes. Adaptation of the concept as a management tool for threatened avian species however, would seem a relatively recent innovation.

Perhaps the first avian reintroduction for conservation purposes was in the 1890s when the New Zealand government recognised that some native birds, particularly flightless species, were in steep decline as a result of predation by introduced mustelids. Resolution Island in Dusky Sound, Fiordland, was designated a sanctuary and a custodian employed to transfer Kakapo (*Strigops habroptilus*) and Kiwi (*Apteryx* sp.) from the mainland for release on the island. Several hundred flightless birds were relocated, however, stoats reached Resolution in 1900 and the venture failed.

The first *successful* avian reintroductions for conservation purposes appear to be those of the early 1960s involving a New Zealand wattlebird, the saddleback (*Philesturnus carunculatus*). By the early 20th century the two subspecies of saddleback had been exterminated from their mainland ranges by introduced mammalian predators and were each confined to a single island. Following three unsuccessful attempts in the 1920s–1950s effective reintroduction techniques were pioneered and self-sustaining populations of the North Island race (*P. c. rufusater*) were established on a number of islands. In an 'eleventh-hour' rescue in 1964, the southern race (*P. c. carunculatus*) was saved from the very brink of extinction following colonisation of its final island refuge by *Rattus rattus*. Although now extinct throughout its former range, it too flourishes on a number of islands.

Techniques pioneered then are now an integral part of threatened species management within New Zealand and beyond. Since that time capture, captive-management, transportation, release techniques and associated protocols have continued to be refined, and reintroduction has become the mainstay in the conservation management of New Zealand's threatened birds. At least five endemic taxa and countless threatened bird populations owe their existence to reintroduction, and genetic health could not be managed without it.

Future challenges to bird life in general and to island endemics in particular would seem formidable and intervention a necessity. Already, for some species such as the kakapo, survival within their natural range is no longer an option. With an ever-expanding human population and footprint on the planet, coupled with anticipated impacts of climate change, this situation is set to intensify. Modern reintroduction techniques offer a lifeline for such displaced and threatened species - a means by which they might be relocated and thus continue to live and evolve in a free-living state.

The challenges of appropriate capture, holding, movement and release for successful reintroductions

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The reintroduction process is essentially a forced dispersal event with no evolutionary precedent. And yet the health of birds following this highly unnatural process of capture, holding and movement will be a significant factor in reintroduction success. The most appropriate methods for capturing, holding, moving and releasing birds are usually a matter of expert opinion. This opinion is a combination of the experience gained when conducting reintroductions and an intimate knowledge of the species concerned. While this expertise is invaluable and facilitates quick decisions when faced with uncertainty, there is a clear need for published studies to improve our reintroduction success.

Here we present our experience from approximately 40 translocations, primarily of passerines, but also of kiwi, parrots and waterfowl. While offering our own expert opinions on this process, we also suggest areas where we think reintroduction success and knowledge could be improved through planned studies of the capture, holding, movement and release process. Reintroduction is clearly a stressful experience for the translocated individuals and the impacts of acute and chronic stress appear to differ not only between species but also between individuals. It is likely that these stressors have a significant impact on the outcome of reintroductions, and we suggest that they should be examined relative to current reintroduction practice and techniques.

Aggressive strategies for the restoration of critically endangered species novel strategies for difficult situations?

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There have now been many successful restorations of critically endangered species and some notable failures. I will look at those case studies and evaluate the processes involved. Many species have been restored from tiny populations even though the limiting factors were not fully understood at the start of the restoration efforts.

The process of restoration and the process of understanding the species are inextricably linked and most restorations have progressed by applying management and then reacting to the response. Hence by empirically evaluating and then mitigating the proximate limiting factors it is possible to increase failing populations. This may involve feeding populations that are suffering from food shortages, or to provide artificial nest sites for those suffering from nest site shortages, or the control of exotic mammalian predators that depress survival and productivity in many species. These successes subsequently provide the motivation to tackle the ultimate problems such as restoring habitat quality. These techniques for the restoration of highly endangered bird populations have been developed by modifying those used in game-bird management.

The use of these techniques for restoring endangered bird populations has a long history and the restoration of the snowy egret (*Egretta thula*) in North America in the late 19th century is an important early example. With the increasing numbers of endangered bird species there is a need to further develop long-term management techniques to sustain failing populations.

In this talk I will describe my work with endemic birds in Mauritius and highlight the restoration of the Mauritius kestrel (*Falco punctatus*) from four known wild individuals to several hundred, the pink pigeon (*Nesoenas mayeri*) from nine wild birds to 400, the echo parakeet (*Psittacula eques*) from about 12 known birds to 340, and the current projects to restore the Critically Endangered Mauritius fody (*Foudia rubra*) and olive white-eye (*Zosterops chloronothos*). I will illustrate how these and other species restoration projects have driven whole ecosystem restoration.

An analysis of bird restoration projects worldwide shows that most populations do not start to respond to conservation action for many years and to achieve recovery of the larger K-selected species it is likely to take a century or more. Even when populations have recovered to long-term viable numbers it is probable that most will require careful population management for the foreseeable future.

Avian reintroductions in the UK: Lessons learnt and future plans

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The RSPB recognises that translocation is a valuable tool in conservation, and is likely to become more so as the effects of climate change begin to bite. The RSPB will support and participate in projects to reintroduce formerly occurring species to the United Kingdom, and to restore the former range in the UK of a selection of species, which are currently restricted in distribution.

We believe that the IUCN guidelines on translocation should be used as a framework in the planning and execution of projects. The success of any project will depend on the reasons for previous decline having been identified and rectified. Thus translocation is not a replacement for, but a compliment to, the traditional approaches to conservation such as habitat restoration. Additional benefits of translocation include a high level of public engagement and the generation of positive messages for conservation. Here, we present four case studies of species, which are the subject of current reintroduction projects: white-tailed eagle, red kite, corncrake and cirl bunting.

Translocation projects will rarely prove to be easy and we present some of the lessons we have learnt over the past 15 years or so. These include the need for adequate resources and planning, the value of population modelling to help set milestones and so gauge progress, the need for partnership working and the difficulties this creates and the need for a systematic yet pragmatic approach to disease risk assessment in order to aid the process of making operational decisions. Finally, we look forward to some of the projects we have in the pipeline.

Using species distribution models to identify suitable release sites for reintroductions

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It has been known for some time that one determinant of success in reintroductions is geography: it matters where species are released. This is true both at local scales where suitable habitat is clearly a key requirement, and globally where location within a species range often has an effect. The IUCN guidelines for reintroductions take account of this by including assessments of habitat suitability and the recommendation that release sites should be within the historical range of the species. The latter in particular is rather a blunt requirement as environments change both positively and negatively. Habitat assessments too are often difficult to carry out over extensive regions. Furthermore, the high cost of reintroductions means that some prioritisation should be given to those most likely to achieve long-term success and ways to predict this are still required.

This paper will examine the potential of species distribution modelling to aid the selection of suitable sites for reintroduction projects. The term ''species distribution models'' (SDM) refers to a group of techniques for predicting the full range of a species over a given area from partial species location data. The numerous approaches available for building SDMs will be introduced for non-specialists, showing how they attempt to capture aspects of the species' ecological niche and translate these into habitat suitability maps. SDMs may be used to identify core areas in ranges, where habitats are least fragmented, where local restoration work could reconnect fragmented landscapes, and how likely the present suitable conditions are to persist into the future given environmental change.

Using published and unpublished examples, the emphasis will be on what SDMs can and cannot do, and therefore suggest what we can learn for species translocations. The aim is to provide a set of tools for practitioners attempting reintroductions to consider the broader geography and sustainability in their projects. Organisations such as IUCN could also use these tools to identify those projects most likely to succeed and to discourage others where predicted success is much lower.

