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Towards Integrated Species Conservation

The endangered African wild dog (*Lycaon pictus*) has been restored in South Africa using an integrated species conservation approach, including active metapopulation management. | © Rob Till

Contents

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Editorial

In the *WAZA Vision and Corporate Strategy Towards 2020*, published in 2009, the very first operational objective includes "...the demonstration of links between *ex situ* and *in situ* conservation work...". In line with this objective, we postulate the dawning of the era of integrated species conservation. Under this new paradigm, conservation holistically refers to activities aimed at sustaining biodiversity (i.e. genetic, species and ecosystem diversity), whether conducted in or out of the natural habitat, integrated across the conservation community. Integrated conservation works along a continuum of management intensity, including hardly any human intervention in wild populations all the way to intensively managed populations in human care.

Many wild populations are like populations in human care – small in size, fragmented and with limited gene flow between them. For example, African wild dogs (*Lycaon pictus*) have been reintroduced into small, fenced reserves in South Africa, which necessitates periodic translocation of animals to mimic natural dispersal and maintain gene flow (Davies-Mostert & Gusset, this issue). This model is referred to as a managed metapopulation, as natural metapopulation processes such as dispersal are subject to human intervention. Metapopulation management involves managing a set of interacting populations under a common conservation goal. Its components may include multiple regional populations managed in human care (including in-country breeding programmes), multiple wild populations (including reintroduced populations) and even genome resource banks.

Intensive population management serving conservation goals thus requires transfers of animals. Traditionally, this includes the exchange of animals between holders of the population in human care, import of animals from the wild to either bolster existing or establish new populations in human care, and export of animals from populations in human care to the wild. These transfers can be combined under one umbrella of interactive exchanges of animals (or gametes) between populations in the wild and in human care for mutual reinforcement. The role of populations in human care can vary from little interaction with wild populations all the way to populations with extensive gene flow in both directions. This will greatly enhance our capacity to sustain viable populations both in human care and in the wild.

The science of small population management, developed primarily for managing populations in human care, is therefore of direct relevance to field conservation. For example, fencing is highly effective for conserving lions (*Panthera leo*) in Africa (Packer *et al.* 2013; *Ecol. Lett.* 16: 635–641), but fenced lion populations require human intervention to be viable in the long term. Similarly, subpopulations of the rarest of Africa's carnivores, the Ethiopian wolf (*Canis simensis*), are fragmented to the extent that translocation of animals among the few remaining sites is recommended to restore gene flow (Gotelli *et al.* 2013; *Anim. Conserv.* 16: 234–247). As habitat fragmentation progresses and climate change shifts the boundaries of species' distribution ranges, translocation is likely to become an increasingly important conservation tool. The skills and knowledge of experienced zoo and aquarium professionals are needed to guide such translocation work.

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Cheetahs (*Acinonyx jubatus*) in the Serengeti.

In this edition of the WAZA Magazine, we have compiled various conceptual approaches to integrated species conservation, collectively declaring the end of the *ex situ* and *in situ* conservation dichotomy. Moreover, several case studies of integrated species conservation in practice are presented. We hope that this edition of the WAZA Magazine will demonstrate links between conservationists working at any point along the continuum of management intensity, and thereby further increase the contribution of the world zoo and aquarium community to global biodiversity conservation.

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The One Plan Approach: The Philosophy and Implementation of CBSG's Approach to Integrated Species Conservation Planning

Summary

An increasing number of threatened species are dependent on continuing management for their survival. For these species, it makes little sense to conduct separate and independent conservation planning efforts based on whether these interventions take place in the wild, in increasingly managed parks and reserves or in zoos. The One Plan approach proposed by the IUCN SSC Conservation Breeding Specialist Group (CBSG) promotes integrated species conservation planning, which considers all populations of the species, inside and outside their natural range, under all conditions of management, engaging all responsible parties and all available resources from the very start of any species conservation planning initiative. The One Plan approach aims to: establish new partnerships; ensure that intensively managed populations are as useful as possible to species conservation; increase the level of trust and understanding among conservationists across all conditions of management of a species; accelerate the evolution of species planning tools; and ultimately lead species conservation towards the aspirations embodied in the Aichi Biodiversity Targets.

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The Need

As habitats are increasingly altered and wild animal and plant populations impacted by human activities, a growing number of the world's species are dependent on continuing management for their survival and ultimate conservation. Scott *et al.* (2010) stated that 84% of the species listed under the US Endangered Species Act could be classified as "conservation reliant" and will require continuing, species-specific interventions. Widespread threats such as habitat loss, poaching, invasive species and disease often lead to smaller, isolated populations that require conservation action, not only to avoid extinction but to achieve conservation as defined by WAZA (2005): "securing, for the long term, populations of species in natural ecosystems and habitats", and more specifically by Redford *et al.* (2011): "maintaining multiple populations across the range of the species in representative ecological settings, with replicate populations in each setting. These populations should be self-sustaining, healthy, and genetically robust – and therefore resilient to climate and other environmental changes".

These threats are not only impacting currently endangered species. In their recent analysis of the effects of climate change on biodiversity loss, Warren *et al*. (2013) found that without mitigation, large range contractions can be expected even among common and widespread species, amounting to a substantial global reduction in biodiversity and ecosystem services by the end of this century. Effective integration of planning, and the optimal use of limited resources, across the spectrum of management is essential if we hope to contribute to achieving the global biodiversity targets agreed upon by the Conference of the Parties to the Convention on Biological Diversity in Nagoya, Japan, in 2010, commonly referred to as the Aichi Biodiversity Targets.

Two Plans Are Not Better Than One

An obstacle to this, however, is that species conservation planning has traditionally followed two parallel but separate tracks. Field biologists, wildlife managers and conservationists monitor wild populations, evaluate threats and develop conservation strategies and actions to conserve threatened species in the wild. Meanwhile, the zoo and aquarium community develops long-term goals for *ex situ* populations, sometimes without full access to information about the threats faced by the species' wild counterparts and the opportunities for supporting those populations. While each management plan strives for viability of a particular population, too seldom are these plans developed together to maximise the conservation benefits to the species.

The international zoo community has made tremendous progress recently on the design and development of Global Species Management Plans (GSMPs). However, this label is a misnomer, as the population being planned for is the global captive population, not the global population as a whole. These programmes are designed to general principles usually aimed at retaining conservation value through close management of demographic health and gene diversity. However, their planning lacks the comprehensive input from *in situ* conservation managers that would enable customisation towards the specific management needs of the species as a whole. Without this input, GSMPs, or indeed any captive breeding programmes, will not necessarily be large enough, genetically diverse enough, productive enough, in the right kinds of facilities or in the right place at the right time to provide the support that they could to wild populations.

On the other hand, too many conservation planning and Red Listing workshops take place without sufficient active involvement from the international zoo community. Species conservationists working to conserve unmanaged wild populations often do not see the potential contribution from intensively managed populations; intensively managed populations are rarely considered as part of wider metapopulations from the start, if at all. Redford *et al.* (2011) stated that "we must view captive management as only a stop-gap measure in efforts to move species up the continuum" towards a fully conserved state.

The IUCN Red List of Threatened Species recognises the impact of captive stocks on a species' conservation status in its distinction between Extinct and Extinct in the Wild. However, it makes no attempt to quantify this contribution, either at any point prior to the complete loss of the species in the wild or at any point after, despite the fact that, as a species approaches extinction in the wild, the chances of establishing a healthy captive programme or of reshaping an existing one into an appropriate programme of management become increasingly small. When existence in the wild is threatened, then populations of that species, wherever they are, are potentially of conservation value. A status assessment that includes and evaluates all populations of a species, inside and outside their natural range, would thus be a useful aid to planning and prioritisation.

We are all trying desperately to save species, and the definition of conservation is, for the most part, agreed upon. What differentiates the captive community from other conservation entities is its ability to buy time. It can do this by securing populations from threatening processes in the wild, while concurrent conservation activities battle these threats *in situ*. In the majority of cases there is no consensus on how to remove these threats, and in many instances (e.g. for species threatened by amphibian chytrid fungus) we do not have the technical ability to do so. For a number of species, captive populations could well provide a critical and ongoing conservation resource for the foreseeable future.

Where there are populations in captivity, we must consider those populations when developing a conservation plan. CBSG is placed at the interface between the zoo community and the global species conservation community, has over 30 years of experience with species conservation planning, and can therefore potentially bridge this gap and facilitate an improved contribution of the zoo community to successful species conservation globally. (Fig. 1)


Fig. 1
Captive Okinawa rail with radio-transmitter.
© Kathy Traylor-Holzer

The One Plan Approach Defined

Population management across a continuum that bridges wild and intensively managed conditions can serve as an important tool to progress species "up the ladder", towards fully conserved status. CBSG, through its One Plan approach, supports integrated species conservation planning through the joint development of management strategies and conservation actions by all responsible parties to produce one comprehensive conservation plan for the species. Integrated species planning is not a new concept: such holistic conservation efforts have led to several well-known conservation successes, from golden lion tamarins in Brazil to Puerto Rican crested toads in the Caribbean to Arabian oryx in the Middle East. Previous CBSG workshops for species such as the Okinawa rail (Figs 1 and 2), red-headed wood pigeon and black-footed ferret developed integrated species conservation plans across an interactive wild–*ex situ* spectrum. Other examples include African penguins (Schwitzer *et al.*, this issue) and Tasmanian devils (Lees *et al.*, this issue). Our vision is to make comprehensive conservation planning more commonplace and effective. (Fig. 2)

The Benefits of Implementation

Assessment of threats to wild populations and evaluation of potential strategies to address those threats should consider the wide array of options offered by intensive population management, and if and how these tools might promote conservation of the species in the wild. Options include: source populations for demographic or genetic supplementation; assurance populations against imminent threats such as disease or invasive species; research populations to develop monitoring or management techniques; and head-start programmes that temporarily shelter juveniles from high mortality and promote population growth. In turn, wild populations will boost the long-term viability of *ex situ* populations by supplying genetic founders that can or must be removed from the wild, such as excess offspring, nuisance or injured individuals that cannot be released or non-viable population fragments.