Managing expectations and outcomes for successful re-introductions and multiple stakeholders in Seychelles

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Re-introductions are typically complex and in developing countries difficulties increase because of limitations of resources including human and financial. In the Seychelles, modern approaches to re-introductions have led to major success in reducing threat levels to endangered birds. The ecosystem-based approach of the national NGO *Nature Seychelles*, which includes both biological and social, has underpinned these re-introductions.

The re-introductions have been embedded in island restoration projects where many stakeholders, ranging from owners of privately owned islands to local schools, have been intimately engaged in decision making and taking of responsibility. In addition a wide range of foreign partners, including donors such as the World Bank, veterinarians, avian care specialists, Universities and specialist agencies, have been articulated into the program. The management of expectations from such a diverse and number of stakeholders has not been easy but the results have been spectacular ranging from private island management funding the conservation programs to critically endangered birds being down listed in the IUCN Red Data book. Much of the success has been due to the local leadership of the NGO with the financial and technical backing of RSPB and BirdLife International.

Parasites, disease and reintroduction programmes

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Parasites, the causative agents of infectious disease, play a complex role in conservation biology, particularly where anthropogenic interventions and conservation actions, such as avian reintroductions, are involved. As with other host-species, birds are infected with a wide range of parasites, many of which have co-evolved with their hosts over millennia. Human interventions, including those undertaken for conservation reasons, can alter these host-parasite relationships, sometimes with unintended and unforeseen consequences.

Factors that influence the impacts of parasites on their hosts will be examined, including the host-specificity of the parasite, the strategy that a parasite employs to exit an infected host and to enter a new host, and the ability of the parasite to cause disease in an infected host. Anthropogenic factors that influence the outcomes of host-parasite interactions include a variety of parameters linked to captivity, such as: source of birds; aviary size and design; period of time in captivity; stocking density; diet, and contact (direct or indirect) with other species.

Recently, the anthropogenic introduction of parasites across boundaries of ecological isolation (pathogen pollution) has been cited as a major threat to biodiversity conservation. Such boundaries can be crossed inadvertently through ill-informed or poorly executed reintroduction programmes. Infectious diseases can threaten the success of conservation and reintroduction of birds at various stages of these programmes by causing increased mortality or decreased reproductive success of the target species or by impacting sympatric species post-release.

However, whilst it might appear to be desirable for birds used for reintroduction programmes to be free from parasites, the maintenance of a ''natural'' parasite burden, and hence the maintenance of genetic and other adaptations to these parasites, might help to ensure the survival of animals once they are reintroduced to the wild. Also, while parasites play an important role in driving and maintaining biological diversity, they are themselves important components of biodiversity. Avian conservation and reintroduction projects, including disease control measures, therefore, need to be undertaken with consideration of biodiversity conservation in the round.

Realised impacts of disease in bird reintroductions

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The contribution of infectious and non-infectious disease to the decline and extinction of wildlife populations is increasingly documented. When reintroduction and translocation are used to re-establish extirpated populations, disease issues can influence reintroduction practices and impact reintroduction success. When planning a reintroduction, the risk of introducing a novel pathogen into the environment tends to be afforded disproportionate importance in comparison to the risk to the released bird from pathogens existing in the wild, which may be the same pathogens that caused the species original decline.

Examples from bird recovery programs in Mauritius suggest that reintroduced populations are now permanent hosts to pathogens contracted from wild native or introduced species, which cause reduced survival and productivity in Mauritian native birds. Pre-release screening for pathogens needs to include disease profiling of birds, both native and non-native, at the source and recipient sites to evaluate risk. Because of a lag time to disease manifestation caused by density-dependent factors, vigilance and long-term post-release monitoring for pathogens may be required.

In a reintroduction, there is a need for both veterinarians and disease ecologists to treat and understand disease problems at the individual level and population level, to separate background disease from that which truly threatens the population, and to evaluate the interaction of disease with population recovery.

A collaborative approach to wildlife disease management in New Zealand

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The reintroduction of threatened birds into parts of their former range, following a period of habitat restoration, is now a global phenomenon. While each translocation has its unique features, many of the issues faced and techniques involved are generic. Consequently there is much we can learn from each other and a great deal to be gained from a collaborative approach.

New Zealand has much to offer the world as a laboratory for the development and trailing of techniques for the recovery of endangered species populations and their habitats. As an island nation, separated from other land masses for some 80 million years, it has a high level of endemism among its plants and animals, many of them extremely specialised in their habits and, therefore, highly vulnerable to major ecological changes.

As a result the arrival of people and their associated invasive plants and animals has wreaked devastation on the nature of New Zealand. While historically, the main focus of the country's wildlife conservation efforts has been on the eradication of introduced invasive species and the ecological restoration of offshore islands, the impact of disease on native fauna is now receiving increasing attention. Consequently we are starting to gather a valuable body of data on the pathogens present in and around our native fauna - their distribution, abundance and relative significance as threats to species survival.

The Auckland Zoo's increasing involvement in recovery programmes for native species over the last 18 years has inevitably led to a close affiliation with the NZ Department of Conservation (DOC) and other bodies involved in wildlife conservation. We have participated in, and provided technical advice for, a wide range of avian translocations during this time. The particular focus of the New Zealand Centre for Conservation Medicine (NZCCM), based at the Zoo, has been the collection of baseline health data and the establishment of quarantine and health screening protocols designed to identify and minimise the risks of disease transfer into naÿve (non-immune) free-living populations. This paper describes the collaborative development of a process for establishing situation-specific quarantine and health screening protocols in New Zealand. The deployment of this disease risk management tool internationally and its integration with other, complementary tools through the IUCN's Conservation Breeding Specialist Group (CBSG), is discussed with reference to some of the issues that have arisen along the way and that continue to provide challenges.

Risk assessment as a solution to disease management

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Reintroduction is a growing field of science and concern was expressed from the earliest attempts, about the risks of transmitting novel disease agents from individuals to populations and across geographical zones. Examples of why this was the case historically will be given. At that time mitigation against adverse disease impacts in animal translocations was applied, following general veterinary guidelines and recommendations. These were part of what would now be termed a ''risk assessment''.

Inevitably, with a new field of conservation science emerging, lack of experience often resulted in mistakes being made and what guidance that was provided was more theoretical than practical. There was a tendency, given the wide species and geographic scope, to simply list prominent diseases and give the available information on surveillance and screening technology without giving consideration to practicalities and cost.

Another important current issue is that of validation of tests (sensitivity and specificity) used to screen for pathogens in non-domestic species that has hardly been addressed and results continue to be misleading. The manager(s) of reintroductions is often put in a difficult position of deciding on how to apply these measures without much confidence in the results.

Often the only work that is done is that required by regulatory veterinary authorities on economically important diseases of livestock. This is done without any consideration of other diseases that could be of concern to recipient populations of sympatric species and others or about risks of recipient population disease on the source animals. This is more or less the same situation today so the onus is on the conservation community to consider other disease risks when undertaking translocation that are relevant to the specific species and pathogens likely to be important.

Birds, particularly migratory species, are an interesting case and are confounding of convention. Some examples of how more responsible practical disease prevention might be approached through a risk-assessment protocol will be illustrated. A few of the most important diseases relating to birds will be briefly reviewed with highlights of aspects relevant to reintroduction. With improving, more cost-efficient technologies for diagnosis and screening, considerably more work can now be done on this aspect of reintroduction than hitherto but many difficulties and few 100% safe-screening protocols exist.

Common sense is still most probably the key element when undertaking a risk assessment for reintroduction today. Some time will be given to discussing how to use common sense, without risking negligence in the process. Unfortunately with the considerable hype associated with emerging disease, good intentions can fall foul of precautionary restrictions applied in a blanket manner. The role high pathogenic Avian Influenza H5N1 is playing currently in this respect will serve to illustrate the point. Political considerations probably outweigh technical ones and since reintroduction is an exceptional circumstance, the possibility of special case application to risk considerations is worth pursuing.

Inbreeding and other genetic effects and their implications for reintroduction

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Inbreeding depression, the deleterious consequences of matings between relatives, has been a long-standing concern of conservation biologists. As a result, extensive research on inbreeding depression has been carried out over the last 20 years both in laboratory and natural settings. In summarising what we have learnt about inbreeding depression in the wild, I will show that severe inbreeding depression can occur in nature even in isolated island populations or in species that regularly experience inbreeding. Furthermore, evidence is accumulating that the magnitude of inbreeding depression can be substantially modified by the environmental conditions to which the organisms are exposed but that inbreeding depression is not necessarily always most pronounced when environmental conditions are poorest.

Taken together, these data suggest that genome purging is not as powerful at reducing the genetic load as has sometimes been assumed, and that even highly inbred populations may sometimes harbour a significant genetic load. Thus, it is now abundantly clear that inbreeding and its deleterious consequences have to be taken seriously in reintroduction programmes, and in conservation biology in general.

Inbreeding is only a serious conservation concern, however, if inbreeding not only reduces the fitness of individuals but also population growth. Laboratory studies, which have proven to be remarkably reliable indicators of the effects of inbreeding in the wild, suggest that the effects of inbreeding on population growth may be substantial under certain circumstances. There is thus an urgent need to better understand the effects of inbreeding on population growth rates. As with inbreeding depression within populations, it is highly likely that the effects of inbreeding on population growth are modulated by environmental conditions. I will conclude by discussing some common reintroduction practices and how they inadvertently may increase inbreeding and decrease genetic variation in reintroduced species.

The Major Histocompatibility complex, inbreeding and disease risks in introductions

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Inbreeding and loss of genetic diversity are inevitable in small populations and can be detrimental to their viability, both in the short and long term. Molecular tools provide a means of estimating levels of inbreeding and genetic diversity within populations, which can then be used to inform conservation programmes. This can be especially important when establishing new populations with a limited number of individuals, as in the case of translocations. Heterozygosity, measured across a suite of neutral DNA markers (*e.g.* microsatellites), is currently the preferred way to infer levels of inbreeding and genetic diversity within a population. However, such measures may be inaccurate or misleading for a number of reasons. For example, unless heterozygosity is measured across a very large number of markers it may not reflect genome-wide patterns of diversity. Furthermore, neutral variation will not necessarily reflect levels of variation at important fitness related genes, where balancing selection can maintain higher levels of variation even within small populations.

The major histocompatibility complex (MHC) is a set of genes that play a fundamental role in the vertebrate acquired immune system and differences in the MHC (between individuals and populations) have been shown to influence pathogen resistance. The MHC also appears to play a role in mate choice and inbreeding avoidance in some species. Therefore, measuring and maintaining genetic diversity at the MHC, rather than at neutral loci, may, be more important in the conservation of small populations.

I will review these arguments and the information that is currently available regarding patterns of MHC and neutral variation in rare species. I will present results from an ongoing study into the role of the MHC in the Seychelles warbler, a species that has been translocated successfully a number of times, to highlight why measuring MHC variation within such populations is both interesting and important. I will finish by discussing how the translocation and establishment of new populations may affect, or be affected by, levels of MHC variation.

Historical declines and their possible consequences for the reintroduction of recovering populations

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Inbreeding and the associated genetic problems that this brings for small natural populations is a common concern of reintroduction biologists seeking to reintroduce captive-bred or captive-reared birds back to the wild. The effects of inbreeding depression, such as reduced fitness and survival of inbred individuals, are frequently observed during field studies of closely monitored reintroduced populations that have recovered from a recent population bottleneck. However, some cases have shown such predicted effects to be minimal.

One important consideration is the amount of existing genetic diversity and the impact of the historical decline of the population. Advances in molecular genetic techniques have enabled genotyping of 100–150-year-old museum skins that were collected by early naturalists, often before a species' population has begun to decline. These genetic data can provide an important insight into the extent of genetic impoverishment of the extant population, and can help to interpret when low levels of genetic diversity and effective population size observed in an endangered species are attributable to recent population decline; this information may be valuable to reintroduction biologists when attempting to forecast future genetic problems in reintroduced/restored populations.

I present data from microsatellite DNA markers that describe historical genetic diversity for several endemic bird populations from Seychelles, Mauritius and Hawaii. Field records for the Seychelles kestrel (*Falco araea*) suggest that this species experienced a reduction in population size during the 1960s and 1970s; a comparison of historical and modern genetic data supports this hypothesis, suggesting a reduction in effective population size that is broadly comparable to that of the Mauritius kestrel, which experienced a severe population crash in 1974. On Seychelles, a reintroduction programme in 1977 attempted to reintroduce kestrels on to Praslin island where they had previously been extirpated, but with relatively limited long-term success; surveys in 1980 revealed 10 pairs, but by 2002/3 only five territories remained with no evidence of breeding success. Clearly, a range of non-genetic factors may have been responsible, such as habitat, nest site and prey availability, but genetic impoverishment may also have contributed to the low population viability. By comparison, reintroductions of Mauritius kestrels have been successful in the east of Mauritius but have largely failed in the north.

Whilst such case studies can be highly informative on a case-by-case basis, ultimately what may be needed in order to examine the role of genetic and non-genetic factors in determining reintroduction success is a broader comparative approach to assessing avian reintroductions.

The role of genetic factors in extinction risk: lessons from avian reintroduction programmes in New Zealand

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Genetic factors may be the rate-limiting step in ensuring population recovery and long-term survival in restoration programs focused on isolated islands. Most of the evidence for inbreeding increasing the risk of extinction of island populations comes from models that assume such populations harbour considerable genetic load.

Our analysis indicates that many of New Zealand's threatened species of birds, especially those surviving as isolated remnants, have some of the lowest levels of genetic diversity recorded. This pattern is consistent with these endemics having gone through a long period of small population size and inbreeding, and thus possibly having reduced genetic loads through the process of genetic purging.

Other data indicate that the frequency of current inbreeding in reintroduced populations is variable, depending on the number of individuals that survive the initial release and on the carrying capacity of the island. The magnitude of inbreeding depression is also variable, being lower in reintroductions sourced from populations subjected to historical bottlenecks. Inbreeding depression can no doubt decrease population fitness but the time scale over which these effects occur are long relative to the day-to-day risk of re-invasion by introduced predators such as rats and mustelids.

Management plans for reintroductions tend to be of short duration (*e.g.*

5–20 years) and focus on population recovery rates rather than the long-term risks of extinction. There may be benefit therefore of seeing the management of inbreeding as enhancing the recovery process of threatened species rather than focusing narrowly on the risks of long-term extinction that inbreeding depression may impose.

From inbreeding depression to population dynamics

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This modelling work aims to assess the effect of genetic deterioration on the dynamics and viability of populations reintroduced from captive-breeding programs. It was motivated by two concerns: firstly, the necessity of considering management constraints (*e.g.*, duration of the reintroduction project, number of founders of the captive population, capacity and number of captive-breeding units) to define and compare reintroduction strategies. Secondly, the need to integrate demographic and genetic aspects when comparing these strategies.

I developed a two-sex stochastic demo-genetic model that explicitly described the captive and reintroduced population dynamics. The dynamics of mildly deleterious and lethal mutations in these populations were considered, assuming that deleterious alleles reduced juvenile survival. I assumed that (1) population growth was more rapid in the captive population as compared to the reintroduced one; and (2) selection against deleterious alleles was relaxed in the captive population.

Results indicated that variation in the duration of the reintroduction project (*i.e.* time from the foundation of the captive population to the last release event) had contrasting effects on demographic and genetic processes in the reintroduced population. While increasing duration resulted in less demographic stochasticity (because more individuals were released), it also resulted in less fit population (due to many generations of relaxed selection in the captive source population). As a result, maximum viability of the reintroduced population was obtained for intermediate project duration.