The CBSG workshop process is ideally suited to implementation of the One Plan approach. As Redford *et al.* (2011) note, "developing such a positive vision with a broad range of stakeholders produces a positive atmosphere, facilitates cooperation, and allows for development of essential partnerships and political support". In addition, the newly revised *IUCN SSC Guidelines on the Use of Ex Situ Management for Species Conservation* (IUCN SSC, in prep.), in essence, call for just such an approach, and the SSC/Global Species Programme strategic plan, which guides the work of CBSG and all other SSC Specialist Groups, includes among species conservation planning targets the application of the One Plan approach over the next quadrennium.


Fig. 2
Wild Okinawa rail.
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The zoo and aquarium community is actively building links with the SSC Specialist Groups and field conservation agencies. Its members are committed to making available to their conservation colleagues the captive community's specialised skills and valuable resources to assist in conservation. The One Plan approach is a working model of how the benefits of this conservation opportunity can be fully realised. Our goal is to promote and routinely apply the One Plan approach in the coming years. The result should be integrated conservation plans that mobilise the full suite of skills and resources available to species in trouble, giving them a better chance at a future in the wild.

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Integrating Assessment of *Ex Situ* Management Options into Species Conservation Planning

Summary

As the biodiversity crisis intensifies, an increasing number of species will likely require some form of intensive population management in order to avoid extinction. The revised *IUCN SSC Guidelines on the Use of Ex Situ Management for Species Conservation* will provide better guidance on *if* and *when ex situ* activities are a beneficial component of an overall species conservation strategy. These guidelines outline a five-step decision-making process that defines potential *ex situ* conservation roles, the type of *ex situ* activities needed to fulfil those roles, and the feasibility, risks and likelihood of success. *Ex situ* management can be used more effectively as a conservation tool if the specific ways in which *ex situ* strategies can improve population viability or prevent extinction are identified and critically evaluated as part of an integrated approach to species conservation planning.

Why Wild Populations Go Extinct

Wildlife populations are increasingly under risk of extinction. Climate change, habitat loss, exploitation, invasive species, disease – these all-too-familiar threats frequently result in wild populations becoming small and fragmented. At this point a new threat emerges – the added vulnerability of small populations to random stochastic processes (e.g. environmental variation, catastrophes, random variation in survival and reproduction, skewed sex ratio, genetic drift, inbreeding) that can feed back into each other, causing a species to be caught in the "extinction vortex" (Gilpin & Soulé 1986). Once caught in this downward spiral, populations may be doomed to extinction, even if the original primary threats are removed.

Conservation planning for species needs to consider all threats to species survival, both long-term and immediate, both deterministic and stochastic. As the biodiversity crisis intensifies and wild populations decline, more species will likely require some form of intensive management at the level of populations and individuals to avoid extinction. Intensive management of populations for conservation can take place across a broad *in situ–ex situ* continuum, within and/or outside of zoos and aquariums (Baker *et al.* 2011; CBSG 2011). In some cases, *ex situ* management can play a significant role in species conservation and therefore should be assessed as a possible conservation tool in species conservation planning.

How *Ex Situ* Activities Can Help

Ex situ conservation activities can support species conservation and prevention of extinction in a variety of ways, by:

Offsetting the Effects of Threats. Ex situ activities can improve the demographic and/or genetic viability of a wild population by ameliorating the impacts of primary or stochastic threats on the population, such as reduced survival, poor reproduction and genetic isolation. Examples include head-start programmes that remove juveniles from the wild for *ex situ* care and return them once they are less vulnerable to predators or other threats (e.g. hellbenders, Western pond turtles), and cross-fostering of captive-born neonates to wild parents (e.g. red wolves).

Addressing the Causes of Primary Threats. Ex situ activities can help reduce primary threats such as habitat loss, exploitation, invasive species or disease through specifically designed research, training or conservation education activities that directly and effectively impact the causes of these threats (e.g. education to reduce the spread of invasive species or buying of exotic pets, research to eradicate or treat disease).

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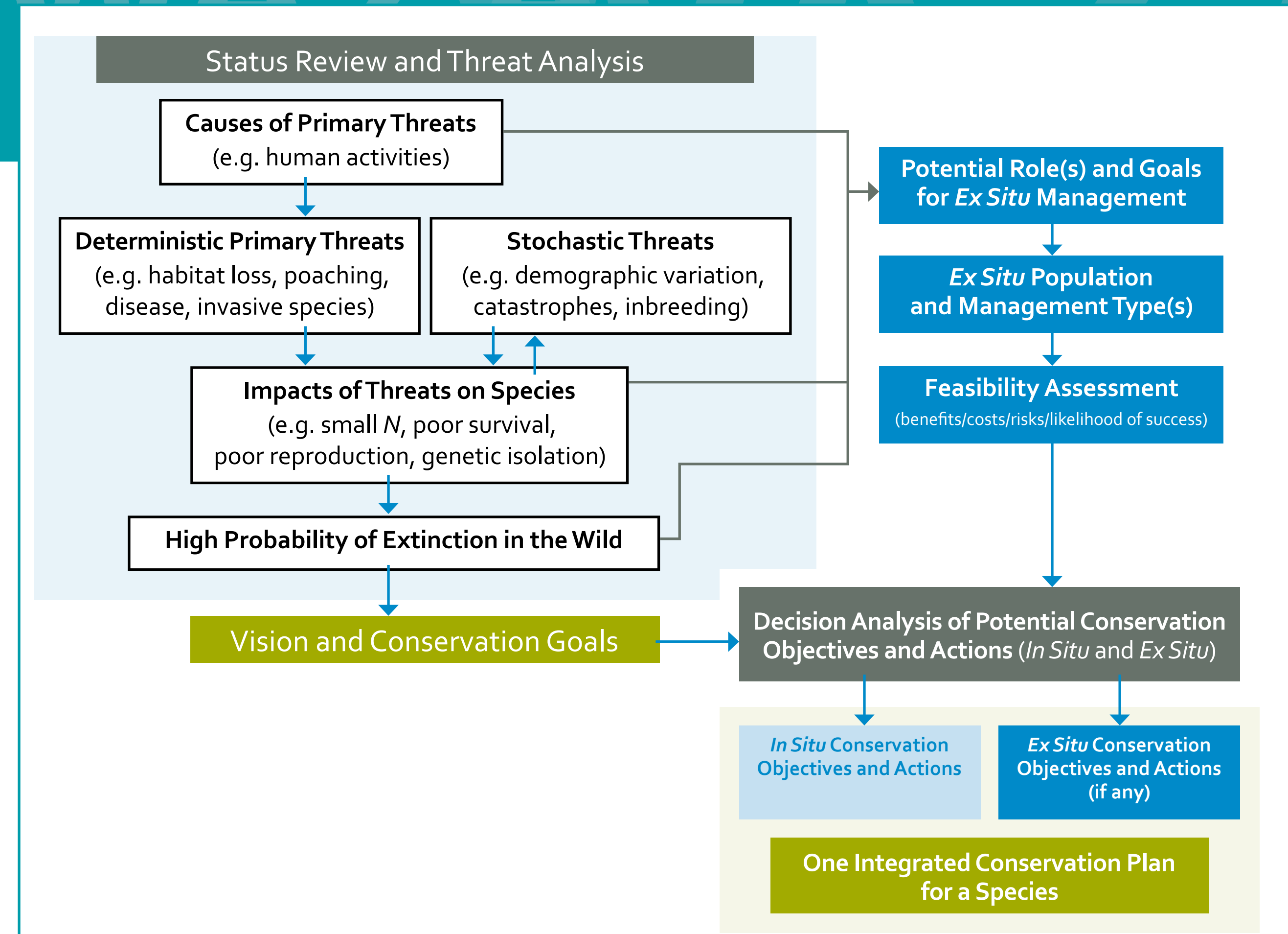

Fig. 1
Incorporation of the decision process proposed in the revised IUCN guidelines (dark blue boxes) into the species conservation planning process to develop one integrated plan for the species.

Buying Time. Establishment of a diverse and sustainable *ex situ* rescue or assurance population may be critical in preventing species extinction when wild population decline is relatively steep and the chance of sufficiently rapid reduction of primary threats is slim or uncertain or has been inadequately successful to date. Examples include *ex situ* populations in response to severe disease threat (e.g. Tasmanian devils facing facial tumour disease, amphibian species susceptible to chytrid fungus), catastrophic events (e.g. Perdido key beach mice at risk due to hurricanes) or continued habitat degradation (e.g. golden-headed lion tamarins in fragmented and degraded Atlantic Forest).

Restoring Wild Populations. Once the primary threats have been sufficiently addressed, *ex situ* populations can be used to genetically and/or demographically re-establish wild populations (e.g. Puerto Rican crested toad, Vancouver Island marmot, Arabian oryx, Mauritius kestrel).