In the case of long programme duration, the use of distinct, genetically independent captive-breeding units allowed more efficient purging of the genetic load in the reintroduced population, and substantially improved its viability. Overall, the results highlighted the antagonism between some short-/long-term genetic and demographic effects, which may complicate the assessment of reintroduction strategies. Accurate comparison among management options requires: (1) integrating different disciplines in population viability analyses; (2) using specific population parameters;and (3) defining specific conservation targets (*e.g.* time horizon considered to assess viability).

A guide to developing useful models for managing reintroduced populations

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Modelling reintroduced populations is an increasing practice in reintroduction biology. A great range of concepts and tools are now available but their appropriate use relies on asking useful questions. Among them, it appears that despite numerous attempts, there is no general agreement on the definition of reintroduction success criteria.

Restoration ecology already set up a detailed list of success criteria for ecosystem restoration that could provide directions for reintroduction. Indeed, sustainability, resilience and connection clearly remind that long-term population viability is the ultimate goal of these programs. Nevertheless, if all agree that reintroduced populations should be viable, we still need general approaches, targets and thresholds to define and model success.

I propose simple elements that may help to structure these issues and may be widely used among reintroduction programs. First, it seems necessary to distinguish between global versus local targets. In the first case, reintroduction is necessary for the conservation of a globally threatened species. In the second, reintroduction is locally important but concerns a species that is not globally threatened. Second, we can split reintroduced population dynamics into three basic phases: settlement, growth and regulation. In each phase, Population Viability Analyses may help to define success criteria accounting for individual and environmental quality. Finally, the ultimate long-term success relies on the third phase, where IUCN Red List criteria for viability may be used at a global or regional scale. Examples based on long-term studies on scavenger reintroduction in Europe will be used to illustrate these proposals.

Modelling reintroduced populations: the state of the art and future directions

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Population models are essential for projecting growth and persistence of reintroduced populations, and for assessing the effects of alternative management strategies. Although it is impossible to make decisions about reintroduced populations without some type of model, the sophistication of the models used can vary tremendously.

I will start by briefly reviewing progress in population ecology in general, and then review the published literature on application of population modelling to reintroductions. I will show that this is a recently developed field, with most of the published literature appearing in the last 5 years. I will then outline the approaches being used, ranging from simple deterministic matrix models to complex spatially-explicit individual-based models with multiple forms of uncertainty included, and outline the range of management decisions that the models are being applied to.

I suggest that the major factors differentiating the reliability of models being used are the degree to which they take advantage of state-of-the-art developments in model selection and parameter estimation, and the degree to which they incorporate realistic uncertainty into population projections. I suggest that it will be useful to focus further research on developing and improving methods for: (1) incorporating reliable dispersal algorithms in spatially-explicit models; (2) combining prior information with new data when modelling reintroduced populations; (3) predicting vital rates at release sites prior to reintroduction; and (4) creating comprehensive decision frameworks, including optimal allocation of monitoring and management effort taking costs into account.

Incorporating prior information into models for reintroduced populations

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Models that predict the fate of reintroduced populations can help to identify the number of individuals required to establish a population, weigh retention of individuals in captivity against releasing them to the wild, and examine the relative merits of releasing individuals at one or more possible reintroduction sites. These models will typically include parameters on the growth rate or life history rates (survival, fecundity and dispersal) of the population. All models that are used for prediction are based to some extent on prior information because each new reintroduction is novel.

In some cases, we may have information on parameters from previous years, from previous sites, or from related species. However, there is no guarantee that this prior information will be applicable to the next reintroduction, and at least some differences would be expected. A coherent and repeatable framework for incorporating prior information is required to ensure that prior information is treated logically. Bayesian methods provide this framework.

Prior information can also be used as to assess the performance of reintroduced populations. Given that the number of animals released is often small, the available site-specific and/or species-specific information will tend to be uncertain. In such circumstances, it may be difficult to evaluate the performance of a reintroduced population because the outcomes and benchmark for comparison are uncertain.

For example, if the estimated annual survival rate were 0.4 for a particular reintroduced bird species, how should we evaluate whether such a rate is acceptably large to warrant further releases? Meta-analysis of life history parameters can synthesise prior information from other species, sites and years to predict parameter values in novel situations. A meta-analysis based on an allometric relationship for the annual survival rate of adult birds shows that the survival rate of large-bodied birds is highly predictable, but that of small-bodied birds is less so.

Inclusion of environmental variables and simultaneous prediction of multiple life history parameters are fertile avenues for further research. I will illustrate how prior information can be used to help management decisions about avian reintroductions. Ultimately, the value of using different forms of prior information needs to be assessed for a large number of case studies.

Toward a comprehensive decision framework for reintroduced populations

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As with many applications in conservation biology and wildlife management, reintroduction programs are frequently implemented using common sense and intuition. Such approaches do not necessarily perform poorly, but formal approaches to reintroduction decisions would seem to merit consideration. Informed decision processes typically require four primary elements: objectives, management actions, models, and monitoring.

Objectives of reintroduction programs will typically involve maximising some future population size or perhaps minimising a probability of local extinction. In most cases, management cost or effort constraints will also be a component of the objective function. Management actions will involve the release of individual animals into the focal area with decisions involving mode of release (*e.g.* ''hard'' versus ''soft'' releases) and such characteristics of the releases as number, source (*e.g.* wild-caught or captive-reared), age, sex and possibly genetic composition or population of origin.

Models are required for informed decisions and provide bases for making predictions about the responses of released animals and associated populations to different management actions. Mathematical models are used to project the consequences of hypotheses, in this case about the effects of released animals on the status of the focal population. Uncertainty may be accommodated via use of multiple models reflecting different hypotheses, for example about the demographic performance of released animals.

In some situations, all releases are of captive-reared birds, and in such cases models of the captive population may be needed to provide constraints on possible actions. Finally, some sort of monitoring program should be established for the reintroduced population in order to: (1) evaluate success of the reintroduction program; (2) provide a basis for state-dependent decisions; and (3) provide a basis for discriminating among competing models. Monitoring should be designed to deal with spatial variation (it may not be possible to survey the entire area of interest) and detection probability (all animals are not detected even on surveyed areas) and may be especially difficult for small populations.

Adaptive management is one type of informed decision process that may be useful for reintroduction decisions that are characterised by uncertainty and that are made periodically (*e.g.* at the end of the breeding season each year). We describe the steps of adaptive management, providing examples for avian reintroduction to illustrate the process.

The who, where, what, when, and why of avian reintroductions

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Hundreds of releases of avian species have occurred in reintroduction and translocation programs over the last two decades. Thus, scientists and managers who are planning future releases are not developing their plans in a vacuum; they have an opportunity to gather information from past releases. Yet gathering this information is a challenge as it is dispersed over many different sources and media.

To centralise this information, we developed a comprehensive, standardised database, the Avian Reintroduction and Translocation (ARTD) database. The database is structured to provide access to three areas of interest to managers and researchers:

species, site, and release event data. Within these areas, variables are structured to be quantitative and relevant to factors that impact the efficacy of releases. These factors are diverse, ranging from the species' biology and ecology to habitat suitability, demography, genetics and management.

Data were collected from a wide range of sources, including peer-reviewed and grey literature, and the ARTD is now populated with data for releases of 128 species at 405 sites and 1207 release events. I present example research on variables for a single species such as which birds are released, where they are released and what number are released. In analyses across programs, I produce descriptive statistics such as which species are released by IUCN status, how the source influences mortality, and how many birds are released per event and per site. The ARTD with data on factors in past releases is available at www.lpzoo.org/ARTD our web site to inform managers and researchers as they plan future releases.

Conservation evidence and the power of knowledge

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This study examined how we collected evidence of the effectiveness of avian re-introductions. Currently the extent and type of monitoring varies greatly between projects. We wish to suggest a more detailed set of criteria for monitoring reintroductions. Our objective is to ensure that as a community we collect a more complete set of data.

The current approach to monitor reintroductions varies enormously between projects. We believe that the lack of consistent standards makes difficult to make comparisons that will effectively inform future releases. We suggest reintroductions are documented through www.conservationevidence.com and the Avian and reintroductions database at Lincoln Park Zoo. We will outline a protocol that can become the standard approach. The collation of evidence followed by their synthesis and dissemination should lead to more effective conservation, robust defendable practises and more convincing proposals. We will discuss how progress in evidence-based conservation (Sutherland, W.J., Pullin, A.S., Dolman, P.M. and T.M. Knight [2004] *Trends in Ecology and Evolution*, **19**, 305–308) can be used to improve reintroduction science. We believe that this approach will strengthen the science and also increase funding by showing how practice is continually improving.

ABSTRACTS FROM POSTERS

A genetic assessment of captive breeding and reintroduction programs of the lesser kestrel (*Falco naumanni*) using neutral and adaptive loci

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Genetic monitoring has become a promising tool to assist captive breeding and reintroduction programs. We have conducted a genetic assessment of captive and reintroduced populations of the lesser kestrel (*Falco naumanni*) using microsatellites and major histocompatibility complex (MHC) class IIB genes.

Adequate levels of microsatellite diversity cannot explain the high levels of hatching failure occasionally documented in captivity. Nevertheless, we found significant decreased heterozygosities and increased inbreeding coefficients within reintroduced populations in relation to the captive demes where released birds come from. Given that MHC genes play a crucial role in the vertebrate immune system, genetic profiles of individuals and populations at these loci have been widely related to fitness components and long-term persistence.

We obtained the distribution frequencies of MHC haplotypes in wild populations of lesser kestrels in order to investigate putative fitness consequences derived from the possession of common or rare alleles. Our analyses show significant higher frequencies of common MHC sequences within the most successful breeding pairs kept in captivity, as well as significant deviations of Mendelian proportions when analysing the segregation of such alleles from parents to fledglings.

Although the occurrence of genetic bottlenecks resulting from a relatively small number of founder individuals with biased reproductive performance can be easily predicted, these findings inform us about larger founder effects at loci under selection. We encourage refreshment of genetic stocks, the contribution of different captive-raised broods to reintroduction and the promotion of immigration to minimise loss of genetic variation at fitness-associated genes determining the adaptive potential of reintroduced populations.

Coordinating efforts to conserve the northern bald ibis (*Geronticus eremita*) and why reintroduction is not a straightforward option

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The northern bald ibis (*Geronticus eremita*) is classed as Critically Endangered by IUCN, with just over 100 breeding pairs left in the wild. Conservation priorities for the species relate mainly to *in-situ* threats to the remaining populations in Morocco and Syria. A large captive population exists, presenting the theoretical potential for reintroduction to parts of the former range.

Due to the social complexity of the species and a variety of other factors, early release attempts were unsuccessful, and the actual potential for reintroduction has proved to be very difficult. However, there has been very significant progress towards this over the past ten years. There is now a proven (if highly intensive) method developed for establishing a sedentary population, but most populations were migratory, and progress with developing a way to re-establish migratory behaviour is more complex and at an experimental stage. Less intensive options are also being tested.

A very diverse set of organisations and individuals have relevant expertise for the species. These include *in-situ* conservationists, government bodies, NGOs, zoo and captive experts, as well as behavioural biologists. Focusing and coordinating efforts between the diverse players involved, and at the same time maintaining the conservation priorities for the species has been the key objective of the International Advisory Group for Northern Bald Ibis (IAGNBI), an independent group that has been effectively pursuing these aims since 1999. IAGNBI holds meetings, produces newsletters and detailed meeting reports, and has contributed heavily to the recently produced Species Action Plan.

Inbreeding, giant sperm and other sperm aberrations in the hihi (*Notiomystis cincta*)

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The hihi is an endangered and endemic passerine from New Zealand. Hihi are highly promiscuous with a vicarious polygyandrous mating system displaying many adaptations to sperm competition. They have gone through a series of bottleneck events associated with reintroduction. Bottlenecks may reduce genetic diversity and increase inbreeding, lowering heterozygosity and increasing genetic load and expression of deleterious alleles. Inbreeding is thought to compromise sperm quality as spermatogenesis requires strong genetic control, and in turn fertilization success and embryological development. This process is particularly relevant to the hihi as they have high levels of hatching failure (approx 30% on Tiri) when compared to other outbred bird species (approx 10%) and sperm quality is extremely variable with some males displaying up to 90% sperm abnormalities in one ejaculate. Understanding how sperm competition, sperm quality and genetic variability interact is essential in terms of reproductive success and will give an insight to device new conservation strategies in the future.

Bird re-introduction and analogue options in the oceanic islands of the western Indian Ocean

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The Mascarene Islands (Mauritius, Réunion, Rodrigues), and to a lesser extent the Seychelles, have suffered numerous anthropogenic extinctions. Although many of the lost bird species, such as the Dodo *Raphus cucullatus*, were high-order endemics and thus irreplaceable, others survive on neighbouring islands, or ecologically similar congeners do, which can be used to help reconstruct failed ecological webs. This poster matches avian extinctions with species potentially available for translocation, including possible ecological analogues (but excludes exchanges within the granitic Seychelles and within the Aldabra group). Restoration of several birds to Réunion from Mauritius (*e.g. Nesoenas mayeri*, *Psittacula eques*, both important for species conservation) or congeners for lost species (*e.g. Falco netwoni* and *Foudia omissa* from Madagascar) are examples. The endangered *Papasula abbotti* could be restored to its previous distribution in Rodrigues, Mauritius and Assumption. The full data includes many more suggested species. Similar data could also be tabulated for reptiles (lizards and tortoises) and mammals (bats). The full version is available (modified for standard A4 pdf format) from the author.

Threats control actions in the LIFE project "Actions for the reintroduction of the bearded vulture (*Gypaetus barbatus*) in Andalusia"

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In 2004 Gypaetus Foundation established the LIFE project "Actions for the reintroduction of the Bearded Vulture (*Gypaetus barbatus*) in Andalusia" (southern Spain). Within the framework of the project several threats control actions for the species were developed. Illegal poisoning of predators and feral dogs is the major threat to the bearded vulture in Europe. In Spain, it is currently the cause of 36.7% of non-natural deaths ($n = 30$). Anti-illegal poisoning actions have been developed and are listed in the "Gypaetus Foundation Action Plan against Poisoning".

The Plan includes 24 specific actions, grouped into three work lines: (1) Information gathering: regional information about cases of poisoning (baits and carcasses) are analysed peri-

odically (more than 700 cases to date). Mapping and reporting are carried out in order to develop and improve action against illegal poisoning. (2) Prevention and deterrence: direct collaboration, partnership and awareness-raising activities focused on target groups, such as hunters, stockbreeders, journalists, local authorities and students. (3) Fighting the crime: officers are provided with training on the removal and custody of potentially poisoned carcasses. Gypaetus Foundation acts as a private prosecutor in all trials related to illegal poisoning in Andalusia, and some imprisonment of offenders has been achieved.

Regarding power lines, those identified as potentially dangerous are being modified or signalled. Since 2004, as part of the preventive threat control activities, Gypaetus Foundation checks all applications for projects that may have a negative impact on the species or its habitat within reintroduction areas, and to date, two major projects have been rejected by the environmental authorities.

The UK Great bustard reintroduction

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Listed as Vulnerable on the IUCN Red List, the Great Bustard has undergone a substantial decline in numbers and severe contraction in range which is forecast to continue. Formerly native to the UK, they were extirpated in the early 19th century, primarily as a consequence of trophy hunting and egg collection. Suitable habitat remains, although their current geographic distribution means that UK recolonisation is unlikely to occur naturally.