How the IUCN Guidelines Can Aid in Planning

The IUCN Species Survival Commission (SSC) is finalising a revision of its guidelines on the use of *ex situ* management for species conservation, coordinated by the IUCN SSC Conservation Breeding Specialist Group (CBSG) (IUCN SSC, in prep.). Although not yet formally approved by SSC, these guidelines are anticipated to outline five steps for a more formal, informed and transparent decision-making process to provide guidance on *if* and *when ex situ* activities are a beneficial component of an overall species conservation strategy. This process ideally would be used as an integral part of, and in complement to, existing species conservation planning processes such as CBSG's Population and Habitat Viability Assessment (PHVA) process and IUCN SSC's handbook for *Strategic Planning for Species Conservation* (IUCN SSC 2008) (Fig. 1).

These steps are:

1. *Conduct a Thorough Status Assessment and Threat Analysis.* A thorough and detailed examination of the causal factors leading to the primary threats, as well as the precise effects that both the primary and stochastic threats have on the reproduction, survival and distribution of the species, allows the identification of potential intervention points for conservation action.
2. *Identify Potential* Ex Situ *Conservation Roles.* Potential intervention points can guide the identification of *ex situ* activities (as well as other conservation actions) that can prevent or reduce negative impacts on the wild population. This will define any potential conservation roles that *ex situ* management can play in the overall conservation of the species.

3. *Define the Required Programme Structure*. The purpose and function of an *ex situ* population or activity will determine the characteristics and dimensions of the programme needed to fulfil the identified conservation role(s).
4. *Assess Programme Feasibility*. It is important to assess not only the potential value of an *ex situ* programme, but also the resources and expertise needed for such *ex situ* activities, the costs and risks associated with them and the feasibility and likelihood of success.
5. *Make a Decision on* Ex Situ *Options*. The above information is used to reach a decision regarding *ex situ* activities for conservation that is informed and transparent (i.e. demonstrates how and why the decision was taken).

Following such a process, whereby the need for *ex situ* activities is not automatically dismissed, nor automatically included, but carefully evaluated as a normal part of conservation planning, will ensure that any *ex situ* activities selected are carefully tailored, in form and function, to the needs of the species.

The guidelines for the use of *ex situ* management for species conservation are undergoing the final revision and review process within IUCN SSC and are expected to be finalised in late 2013. These guidelines will be applicable across taxa, to biobanks as well as to individuals, and for situations in which *ex situ* management is or is not already underway. Not all species conservation strategies will require an *ex situ* component, in the same way that other management interventions may or may not be required to conserve a species. In some cases *ex situ* management will be central to a conservation strategy, in others it will be of secondary importance, supporting other interventions, and in yet others it will not feature at all.

Case Study: North American Bats

Many species of North American insectivorous bats are at risk due an emerging disease – White Nose Syndrome (WNS) – that is rapidly spreading across the eastern USA. WNS infects hibernating bats and has resulted in mortality as high as 95% in many wild bat colonies. Up to 40 bat species, including several threatened species, could be vulnerable. While rescue *ex situ* populations might be indicated, it is difficult to maintain insectivorous, hibernating bats under *ex situ* conditions. A collaborative US Fish and Wildlife Service–CBSG workshop brought a diverse group of bat experts together to consider the feasibility of *ex situ* management options for these bat species as part of an overall conservation strategy (Traylor-Holzer *et al*. 2010).

Conservation goals were identified, a threat analysis was conducted and numerous potential conservation roles of *ex situ* populations were identified. The required *ex situ* programme structure and expertise differed substantially across these different roles. Table 1 outlines some examples of how the purpose of an *ex situ* bat population may require different number of individuals, number and type of facilities, different expertise, different time frames and even different taxa. To complete this evaluation process, extensive data were compiled for each bat species regarding relevant life history, behavioural traits and existing captive expertise to guide the assessment of programme structure, costs and likelihood of success. This thorough analysis followed the decision-making process suggested in the revised IUCN guidelines and led to a well-informed and documented evaluation from which species-specific conservation planning could be conducted and reassessed in the future.

Table 1 An example (using bats) of how the conservation role of an *ex situ* population can determine the required programme structure, length, taxon, expertise and other characteristics (WNS = White Nose Syndrome).

Role	Type	Structure/expertise needed
Temporary rescue from imminent threat	Short-term holding during winter hibernation	Ability to hold large number of animals, hibernate successfully through winter (off-exhibit) and release successfully in spring
Assurance population against extinction	Long-term breeding population as a genetic and demographic backup	Capture sufficient founders and breed successfully for many generations while minimising adaption to captivity
Mitigation of WNS impacts on bats	Research population for understanding and treating WNS	May be able to use a related common species and apply results and techniques to endangered bat species
Mitigation of spread of WNS to other sites	Exhibits that raise public awareness about spreading WNS while exploring caves	Can use a common species that is easy to maintain in captivity, with exhibits in multiple zoos near species habitat

How to Achieve Integration

Ex situ management can be used more effectively as a conservation tool if it is part of an integrated approach to species conservation planning, whereby *in situ* and *ex situ* communities together form one overall species conservation plan, including, where appropriate, intensive management of populations *in situ* and/or *ex situ*.

What does this mean for zoos and aquariums committed to conservation? In the ideal future world, integrated conservation plans would exist for all threatened species, in which potential conservation role(s) for *ex situ* management have been carefully evaluated for appropriateness, feasibility and effectiveness. This would facilitate regional collection planning for zoos and aquariums, at the least from the point of view of direct *ex situ* conservation, as each threatened species would have clearly identified *ex situ* conservation activities, if any, and it would be clear if and how zoos can support those activities. This would also ensure that all potential conservation efforts were being used to save a species from extinction.

Integrated species conservation planning needs to come from both sides. The field conservation community needs to embrace *ex situ* management options as part of the larger conservation toolbox to address threats to wild populations and avoid extinction. Likewise, the *ex situ* community needs to re-evaluate its existing and proposed programmes in terms of the conservation role(s) that they can play and structure those programmes to meet those roles effectively (see Lacy *et al.*, this issue). The revised *IUCN SSC Guidelines on the Use of Ex Situ Management for Species Conservation* provide a decision-making process that can be used by both conservation communities to evaluate *if* and *when* to pursue *ex situ* management options. When included as one component of a larger, stakeholder-inclusive species conservation planning process (involving collaborations between zoos, aquariums and other *ex situ* specialists, wildlife agencies, researchers, non-governmental organisations, etc.), application of these guidelines can promote a truly integrated One Plan approach (Byers *et al.*, this issue) to the conservation of a species. The species mentioned as examples above are sound testimonies to this principle.

There is increasing need to strengthen the integration of *in situ* and *ex situ* conservation planning to ensure that, whenever appropriate, *ex situ* management is used to support *in situ* conservation to the best possible effect. When used strategically, *ex situ* conservation can be a potent tool for species conservation that does not undermine, but complements, the imperatives of field conservation.

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Managing for True Sustainability of Species

Summary

Despite the increasing conservation need for intensive population management, zoos are failing to maintain sustainable and diverse *ex situ* populations that contribute to species conservation. In this paper, we define the problems and identify strategies and actions for meeting this challenge.

Recognising the Problems

The "wild" of our childhood is no more. Human populations continue to expand, habitats are increasingly altered by human activities, invasive species are spreading, new diseases are emerging – and species need to adapt to these new challenges if they are to persist. Increasingly fragmented wildlife populations are at greater risk and in more need of support because they face unique threats and lack the diversity to respond. The call to action is widespread and urgent, imploring all conservation partners to use their resources and expertise effectively to advert widespread species extinctions. Zoos (including aquariums) have an expanding role and responsibility to contribute to species conservation amid this biodiversity crisis (Baker *et al.* 2011).

The increasingly necessary conservation tools of assurance populations, reintroduction and supplementation require sustainable *ex situ* populations. Unfortunately, zoos are failing to achieve this on many levels. First, currently only a small percentage of threatened species are held by zoos. Second, a small percentage of species in zoos are managed scientifically, and, finally, few of these are considered to be managed sustainably (Traylor-Holzer 2011). Moreover, our measuring stick for "sustainability" typically has been the maintenance of 90% gene diversity for 100 years, usually applied to an independent regional population. However, true sustainability is the maintenance of a resource without depletion or loss of its value. Thus, our benchmark by which "sustainability" is measured is not an indicator of true sustainability but rather acquiescence to an accepted rate of genetic decay (Ballou & Traylor-Holzer 2011; Lacy 2013). Zoos cannot serve as secure havens for averting extinction or be used as source populations for species conservation activities if we accept depletion of the adaptability that those populations will need to survive, and then often fail to meet even these inadequate goals.

Achieving Sustainability

Achieving success must start with clear goals, derived from a comprehensive conservation strategy for the species that defines what the broader community values – not just the individual zoo or zoo association or even the global zoo community, but the global conservation community. What do we mean by saving the species? Who will take responsibility for conducting each component of the conservation plan? And, perhaps most critically, who will be the species' champion to make sure that we do not just watch extinction occur? Addressing these questions is beyond the scope of this contribution, but they need to be addressed at a global level, species by species (IUCN SSC 2008).

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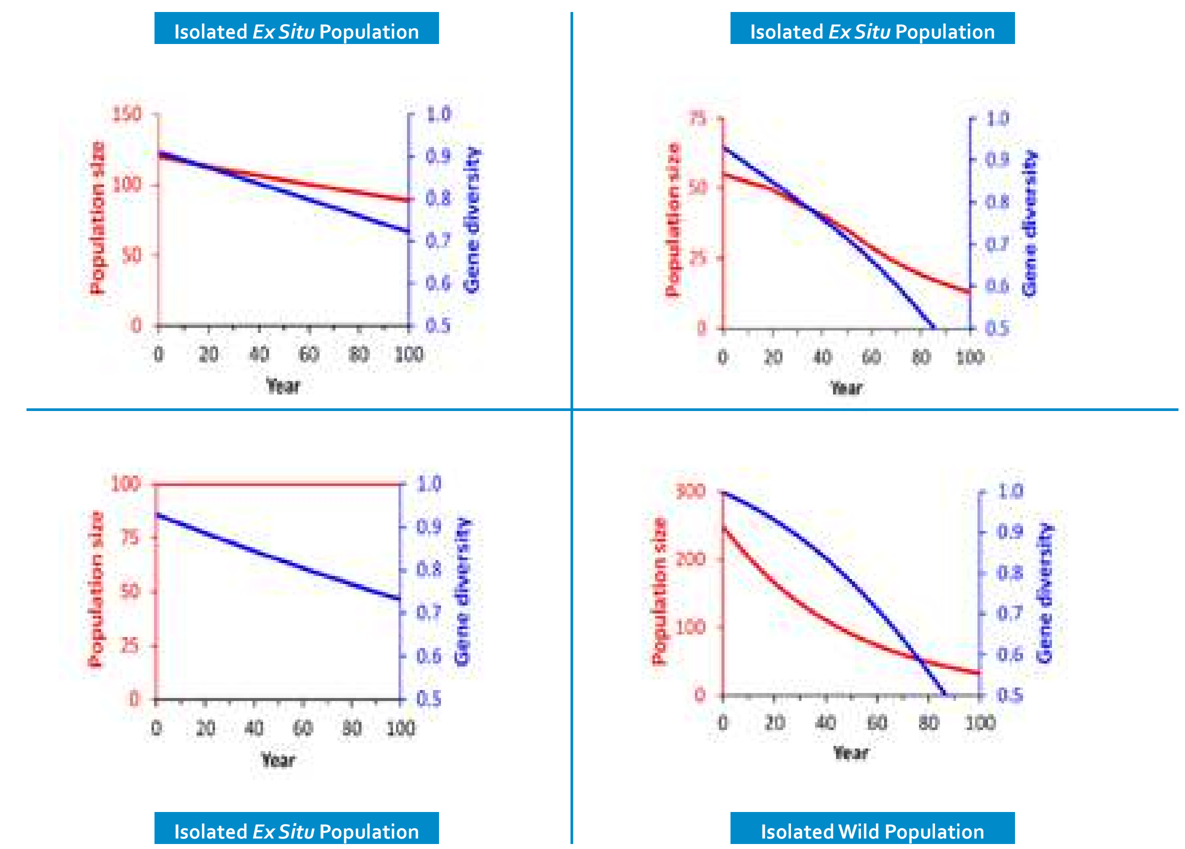

Fig. 1
Small isolated populations. Small population size with poor growth (red line) and rapid loss of gene diversity (blue line) lead to increased inbreeding and instability, resulting in decreased individual fitness, loss of genetic evolutionary potential and increased risk of population extinction.

For many species, this comprehensive species-level strategy will include the question: What are the roles of populations held at zoos? To serve as an effective source for restoring healthy wild populations, *ex situ* populations must be truly sustainable and they must contain evolutionary potential to allow adaptation to a rapidly changing global environment. True population sustainability cannot be achieved through small isolated populations managed through independent plans, but will require new and integrated management approaches among interacting populations that may transverse a broad management continuum (Redford *et al.* 2012; Lacy 2013). Collaborative management among zoos, among zoo regional programmes, between captive and wild populations, between living individuals and gametes held in a genome resource bank are all important components of integrated metapopulation management programmes that support species conservation – a One Plan approach as discussed by Byers *et al.* (this issue).

An integrated approach leads to larger and more robust populations that can maintain genetic variation through periodic, well-planned exchanges, moving from a plan for slow decay (Fig. 1) to one of sustainable maintenance (Fig. 2). In addition, the diversity of environmental conditions and management strategies across such a metapopulation better allows us to move from the narrow target of maintaining neutral genetic diversity measured through pedigree analysis to preservation of other types of variation, including behavioural, morphological, physiological and adaptive genetic variation. Through effective integration, a holistic metapopulation approach can pool "resources" in the broadest sense of the term – space, animals, genes, expertise, funds – to have the greatest conservation impact. It should also be obvious that numerous diverse, healthy, breeding animals serving to help save species will promote other purposes of zoos as well.

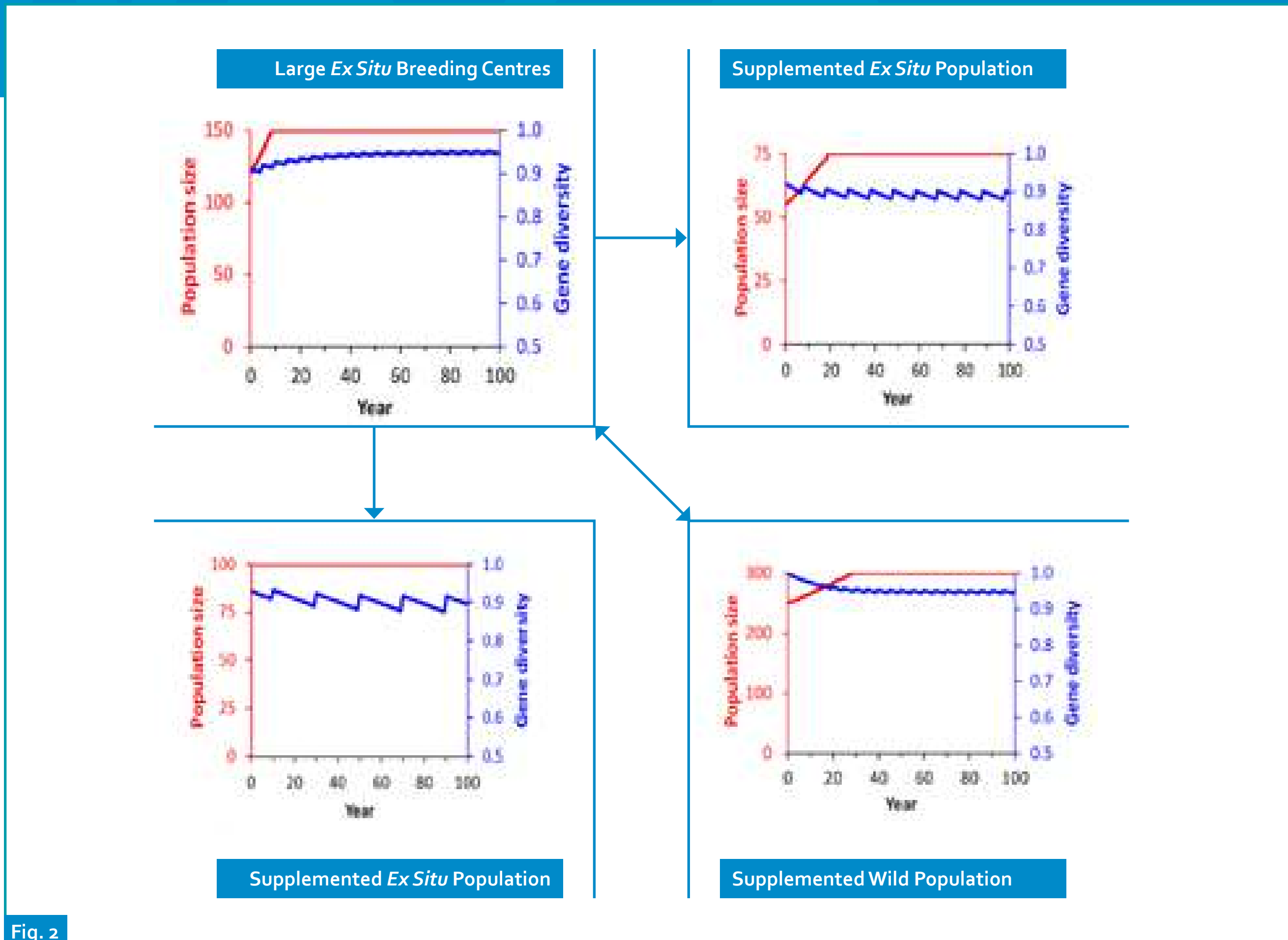

Fig. 2
Interconnected metapopulation. Improved breeding success and periodic animal exchanges promote strong population growth (red line) and maintenance of genetic potential (blue line), resulting in sustainable populations in both captivity and the wild.

Tailoring Solutions to the Problem

With a clear understanding of the goals for sustaining a species and the roles to be filled by zoo populations, the methodologies necessary to successfully fill those roles can be determined. This analysis must start with specifying what trajectory (in terms of population size, growth, stability, variability and resilience, and in terms of impacts on audiences) we desire for each population – with constant reference back to the overall species' conservation plan, rather than relying on *ad hoc* justifications or a generic template, as is the case for many of the current breeding programmes. Current and expected trajectories must be compared, the reasons for any gaps between the two identified and plans put in place to correct the deficiencies. Listed below are several types of deficiencies not uncommon in managed populations, along with some strategies for resolution.