In 2003, the UK government licensed a 10-year trial-reintroduction project. It is the first attempt to establish a new population of this threatened species and increase its range. Birds for the UK project are sourced from a long running scheme in the Russian Federation, managed by a branch of the Russian Academy of Science, which rescues a small proportion of eggs from wild nests situated in fields that are exposed or destroyed during routine cultivation. Artificial incubation and rearing produces stock for conservation purposes that is unlikely to have a detrimental effect on the donor population, estimated at 8,000–11,000 individuals.

Annual releases began in 2004. The birds' behaviour appears natural and the overall survival is as predicted, suggesting the reintroduction may succeed. Birds undertake seasonal movements throughout southwest England, selecting a wide range of open habitats that includes lowland wet meadows, natural chalk downland, fallow and autumn sown crops. Individuals alive from all years of releases flock together and males display to females each spring. In 2007 the first wild nest was discovered, several years before anticipated.

In the UK, current research includes trials of habitat plots with the expectation of including these as future options in agri-environment schemes, modelling habitat use by combining remotely-sensed data with distribution data and assessing genetic composition of released birds. The UK project also collaborates on research and conservation schemes targeting the Russian donor population.

Maximising the effectiveness of artificial incubation techniques in *ex-situ* conservation of birds

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Captive breeding of birds often relies on pulling of eggs to increase the reproductive performance of individuals. Eggs removed from the parent(s) are typically subjected to artificial incubation techniques. Broody hens are often employed to incubate larger eggs, because it is felt that artificial incubators are not providing the correct environment for successful development. This is often not the case but rather reflects the failings of either the incubator or how it is managed.

Some small machines do not provide good results because they exhibit poor design. For instance, incubator cabinets should have different holes for the ingress of fresh air and the egress of stale air. Some apparently high-quality incubators have only one hole and so the internal atmosphere can become stale very quickly, which adversely affects embryonic survival. Provision of the appropriate temperature in a balanced environment, avoiding hot and cold spots is critical for normal development. Maintaining the correct humidity by reacting to actual rates of weight loss during incubation can maximise hatchability. In some species, *e.g.* the Houbara (*Chlamydotis undulata*), an understanding of shell quality can assist in ensuring that weight loss is optimised from the start of incubation. Finally, understanding that rates of egg turning differ between species, and are not the same as those exhibited by domesticated Galliforms, can have a significant impact on success rates of eggs under artificial incubation.

In conclusion, there is no reason why incubators cannot be used to incubate eggs of any species of bird in conservation programmes.

Translocation of cirl buntings (*Emberiza cirlus*) within the UK as part of a wider recovery programme

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Cirl buntings have been the subjects of a long-running recovery project in the UK. Once locally common and widespread, their UK population collapsed in the mid-1970s as a result of agricultural intensification. In the past 14 years evidence-based conservation measures aimed at habitat provision through agri-environment schemes have resulted in the population recovering from 118 to over 800 pairs. This recovery has been confined to the remaining restricted range in South Devon.

The Biodiversity Action Plan includes targets to re-establish birds across parts of its former range by 2020. The species' poor dispersal ability coupled with the fragmented nature of the remaining suitable habitat means that these targets are unlikely to be met without translocation. South Cornwall was identified as the most appropriate receptor site, based on habitat suitability and logistical reasons.

In 2006, following a successful trial, 75 *circa* 6-day-old chicks were taken, under licence, from the South Devon population, hand reared in quarantined premises and 72 soft released into Cornwall following a disease risk assessment and with concomitant health monitoring. At least 24 survived to the following spring, forming nine pairs. Despite poor weather, they had 12 breeding attempts collectively producing a minimum of 11–15 young. A further 47 hand-reared chicks were released in summer 2007.

Predictive population modelling shows that 4 years of releases on this scale should result in a self-sustaining population of 35 pairs by 2010. Modelling and monitoring show a negligible impact on the donor population. If successful, we believe this will be the first translocation of a passerine in Europe carried out for conservation reasons.

The role of genetics in the reintroduction of the Floreana mockingbird (*Mimus trifasciatus*) in Galápagos

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Since its disappearance from the large Galápagos island of Floreana at around 1880, the Floreana mockingbird (*Mimus trifasciatus*) only occurs on two very small islets that are inhabited by 45 and *circa* 150 individuals, respectively. Accordingly, it has been classified as endangered by the IUCN, and plans are being developed by the Galápagos National Park Service and the Charles Darwin Research Station to reintroduce mockingbirds to Floreana.

This study aims to provide the genetic background information necessary for a successful reintroduction programme. The following questions are of particular management importance: do the two islets harbour genetically distinct populations or do they form a single management unit? Are both islets equally suited as source populations or is one considerably more inbred than the other?

Preliminary population genetic analyses show that the genetic differentiation between the two islets is as high as between other mockingbird species in Galápagos. Furthermore, one of the two populations seems to be highly inbred whereas the other population is more diverse than anticipated, suggesting that it may have retained a large proportion of the original genetic diversity on Floreana island. Future genetic analyses of museum specimens will help resolve this and other questions relevant to this reintroduction project.

Minimising risks and maximising benefits in a reintroduction programme in Central Africa

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Wildlife reintroductions are becoming increasingly popular conservation tools around the world, for a variety of reasons. However, reintroduction projects are often controversial. Many criticisms of reintroductions are based on the view that the risks of the project may outweigh the benefits.

The World Conservation Union proposes that a ''precautionary principle'' should guide reintroduction efforts, through recognising risks and prioritising the protection of wild populations and habitats over other considerations. Identification of potential risks is therefore an essential component of the early reintroduction planning process. A structured risk-benefit analysis can then be a valuable tool in reintroduction planning and assessment.

For example, a case study of The Aspinall Foundation's ongoing programme to reintroduce the critically endangered western gorilla to the Batéké Plateau region of Congo and Gabon shows that a cautious approach to reintroduction planning and implementation has led to risks being minimised throughout the 20-year programme. However, for a reintroduction to be considered an effective conservation tool, minimising risk must be complemented by maximising benefits. These risks and benefits can be assessed from four principal perspectives: (1) the released individuals; (2) wild populations; (3) the habitat of the release sites; and (4) the human population local to the release sites. Careful site selection and the implementation of collaborative natural resource management programmes appear to be major aspects of both minimising risks and maximising benefits from most perspectives.

Integrating dispersal in metapopulation viability analysis: the case of griffon vulture (*Gyps fulvus*) in France

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Although dispersal is a crucial process for population dynamics, it has often been neglected as a factor of success or failure of reintroduction projects, mainly because of a lack of long-term monitoring of released individuals. We aimed to assess the consequences of dispersal on viability of metapopulation restoration in the case of the griffon vulture.

This colonial long-lived species has been released in five sites in France and successfully settled in three of them. Thanks to the data collected during the long-term monitoring in each reintroduced population, we estimated demographic parameters (reproductive success, survival and dispersal rates) to identify key factors of reintroduction success. We then implemented those parameters in a spatially explicit, individual-based model. Behaviour was explicitly taken into account, and we tested various scenario of age at release and spatio-temporal design of releases, which could enhance the viability of the restored metapopulation of this species.

Using multi-strata capture-recapture models, we showed that in all release sites, adult survival rates were reduced in the first year following their release. When dispersal was accounted for in survival estimates, early survival rates were equal among sites. Our results revealed that settlement failures were due to high emigration of individuals from those populations to the nearest and the largest settled population. Including this conspecific attraction behaviour in a metapopulation viability analysis, we advised for sequential releases of adults in several sites that limit metapopulation extinction risks.