If managed populations for a species are too small to be demographically and genetically robust, then a choice must be made as to whether or not *ex situ* populations will serve a conservation role for that species. If it is affirmed that they should, then:

- recruit additional zoos to manage the species;
- have each zoo maintaining the species commit to keeping a larger number of individuals;
- institute exchanges to link formerly disconnected *ex situ* populations through joint management and mutual support;
- create new specialised breeding facilities;
- establish a programme of managed and mutually beneficial exchanges between *ex situ* and *in situ* populations; and/or
- use gamete banks to increase the genetically effective size of a population.

If the source population that founded the existing *ex situ* population was too small or otherwise of limited genetic diversity, of unknown history or of uncertain taxonomy, then:

- determine the taxonomy, history and diversity of the source on which the managed population is based;
- combine programmes for subspecies that are not reproductively isolated or strongly differentiated, especially if sub-specific identity of animals is uncertain or already mixed;
- obtain new founders from other breeding programmes; and/or
- obtain new founders from wild populations able to sustain such removals.

If exhibit practices and husbandry protocols do not result in sufficient reproduction and survival to meet population goals, then:

- transfer animals to facilities that can achieve those levels;
- develop new or redesigned facilities, such as specialised breeding centres; and/or
- change the social management (e.g. natural social groupings, mate choice).

If the species biology or husbandry requirements are not sufficiently known to identify which actions are needed, then:

- implement research programmes in the field or in zoos to provide the needed data.

If the *ex situ* population is being sustained biologically, but the positive conservation effect is not being achieved, then:

- improve integration with efforts for wild populations;
- communicate effectively to audiences to change behaviours that are counter to conservation; and/or
- reallocate resources towards methods that successfully counter threats to the species.

Acting Locally

Many of the above are obvious options, many have been suggested before and almost all either require or are more easily achieved by institutions working in collaborative partnerships – both within the zoo community and with other conservation organisations. However, there are many things that each institution can do by itself and to promote the needed partnerships.

First, develop institutional animal collections based on identified conservation needs and opportunities. If comprehensive conservation plans (or Regional Collection Plans based on broader input) exist for species you are considering, use these plans to identify where your efforts are most needed. If such plans do not yet exist, contact IUCN SSC specialist groups, governmental agencies and others to offer to host or support such an assessment and planning. Let it be known that your zoo has resources for species conservation – such as expertise, access to audiences, breeding facilities, funding – but that you need help to make sure that the resources are used where and how they are most needed. If you do not know where to begin to make the right contacts, ask WAZA or the IUCN SSC Conservation Breeding Specialist Group for help.

For programmes that need coordination, identify who at your zoo can serve as the species manager, support their position and then hold them accountable for success. The species manager should develop a realistic long-term management plan for ensuring that the population can serve the identified goals. If the population serves as insurance against loss of the species, be certain that the number of founders, breeding population size and space for population growth are adequate to sustain a genetically diverse and demographically robust population. If calculations show that this need is not being met, determine from where and how many new founders, additional breeding spaces, new breeding consortium partner or other resources are needed. Do not accept an explanation that although a population is not projected to meet goals, there is no clear solution and therefore management will continue as before. If the husbandry and technologies for managing the species well are not yet known, determine what research needs to be supported by your institution to answer the critical questions. Do not assume that someone will develop the techniques that you will need to succeed with the species; be proactive in pushing for a solution.

For each species that is in your collection because it needs protection, make sure that your institution has a clearly stated conservation goal. These goals should be documented, understood by all involved and specific regarding what purposes those animals are serving in the broader conservation strategy for the species (not just vaguely defined as "display" or "education" or "breeding").

Periodically confirm that you are meeting your institution's goals for each species and contributing to its overall conservation. If you did not meet targets, decide what further efforts are needed. If the species status is not improving in the wild, ask the broader community for a reassessment of threats and the needed responses. Explain to your public, staff, members and trustees or local authorities what you are doing for conservation of the threatened species. Document and then explain proudly how the programmes at your institution helped to save species for which you have accepted responsibility.

Invest in the Future, Not in the Past

True sustainability of the wildlife populations under the care of zoos is necessary for the future of zoos and the future of many species, but success will require new investments in new ideas with new partners. Our current species management programmes are mostly focused on holding on to remnants of the animal resources we once had, and in many cases we are not even meeting short-term goals. Instead of continuing to use only resources and methods that have been insufficient to date, we need to decide what animals, research, facilities, people and approaches will be needed to achieve species conservation goals.

There are a number of programmes in which zoos are already working closely with many partners to achieve success for species – such as the Amphibian Ark, the international golden lion tamarin programme, a consortium working for Humboldt penguins in Peru, efforts to prevent the loss of the Tasmanian devil to disease, restoration of the fire-bellied toad in Denmark and Germany, and the Sumatran tiger Global Species Management Plan. We need many more such programmes – so that the One Plan approach becomes the norm for species conservation by zoos rather than exceptional models. The precarious future for so many species demands such an affirmative response.

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The Need to Balance *Ex Situ* and *In Situ* Conservation

Summary

In situ conservation is central to contemporary global biodiversity protection and is the predominant emphasis of international regulation and funding strategies. *Ex situ* approaches, in contrast, have been relegated to a subsidiary role and their direct contributions to conservation have been limited. Evidence exists for the conservation community to make a strong case for an enhanced role for *ex situ* conservation. We note the advances occurring within institutions specialising in *ex situ* conservation and stress that, although much remains to be done, many constraints are being addressed. The evidence of increasing extinction rates, exacerbated by climate change, challenges the wisdom of a heavy dependence on *in situ* strategies and necessitates increased development of *ex situ* approaches. A number of different techniques that enable species and their habitats to survive should now be explored. Moreover, the relentless loss of "the wild" may soon render the *in situ*–*ex situ* distinction misleading, or even obsolete.

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Introduction

In situ and *ex situ* conservation are seen as two distinct approaches to the protection of wild species. *In situ* conservation, defined by the Convention on Biological Diversity (CBD) with reference to the protection of species in their natural surroundings, derives primarily from scientific considerations concerning the conservation benefits that accrue from the protection of integrated habitats and ecosystems. Since the 1992 Earth Summit in Rio de Janeiro, Brazil, *in situ* conservation has been designated, expressly, as the legal and institutional priority. CBD and other global instruments and funding strategies address a range of practices relating to *in situ* measures for conservation and relegate *ex situ* approaches to a subordinated supply role, as seen in CBD Articles 8 and 9.

We wish to stimulate discussions about the need to revise the contributions that *ex situ* approaches can make to conservation. We consider that *ex situ* conservation has a more important role to play, especially in the face of the evidence of increasing extinction rates, exacerbated by climate change. Integrated conservation management approaches hold much potential, but we must recognise the significance of institutional factors, not just the science, that have hitherto constrained the development of direct conservation contributions from *ex situ* and integrated techniques. We also question the continued validity of the *in situ*–*ex situ* distinction.

Ex Situ Institutions

The vehicles of *ex situ* conservation are those organisations that hold wild plants and animals and genetic material: zoos, aquariums, botanic gardens, arboreta and seed banks. Although these already lay claim to support conservation through a range of education, research and funding activities, their potential to contribute in more direct ways to the conservation of species has increased with recent developments. Specifically, these organisations and their networks have proliferated across the globe, such as Botanic Gardens Conservation International (BGCI) and the World Association of Zoos and Aquariums (WAZA). For example, the International Species Information System (ISIS) is an international non-profit organisation serving zoos and aquariums worldwide, and manages a comprehensive database of animal species and their environments for animal management and conservation goals. It records over 2 million captive animals of almost 15,000 taxa and 10,000 species.

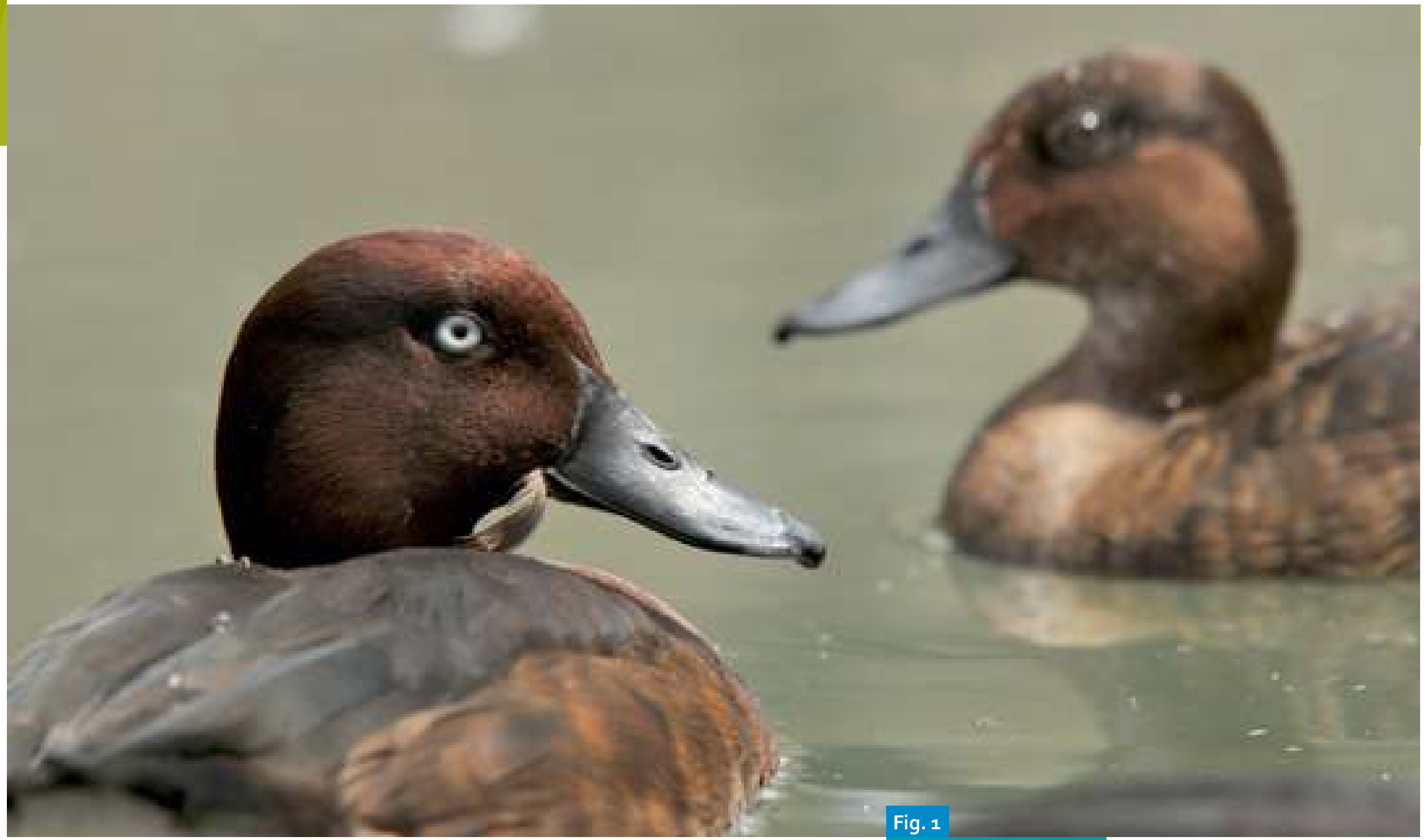

Fig. 1
Madagascar pochard.
© Gerardo Garcia

BGCI manages a database with records of 2,561 botanic gardens worldwide, with 1,000 of these added in the last 10 years. These botanic gardens cultivate 80,000 species in living collections, and increasingly hold seed banks and *in vitro* collections. Close to 700 botanic gardens have supplied collection data to BGCI for the global PlantSearch database that contains 500,000 records of about 180,000 taxa. Facilities for storing and exchanging plant genetic material of cultivated crops have also expanded, primarily in response to the food security and resilience agenda, conforming, *inter alia*, to the requirements of the International Treaty on Plant Genetic Resources for Food and Agriculture. Whereas in the 1970s 0.5 million samples were held in 10 gene banks, now 6.1 million samples are stored in 1,308 gene banks. These represent infrastructural and professional advances to deal with challenges that have hitherto frustrated the capacities of *ex situ* facilities.

Overcoming Limitations

Earlier limitations of *ex situ* facilities to conserve species have been overcome given improved technical knowledge and practices with regard to collection strategies, genetic assessment, storage techniques and captive population management. *Ex situ* organisations have also accumulated a portfolio of direct, tangible impacts on conservation (Figs 1 and 2) and performance indicators have been refined to measure this role. The world's botanic gardens contain 12,000 globally threatened plant species and about 800 botanic gardens are managed with a specific focus on plant conservation. Many botanic gardens also manage nature reserves and other forms of protected areas to combine *ex situ* methods with *in situ* plant conservation, and have increased engagement with local communities on livelihood issues, a key component of contemporary, holistic conservation strategies. Botanic gardens also play an important role in the implementation of the *Global Strategy for Plant Conservation*.

The *ex situ* breeding of animals or plants for direct conservation purposes has been frustrated by limited or conflicting organisational missions. But a further move away from the mere possession of extensive horticultural or exotic animal collections to one fulfilling a more active conservation role is now thwarted by a lack of financial incentives. The largest source of international biodiversity funding, the Global Environmental Facility (the funding mechanism of CBD), has no focal area for *ex situ* activities. How to balance the need, or preference, to generate revenue from visitor attraction with achieving direct conservation is a central and contentious theme within and amongst *ex situ* institutions. The financial pressure is perhaps less acute for botanical institutions, as threatened plant species can be kept in a relatively straightforward and inexpensive manner.

Fig. 2
Ploughshare tortoise.
© Quentin Bloxam

However, this dilemma is particularly challenging for zoos (Stanley Price & Fa 2007). Whilst claims and counterclaims abound regarding the nature and levels of support that zoos actually provide to conservation (Gusset & Dick 2010), sections of the zoo community urge zoos to involve themselves more in the immediate task of saving greater numbers of species from extinction (Fa *et al.* 2011), and "preserving wildlife… through field conservation initiatives" (Bonner 2011) as part of their existing multifaceted portfolio of approaches to support conservation. This more direct contribution can coexist with the other conservation support approaches that *ex situ* facilities currently employ. While it remains to be defined how this can be best achieved, in the case of zoos an immediate advance would be to focus on keeping more individuals of smaller threatened species and to coordinate effective captive breeding programmes for them, given their higher breeding rates and lower maintenance costs. Evidence from European and North American animal collections (Pritchard *et al.* 2012) demonstrates that this is still not happening. The emphasis on large charismatic animals persists (Fa *et al.* 2011).

Changing the Legal Landscape

Whereas international law and policy already deals with *in situ* conservation in relatively complex prescriptive provisions, frameworks that prescribe a meta-strategy for *ex situ* centres have not been developed. For example, although initiatives such as the European Union's Zoos Directive support *ex situ* strategies and global documents such as the *World Zoo and Aquarium Conservation Strategy* urge zoos to contribute to conservation, these fall short of effectively linking zoos into collaborative and strategic conservation activities. The impact of such initiatives is limited by the absence of effective international coordination, which necessarily, being a global issue, cannot be addressed by the array of regional associations and coordinated breeding programmes that currently exist. Moreover, there is no centralised institutional mechanism to access and disseminate data on animal genetic resources within zoos similar to the Food and Agriculture Organisation's Domestic Animal Diversity Information System. This is a tool to conserve elements of global animal biodiversity, even though it was established to manage animal genetic resources for food security and resilience strategies. Despite remaining shortcomings, *ex situ* conservation has an increasingly important role to play. Current circumstances, especially climate change, expose the vulnerability of our reliance on *in situ* approaches that seek to maintain natural systems and processes in specific geographical locations.

If the most important objective of the global conservation mission, to minimise extinctions, is to be coupled successfully with the wider global agenda, including food security and human health, then *ex situ* strategies can no longer be regarded as mere support mechanisms for *in situ* conservation. Emphasis must not only be on increasing the number of threatened species in *ex situ* collections, but on assessing and ensuring the conservation value of such collections. For plants a major issue is that about 33% of globally threatened plant species are cultivated only in one botanic garden. In addition, genetically representative collections are essential if they are to be used for recovery and restoration work. For animals there are known consequences of captive environments on morphology, behaviour and physiology that still need resolution, but substantial improvements have been made on how animals should optimally be kept in captivity (Hosey *et al.* 2009).

Moving Forward

Independently of debates concerning the scientific merits of *ex situ* approaches, there are other entrenched obstacles to an enhanced role for *ex situ* techniques. Prevailing *in situ* conservation work is institutionalised through myriad public and private groups that operate at local, national and international levels. The large international organisations that characterise conservation science and practice exert influence on international conservation policy and facilitate the flow of funding. Borrowing from policy analysis, we can appreciate how the interests of such groups of conservation organisations may become linked to the perpetuation of particular policy interventions around the *in situ* paradigm. Integrating techniques from both *in situ* and *ex situ* approaches may contribute to removing the professional chasm that has for so long divided *ex situ* and *in situ* specialists.

Recognition of an expanded role for *ex situ* conservation techniques will necessarily involve a re-evaluation of accepted concepts and the related legal prescriptions concerning the meaning of what constitutes the range of a species. Range may become meaningless for those species for which predictions imply rapid and unpredictable perturbations in their former natural surroundings. This presents a profound challenge to the notion of *in situ* conservation and may result in the distinction between *ex situ* and *in situ* conservation blurring to the point of disappearing altogether. It is conceivable that a more nuanced appreciation may emerge that goes beyond this false dichotomy to identify instead how best to harness respective and complementary techniques.

Acknowledgements

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The Long Overdue Death of the *Ex Situ* and *In Situ* Dichotomy in Species Conservation

Summary

Successful species conservation has usually been defined as avoiding extinction. Rather than manage extinction risk, it is imperative to provide a positive, science-based definition of success that recognises the role of human alteration of the natural world. Remarkable changes to most of the world's ecosystems have caused the distinction between *in situ* and *ex situ* conservation that has long shaped zoo programmes to become obsolete. The old dichotomy has been supplanted by hybrid approaches that create new, key roles for zoos and zoo professionals to play in successful species conservation.

The Importance of Defining Success

Despite all that has been written on species conservation, little attention has been paid to the question of what success would look like. Instead the focus has been on what failure would look like – extinction. This fact reflects conservation biology's origins as a "crisis discipline", desperate to get the world's attention focused on loss of ecosystems and species. The rise of conservation biology also marked a change in the zoo community, from simple display and husbandry to a focus on genetic and population management of captive populations, so that they might serve as assurance colonies or sources for reintroduction into the wild.