Negative effects of management on population recovery in the endangered California condor (*Gymnogyps californianus*)

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The primary goal in the recovery of any formerly extirpated taxa is the establishment of a viable, self-sustaining breeding population. Reintroduced populations of the endangered California condor (*Gymnogyps californianus*) began breeding in southern California and northern Arizona in 2001. We studied breeding condors in southern California from 2002 to 2006 to determine nest success and identify limiting factors for nesting condors.

Although hatching success was comparable to the historic wild population of the 1980s, fledging success was extremely low (8.3%). Of 12 chicks hatched in the wild since 2001, only two survived to fledge successfully. All post-hatching mortality since 2002 occurred in the mid to late nestling phase. In two cases, heavy metal toxicosis and complications due to the ingestion of foreign material, principally man-made junk, were the cause of death. All but one chick handled since 2002 held such junk (up to 193.5 g). On average, feeding rates were similar to those at historic nests but were more variable. Most nests had lower feeding rates and more prolonged periods of food deprivation than historical nests.

Our data suggested that management, principally supplementary provisioning at single sites, has significantly altered foraging behaviour with detrimental effects on chick survivorship. We recommended altering current management to reduce dependence on single provisioning sites to promote the development of more natural foraging patterns. However, this is likely to come at a cost of increased exposure to lead contamination. Removal of the threat of lead poisoning would allow more flexible and scientifically driven management of condor populations.

Dealing with reproductive habitat selection of released individuals in reintroduction establishment phases: a theoretical modelling approach

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Investigating which mechanisms initiate settlement decisions is crucial to ensure the short-term success of a reintroduction project, since the establishment is the preliminary condition of population growth. We investigated reproductive habitat selection through a modelling approach to assess post-released consequences of this behaviour on the establishment of released animals.

We used a stage-structured population model for short- and long-lived life cycles with five different explicit habitat selection strategies based on: (1) intrinsic habitat quality; (2) conspecific attraction; (3) reproductive success of conspecific; (4) avoidance of conspecific; and (5) a random strategy. We also considered several release frequencies, the presence of a remnant population close to the reintroduction area and a variation of the proportion of breeders among released individuals in the release year.

Reintroductions of species using habitat selection based on social attraction cues – *i.e.* conspecific attraction and reproductive success of conspecifics – seem to be more prone to failure when a remnant population exists. Indeed, in both short- and long-lived species, the fewer the proportion of breeders in the first year and the bigger the remnant population size, the higher the risk of settlement failure. In addition, sequential releases appear preferable for short-lived life cycles, whereas its benefits are more contentious for long-lived species, depending on the remnant population size.

Understanding settlement patterns within a theoretical modelling approach can thus play a key role in future reintroduction planning, dealing with different initial conditions in the reintroduction target area prior to the release.

The reintroduction of osprey (*Pandion haliaetus*) in Andalusia (Spain)

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The osprey (*Pandion haliaetus*) was extirpated from mainland Spain after 1981. Only two breeding populations of 15–20 pairs each remain in the Canary Islands and Balearic Islands. In 2003, a reintroduction program was established in Andalusia (southern Spain) in order to accelerate the return of the species.

Between 2003 and 2007, 88 young ospreys were released by means of hacking in two locations: Barbate Reservoir (Cádiz) and Odiel Marshes (Huelva). Nestlings translocated from wild nests of Germany, Scotland and Finland, stayed 2–4 weeks in the hacking facilities until release at 8–10 weeks old. Movements were tracked with conventional tail transmitters during the post-fledging period. Thirteen birds were fitted with satellite PTTs to track migration to wintering grounds in sub-Saharian countries. The mortality rate before migration was 8%.

For the first time, in 2007 five reintroduced birds released in 2005 were recorded back to the reintroduction areas. In 2005 and 2006 a non-reintroduced osprey breeding pair built a nest and laid at least one egg each year in a reservoir close to the release point in Cádiz. However, the eggs did not hatch and we conducted a successful fostering with two wild osprey chicks both years in order to encourage site fidelity.

Active conservation of the Spanish imperial eagle (*Aquila adalberti*) in Andalusia (Spain): the reintroduction program in Cádiz and the restocking program in Doñana National Park

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The Spanish imperial eagle (*Aquila adalberti*) is one of the most endangered birds of prey in the world, with only 234 breeding pairs in 2007 in the south-west of the Iberian Peninsula. Despite the slow increase since 1980s, the long-term viability of the population is not still assured owing to its small size and the low re-colonisation capacity.

Thus, a reintroduction program commenced in 2002 in order to create a new subpopulation and reinforce the general metapopulation. Between 2002 and 2007, 33 wild young were released by means of hacking in La Janda (Cádiz), a former breeding area. After 2–3 weeks in the hacking they were released when 9–11 weeks old. Nestlings were fitted with conventional and PTT transmitters to track their movements during post-fledging period and dispersal. The registered mortality rate was 31.4% during the first year. In 2006, the first pair of reintroduced eagles bred on a nest 150 km from the release area within an existing breeding subpopulation. However, the only chick to that hatch disappeared when 10–15 days old. In 2005 an extra reinforcement program of the small, aged and sex-biased breeding population of Doñana National Park (Sevilla-Huelva) was developed. As of 2007, eight nestlings have been released following the same protocol.

An assessment of two methods used to release red kites (*Milvus milvus*)

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Between 2003 and 2005, we released 12 red kites (*Milvus milvus*) to the wild in Hampshire, England. Four kites were captive-bred and released as fledglings in artificial nests ('hacking'). The remaining birds were mature and released from a large aviary.

Interaction with electricity power lines killed two of the captive-bred birds three weeks post-release and a third captive-bred kite died as a result of head injuries six months post-release. One mature kite died ten days post-release.

We suggest that the different release methods of the two groups amplified the behavioural variation between individuals and exposed them to different risk factors, and conclude that releasing mature flight-fit kites from aviaries is a likely to be a superior method to hacking pre-fledged kites in artificial nests. The flight skills of the mature kites developed prior to release enabled them to avoid potentially lethal interactions with power lines and aggressive inter-specific encounters.

Modifying or adapting release methods to incorporate behavioural variation between individuals within a release population should be a consideration for reintroduction practitioners, particularly where release numbers are small.

Genetic origin determines success of reintroduced white storks (*Ciconia ciconia*)

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White storks (*Ciconia ciconia*) are being reintroduced to Sweden after local extinction in the 1950s. The size of the population is currently around 45 free breeding pairs. The founding population for the reintroduction consisted of 15 birds imported from Switzerland around 1980. The Swiss population was founded with birds from Algeria. Thus, Algerian storks have been introduced to Sweden. Also spontaneous immigration of ''wild'' or ''native'' storks has occurred, with a total of 12 founders in the same period. These have reproduced, often together with birds of Algerian descent.

The pedigree is known for the whole breeding population, and thus it has been possible to calculate inbreeding as well as degree of genetic nativeness of all breeding individuals and pairs. We have analysed all 289 breeding events of storks in Sweden between 1989 and 2005. Genetic origin, *i.e.* the extent to which the storks descend from the wild or Algerian founders determines reproductive success to a great extent. Birds of pure wild origin are expected to produce twice as many surviving offspring as those of pure Algerian origin.

Inbreeding had no effect on reproductive success in the population, despite the small founding population. In addition, we show that pure Algerian birds are much less likely to migrate. We have also made a risk analysis of the population fate if we breed storks of Algerian or wild decent. It is clear that only wild storks will be able to build up a sustainable population in Sweden.

Climate change impact considerations for reintroduction programmes

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Efforts to better incorporate climate change impact dynamics into mainstream threat evaluation and conservation processes have realised some significant advances over the last year. These impact and conservation response considerations are, of course, equally germane to the reintroduction programme design, implementation and evaluation process. Shifts in ecosystem boundaries are likely to mean that current protected areas will increasingly be less likely to contain the species and habitats they were established to protect. Novel species assemblages, increased disease issues and human/wildlife conflicts are associated stress considerations.