The conservation biology focus on extinction and its avoidance has been codified in science and policy and has served as the basis for education and action. IUCN regularly updates the Red Lists, and as scientists we report amongst ourselves and to the public how many more species are "close to the edge". While many of the agencies responsible for managing endangered species are required to create recovery plans, there is no standard approach to these plans, nor have plans been completed for the majority of species. In the zoo community, few of the species that are cooperatively managed by regional programmes have clearly articulated conservation goals and definitions of success.

If we wish to create a conservation practice that will not continually be addressing species in crisis, we need a proactive definition of successful species conservation that incorporates the major biological attributes of success. In a recent paper, Redford *et al.* (2011) offered such a definition. They proposed that successful species conservation be defined as "maintaining multiple populations across the range of the species in representative ecological settings, with replicate populations in each setting. These populations should be self-sustaining, healthy and genetically robust – and therefore resilient to climate and other environmental changes".

A successfully conserved species would have the following six attributes:

1. be demographically and ecologically self-sustaining;
2. be genetically robust;
3. have healthy populations;
4. have representative populations distributed across the historical range in ecologically representative settings;
5. have replicate populations within each ecological setting; and
6. be resilient across the range.

This sort of a positive, proactive view of species conservation may help turn away the pessimism gripping much of conservation and build enthusiasm for new creative solutions. Working with a broad range of stakeholders towards a positive view of success may help achieve the partnership and collaborative conservation that is required for success. Recent advances in conservation psychology have emphasised the critical importance of hope in bringing about such change. We need to bring a modicum of hope to species conservation.

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A Changing World Demands New Approaches

The version of ecology taught in the 1960s and 1970s presented a world in which ecosystems returned to a stable equilibrium after perturbation. In this view of the world, all conservation had to do was remove outside stresses and success would be accomplished. We have come to understand that the natural world is not organised this way and there are multiple stable points, disequilibrium conditions and constant change – making conservation much more difficult than we originally thought. In this world, conserving a species is no longer as simple as removing human influences. We have come to recognise the extent to which many species have become reliant on the direct and indirect ways and magnitudes in which humans manage the world, including changed land use patterns, alteration of landscapes (e.g. dams), creation of new physical structures, availability of alternate foods, presence of new competitors and mutualists, and changed flows of energy and nutrients.

This rapidly transforming world demands a transformed view of species conservation. In today's world, not all of the six attributes detailed above can be achieved for all species. The reasons for this vary according to the circumstances and history of the species and the nature of their interactions with human-dominated structures and processes. Yet, it is still vital to create a framework for defining success for this range of circumstances. Redford *et al.* (2011) laid out five general states along a continuum of the type and extent of ways that species are reliant on human interventions, both directed and non-directed. Each state differentially achieves the six conditions enumerated above (Table 1).

Table 1 Relationship between states of conservation and attributes of fully conserved species (adapted from Redford *et al.* 2011).

States	Attributes					
	Representative	Replicated	Self-sustaining	Healthy	Genetically robust	Resilient across range
Self-sustaining	XX	XX	XX	XX	XX	XX
Conservation dependent	XX	XX	X	XX	X	X
Lightly management	X	X	X	X	X	O
Intensively managed	X	X	O	O	O	O
Captive managed	O	O	O	O	O	O

XX = fully conserved | X = partially conserved | O = minimally or not conserved.
These are modal values that will vary on a species-by-species basis.

The states range from species completely reliant on directed human management to species able to thrive without directed human intervention. The states are:

1. Captive managed species: species found exclusively in captivity and reliant on caregivers for food, husbandry and propagation. They do not manifest many or any of the six attributes except for those derived from management actions. An example is the Socorro dove.
2. Intensively managed species: species that are found in the wild but are reliant on direct human intervention at the individual and population levels through augmentation from captive populations or very extensive, directed habitat manipulation. An example in this category is the Chinese alligator.
3. Lightly managed species: species that rely on a relatively limited set of human interventions directed at both population enhancement and influencing extrinsic factors, such as habitat management, but are largely capable of maintaining themselves. An example in this category is the corncrake.
4. Conservation dependent species: species that will almost always need significant conservation directed not at management of intra-specific aspects such as feeding, breeding or habitat management, but at extrinsic factors requiring changes in human behaviour. Species in this category are typified by being of significant commercial value, such as the African forest elephant.
5. Self-sustaining species: the final state is one in which species express full levels of all the conservation attributes and can be expected to survive with little to no human subsidy directed intra-specifically or extrinsically. An example of this is the peregrine falcon.

Although this classification was developed at the species level, it can be applied to different populations within a species. As has been pointed out, species like the Arabian oryx have populations that represent almost all of these stages.

The Role of Zoos and Zoo Professionals in this Changed World

As this list of general states of conservation makes clear, the world does not consist of species found only in the wild or only in zoos. They are instead found in a bewildering array of combinations of reliance on human action for conservation or reliance on cessation of human action for conservation. And species conservation faces a panoply of new challenges from emerging diseases to climate change impacts. So, why then does the conservation community in general, and the zoo community in particular, insist on dichotomising conservation as either *in situ* or *ex situ*?

This dichotomy is not only incorrect, it under-represents the actual and potential ways in which captive collections and their curators can contribute to species conservation. In a recent article (Redford *et al.* 2012), we documented some of the myriad ways that species biologists are addressing conservation, using approaches that are hybrids between *in situ* and *ex situ*. Using tools and methods developed and tested in zoos, such approaches include:

- rearing butterfly pupae in captivity and releasing adults into nature (Fig. 1);
- hatching and head-starting turtles before returning them to nature;
- provisioning of next boxes and double-clutching of eggs;
- integrating captive-bred animals into wild social groups;
- transporting individual animals between populations to minimise inbreeding (Fig. 2);
- capturing, medically treating and releasing individual wild animals;
- transporting resistant individuals from otherwise diseased populations to establish new disease-resistant populations; and
- collecting wild animals' gametes, combining *in vitro* and implanting into captive animals so the young can be released in the wild.

Fig. 1
Oregon silverspot butterfly.
© Erin Sullivan/Woodland Park Zoo

What characterises these approaches is the melding of traditional zoo techniques in non-zoo settings to achieve forms of species conservation that are hybrid in their nature.

Why We Want Everything to Be Either One Thing or Another

There seems to be a unique human desire to divide everything into non-overlapping binary categories. Just think about politics, or religion, or race, or gender or most other aspects of human life.

This habit seems to also apply to species conservation with the two categories of *in situ* and *ex situ*. We seem to insist that all species conservation must belong to one or the other of these categories, with little regard given to the possibility that some things do not fit into one or another category. This type of thinking is hampering us as we seek to redefine the role of zoos and captive collections in the reality of the world in which we now find ourselves. Let us declare the death and burial of the false dichotomy between *in situ* and *ex situ* conservation!

It's Just Not the Same World Anymore

The world in which the concepts of *in situ* and *ex situ* were developed is no longer the world we inhabit. The emerging set of changes brought about by climate change, the increasing control humans are exerting on the natural world and the rise of new genetic technologies such as synthetic biology are all working to turn tomorrow's world into a new world – new with threats and new with opportunities. Just as hybrids between populations and between species often are successful at invading new environments, it is time for creative solutions for species conservation success to emerge from blending between once distinct endeavours. Examples of this "blended conservation" include DNA fingerprinting techniques developed from captive populations that are allowing field scientists to track wild populations using non-invasive methods, or to identify the country of origin of illegally poached ivory. The rise in the possibility of restoring extinct species, or rescuing extinct alleles from museum specimens and reintroducing them into dwindling populations, will force us to give up the world of the past. And technology can allow us to store genetic material from functionally extinct species today to preserve our options for the future.

Fig. 2
Oregon spotted frog.
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Species conservation in this century will challenge us to define success across the gradient of human-dominated lands and waters, acknowledging that different levels of intervention will be needed to achieve success. Zoo professionals have a lot to contribute to both setting the goals and achieving the outcomes. And in so doing, we are in a position to redefine success for zoos themselves – creating the modern zoo that generates support for, and is actively engaged in, the conservation of species and ecosystems.

Both the world and the understanding that gave rise to the easy dichotomy of *in situ* and *ex situ* have disappeared. We need new understanding, new science and new ways of communicating the imperatives of species conservation in this new world and the key role that zoos and zoo professionals can play.

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The African Penguin Chick Bolstering Project: A One Plan Approach to Integrated Species Conservation

Summary

The population of African penguins (*Spheniscus demersus*) has seen a rapid and ongoing decline in recent decades, probably caused by a severe food shortage due to overfishing and to movement of sardine and anchovy stocks away from the penguins' breeding colonies. The Chick Bolstering Project has two main aims: addressing the ongoing population decline by supplementing extant wild colonies with locally hand-reared birds; and investigating the factors that determine breeding site fidelity in African penguins through monitoring released birds, thus enabling the artificial establishment of new breeding colonies of African penguins in places more suitable for their long-term survival. The international zoo and aquarium community is contributing technical expertise and practical help with hand-rearing chicks in South Africa, and it is envisaged that the captive populations will eventually contribute to stocking penguin colonies and bolstering the wild population. The Chick Bolstering Project is an example of the One Plan approach to integrated species conservation promoted by the IUCN SSC Conservation Breeding Specialist Group.