Conservation planners need to assess the vulnerability of habitat to climate change together with the target species climate change vulnerability traits. We will also increasingly need to identify potential sites that are not currently protected (and may well fall outside of the target species natural range) but which may have a higher conservation status under changed climate conditions. When such impacts are sufficiently taken into account it is likely that the conservation community will be faced with many species evaluation outcomes that project complete viable range habitat loss or other equally catastrophic situations.

The traditional conservation approach has always been to prioritise the most threatened species but these climate change impact considerations challenge the viability of this approach. It is very likely that rolling establishment and reintroduction programmes will become an increasingly essential and common conservation response.

A study of the winter diet of reintroduced red kites (*Milvus milvus*) from North East England

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The red kite (*Milvus milvus*) was once one of the rarest birds in Britain; however, following several reintroduction projects throughout the UK the red kite is steadily making a comeback. This study examined the winter diet of the population of reintroduced red kites in the north-east.

Feeding pellets were collected from Spen Banks wood, Gateshead. A total of 137 pellets was collected during six collection events from December to March 2007. The pellets were broken down and ten hair or feather samples were taken at random from each pellet. Hair samples from mammals were identified to species and included a wide range of prey items including a range of lagomorphs, mustelids, rodents, domestic cat and roe deer. Other identifiable remains included feathers from pheasants and corvids and chaetae from earthworms. Earthworms were the most commonly encountered food item from wintering kite pellets, with other bird species being second. Non-food items were also identified including rope and loft insulation. The red kites' diet did not change significantly over the winter period.

A 50 m × 50 m grid was also set up look for spatial relationships within the roost. A significant negative correlation ($r = -0.991$, $P = 0.009$) was discovered between the number of pellets and the distance form the edge of the roost. It is not clear whether this is due to dominant birds preferring the middle of the roost, a despotic distribution within the kites, or the outside edge of the roost being more attractive. The project was supported by RSPB Northern Kites.

Reintroduction of the åga (*Corvus kubaryi*) to Guam

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The endangered åga or Mariana crow (*Corvus kubaryi*) is endemic to Guam and Rota, the southernmost islands of the Mariana Island archipelago. On Guam, decline of the åga is due to predation by the introduced brown treesnake (*Boiga irregularis*) while on Rota, loss of habitat, predation by introduced rodents, and possible human persecution, are believed to be the cause. Currently, the Guam population consists of 10 birds, nine of which were translocated from Rota to Guam as eggs or chicks.

All artificial incubation and hand rearing of translocated eggs and chicks occur at the Guam Department of Agriculture's Wildlife Laboratory. In addition, aviculture support was provided for 19 eggs produced on Guam from successfully released Rota birds. To date, 21 åga have been soft-released at ages ranging from nine to 36 months old in snake-controlled areas. Methods for soft-releasing åga include housing birds in hack boxes at the release site seven days prior to release. Also, transmitters are harnessed on the birds to document survivorship and movement as they are monitored daily at 12 hours a day for the first month, then six hours a day thereafter. When nesting occurs, prior to the completion of the inner cup, an electrical barrier is applied and the encroaching forest canopy is pruned to prevent snakes from predating the nest.

Generally, when Guam eggs are pulled, a dummy egg is placed in the nest to keep the nest active in case the decision is made to allow the adults to raise a chick. This prevents the Guam pairs from continually experiencing failure if all young are reared at the Wildlife Laboratory. This poster summarises the success and challenges in re-establishing åga on Guam with hand-reared birds from Rota as well as the results of the different methodologies used.

The saker falcon (*Falco cherrug*) in Bulgaria: a case for reintroduction?

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The saker falcon (*Falco cherrug*) was formerly abundant and widespread in Bulgaria. In the 20th century numbers declined markedly following World War II as a result of changes in agricultural practices that dramatically altered the landscape. In addition, government sponsored campaigns to eradicate predatory birds and rodents directly affected the saker falcon population and its favoured prey species, the European souslik (*Spermophilus citellus*). By the end of the 1980s the saker falcon population had diminished to an estimated 30–50 breeding pairs.

Subsequently, the change of government in 1989 saw an increase in nest robbery and illegal poaching, and now the saker is believed to be extinct as a breeding species in the country. With the accession of Bulgaria to the European Union and the establishment of a network of Natura 2000 protected sites there is an opportunity to restore the saker falcon through a programme of reintroduction. This poster describes the feasibility study currently being undertaken to examine the potential and logistics of such a project.

Disease management in a small population

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Although the effect of disease on a population can be devastating and has played a major role in a number of species declines, it is often not adequately considered when planning reintroduction programmes. Many of the management practices applied to reintroduced populations are similar to those used to intensively manage wild populations and many of the lessons learnt from such programmes can be applied to reintroduction programmes.

The endemic Echo parakeet (*Psittacula eques*) of Mauritius has been managed year round since 1987 and although intensive management in the form of hand rearing and nest manipulations ceased in the 2005/06 season, the close monitoring of breeding attempts and success continues today. The management of the population has meant that the emergence of Psittacine Beak and Feather Disease (PBFD) has been well documented from its apparent first appearance in the population in 1995 to its current prevalence of approximately 20%. PBFD is a highly contagious viral disease and has therefore had a significant impact on the management practices employed by the echo parakeet recovery programme.

Golden eagle (*Aquila chrysaetos*) restoration in the Lake District National Park; an investigation of public demand and economic benefits

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The Lake District National Park is the home of England's only resident golden eagle, located on the hillside above Haweswater, west of Shap. Formerly a pair, until 2004 when the female disappeared, the male continues to display at the site. A questionnaire was conducted with tourists in Windermere at the heart of the Lake District National Park. Respondents were asked for their opinion regarding the restoration of a range of species.

Respondents were largely in favour of restoration. Over 95% of respondents were in favour of a reintroduction of golden eagles, with 44% of respondents putting golden eagle as their top priority for restoration. There are both economic and legislative incentives for reintroduction.

The nearby osprey viewing site at Dodd Wood brings in an estimated È2million per annum to the local economy. Eagle restoration has the potential to bring in additional visitors to the area drawing them away from the traditional Lake District honey-pots. In addition to meeting international and European commitments to restoration, the project would also meet local development agency targets towards sustainable tourism.

What remains unclear at this time is the carrying capacity for golden eagles in the Lake District and surrounding countryside, and the attitude of other stakeholders such as hill farmers. However, there appears to be enormous potential for restoration of an iconic species with the potential funding outside of the normal conservation channels.

Releasing and monitoring techniques in the LIFE project ''Actions for the reintroduction of the Bearded Vulture (*Gypaetus barbatus*) in Andalusia''

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Since 2004 Gypaetus Foundation has developed the LIFE project ''Actions for the reintroduction of the Bearded Vulture (*Gypaetus barbatus*) in Andalusia'' (Southern Spain). Within the framework of this project bearded vulture release and monitoring techniques were implemented.

Birds are released yearly in May in the ''Sierras de Cazorla, Segura y Las Villas Natural Park'', an area selected by feasibility studies carried out between 2001 and 2005. Three and two birds were released with a hacking technique in a selected cave in 2006 and 2007 respectively. Released birds are laid, hatched and reared in a net of breeding centres by its natural or foster parents, within a specific European Breeding Program. Bearded vultures are released when around 90 days old. The hacking period lasts 30 days, without direct human contact, until birds are able to fly. Food was provided before dawn, to avoid birds identifying humans as food source. Fundamental monitoring activity during hacking technique was distant direct observation with binoculars and telescopes during all daylight hours. Additional observation was carried out with two cameras located inside the cave. To enable individual identification birds were ringed with a colour code and specific feathers were decolourised. Satellite transmitter device was also attached.

The daily presence of the birds in the hacking area lasted around 4 months since the release date, and was extremely sporadic after the fifth month. Once out of the hacking area, monitoring is mainly implemented by GPS locations and the Social Participation Campaign.