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Introduction

The African penguin (*Spheniscus demersus*) is the only penguin species found in Africa. Historically, the species has ranged along the western and southern coasts of southern Africa from Port Elizabeth to Namibia, with an estimated population size in the order of one million breeding pairs in the 1920s. It has, however, been hit by a number of human-related activities over the years, with devastating effects on the populations. The species is now classified as Endangered on the IUCN Red List of Threatened Species (BirdLife International 2012). The population decline has accelerated in the recent past, with an estimated 61% loss over 28 years or three generations. The remaining 26,000 breeding pairs left in the wild are distributed in 28 colonies in South Africa and Namibia (Crawford *et al.* 2011), with only seven islands supporting 80% of the global population. It is clear that, unless action is taken, there is a substantial risk that the species will become extinct.

There have been large, long-term changes in regional populations of African penguins, which may have been influenced by changes in the availability of food (Crawford *et al.* 2008). One of the reasons for the recent population decline is thought to be a spatial mismatch between the breeding localities of the penguins in the Western Cape and the availability of small pelagic fish following the displacement of stocks to the east (Crawford *et al.* 2008, 2011). The latter may be the consequence of an ecosystem shift in the current around the South African Cape, the southern Benguela upwelling system, which itself may be due to anthropogenic factors including global climate change.

As a result, although their prey – anchovy (*Engraulis encrasicolus*) and sardine (*Sardinops sagax*) – may still be abundant, it is generally out of reach of the penguins breeding on South Africa's west coast both during the pre-moult and pre-breeding period, when they must quickly rebuild their energy reserves, and during the breeding season, when they are tied to foraging within a distance of about 20–30 km from the colony to deliver food to the nestlings (Petersen *et al.* 2006). This seems to have impacted on the ability of parent birds to raise high-quality offspring (Sherley *et al.* 2013) and has taken its toll on adult survival (Crawford *et al.* 2011). In addition, the absence of energy-rich adult sardine and anchovy on South Africa's west coast and in Namibia may also be impacting negatively on juvenile survival, as fledglings seem to preferentially disperse into these once profitable areas (Sherley *et al.* in press).

The formation of new colonies of African penguins is a rare event, recorded only three times (excluding re-colonisation of two islands) in the last 150 years. It is desirable to maintain extant colonies of African penguins, so that they can provide foci for immigration of birds in the event of future changes in the distribution of prey resources. The loss of a colony may not be reversible in the short term. For example, African penguins stopped breeding at Robben Island in the late 1700s, and breeding did not recommence there until 1983 (Petersen *et al.* 2006).

The Chick Bolstering Project

Evidence from recent studies suggests that the (re)introduction of fledgling chicks can have a significant impact on conserving wild penguin populations (Barham *et al.* 2008); chicks that were hand-reared and released showed equal survivorship to breeding age and higher fecundity than parent-reared birds. This suggests that increasing the number of fledgling birds, through hand-rearing and release, could help arrest the decline in overall numbers and bolster the population. Based on this, and on the slow inherent dispersal ability of the species and a lack of natural disturbance-free sites along the South African coast, the artificial establishment of a new, protected mainland African penguin breeding colony closer to the current centre of gravity of the small pelagic fish stocks has been proposed (BirdLife International 2012). African penguins show a marked site fidelity, but it is unknown at which point in a penguin's life history this is determined. It is thus imperative that we understand the mechanisms that lead fledgling penguins to return to the colonies in which they hatched, or to disperse to other sites as breeding adults. However, the period from fledging until around three to four years of age has not been sufficiently studied, and there are still large gaps in our knowledge (Sherley *et al.* in press).

Fig. 1
African penguin chick hand-reared from the egg at SANCCOB's chick-rearing unit.
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In several South African penguin breeding colonies, including Dyer and Robben islands, penguin chicks that hatch late in the season (September onwards) are frequently abandoned by their parents when the latter begin the annual moult. Adult penguins fast during moult and cannot feed chicks that remain in the nest, thus these chicks would be unlikely to survive if left in the wild; the majority of them would die through a lack of food or unfavourable conditions. The Chick Bolstering Project (CBP) was set up by the Bristol Zoological Society and the Southern African Foundation for the Conservation of Coastal Birds (SANCCOB), along with the University of Cape Town's Animal Demography Unit, national and regional governmental agencies, authorities managing penguin colonies and other partners. Its aim is to investigate the efficacy of using hand-reared chicks, abandoned by their parents in the Western Cape, to bolster declining colonies, as well as to develop the infrastructure and knowledge required to artificially establish new penguin colonies on South Africa's south coast, closer to the current centres of gravity of small pelagic fish.

The CBP also aims to develop local expertise in hatching eggs and rearing penguin chicks for potential future reintroduction of captive-bred birds. To achieve this, a chick-rearing unit has been established at SANCCOB, the implementing partner of the project in South Africa (Fig. 1). From its inception, the CBP included all populations of African penguins into the planning exercise, both inside and outside their natural range, and under all conditions of management. The project partners made a large effort to engage with all responsible parties, using resources and expertise from the zoo and aquarium community, academic community, rehabilitation centres, policy makers, colony managers and other stakeholders. The CBP is thus an example for the One Plan approach to integrated species conservation promoted by the IUCN SSC Conservation Breeding Specialist Group (see Byers *et al.*, this issue).

Methods

Abandoned penguin chicks, as well as chicks below a certain body condition score, are being collected from different island and mainland colonies at the end of the breeding season by the relevant colony managers. Since larger chicks have a significantly higher chance of survival, require less frequent feeding and are less likely to need veterinary interventions, some colony managers collect all remaining chicks from a colony once a certain percentage of adults has gone into moult. The fledglings are then hand-reared at SANCCOB's rehabilitation centre in Table View, Cape Town, and released back into the wild after about 1–2 months in captivity in December/January, when conditions are most suitable for their survival. The birds are banded using silicone flipper bands and released into their colonies of origin or into different extant colonies, and their movements and subsequent breeding behaviour are then monitored to determine the factors that lead to breeding site fidelity in the species.

Using a combination of literature review and analysis of banding and re-sighting data held in various databases, the project aims to answer research questions such as: what proportion of chicks that fledge in a given year return to breed at any colony; what proportion of parent-reared chicks return to breed at their natal colony and what proportion disperse to other sites; and at what stage during the development of a chick does it learn its natal colony? Collaborating researchers from the University of Cape Town's Animal Demography Unit attach satellite tracking devices to hand-reared chicks on release as well as to parent-reared chicks before fledging. The use of such devices will help to identify foraging areas that are important to juveniles shortly after fledging. It will also help answer the question if hand-reared chicks show similar foraging behaviour to parent-reared chicks after they fledge, and if juveniles moult at colonies in close proximity to good foraging areas or if they return to their natal colonies.

Achievements

The CBP started in 2006, when 841 chicks abandoned by moulting parents had to be removed from the Dyer Island, Robben Island and Stony Point colonies. Since then, until the 2012/2013 release season, SANCCOB had hand-reared 2,535 chicks abandoned by moulting parents as part of the CBP. The success rate between 2006 and 2012 was 77% (1,962 out of 2,535; Table 1). Through the CBP, financial and operational support was made available in 2010 and 2011 to Penguins Eastern Cape and to the South African Marine Rehabilitation and Education Centre to support chick-rearing efforts in the Eastern Cape.

Table 1 African penguin chicks admitted to and released by SANCCOB as part of the Chick Bolstering Project (source: Nola Parsons, SANCCOB).

Year	Number admited	Number released	Percentage released	Median duration of stay until release (days)
2006	841	765	91	42
2007	481	351	73	42
2008	90	84	93	36
2009	147	127	86	36
2010	483	372	77	56
2011	171	90	53	54
2012	322	173	54	49
Total	**2,535**	**1,962**	**77**	

Of all chicks released by SANCCOB from 2001 to 2010, 1,708 were individually banded with flipper bands. So far, 76 of these chicks have been re-sighted at least once, most of them in the Western Cape. This relatively small number is not surprising, given that fledgling penguins spend about three to four years at sea before they settle in one of the colonies to start breeding. Data on site fidelity are thus only starting to accumulate, and it will be another few years until a large enough sample is available to allow rigorous analysis. In addition, 21 fledglings (eight hand-reared and 13 parent-reared) from South Africa and Namibia have been tracked with satellite transmitters between 2011 and early 2013 (Fig. 2), and a further 29 will be tracked throughout South Africa in the latter half of 2013.

A purpose-built chick-rearing unit at SANCCOB was officially opened in November 2011 and became operational in January 2012. It consists of a preparation area, an incubation room and a chick room. The building is separate from the rest of the SANCCOB facility to help prevent the spread of disease. It allows hand-rearing penguin chicks "from the egg" and is a major step towards using eggs from captive-bred penguins for bolstering the wild population.

The aims of the CBP have been incorporated into the draft of a national Biodiversity Management Plan for the species, to be signed off by the South African government in 2013, as a priority for conservation action. The project partners are leading a working group on hand-rearing and release that has been formed under this framework.

Fig. 2
African penguin chick with satellite tracking device.
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The Golden Lion Tamarin Conservation Programme's One Plan Approach

Summary

In the 1970s, the golden lion tamarin (*Leontopithecus rosalia*) population was estimated at only 200 individuals, with a declining captive population. Serious efforts were needed if golden lion tamarins were going to be conserved. Over the last four decades, conservation strategies for the golden lion tamarin have involved collaborations between zoos, non-governmental organisations, field biologist, governments and many others. The programme has used an integrated approach, managing *ex situ* and *in situ* populations under a single goal and a unified set of priorities. Under this approach, the captive population is stable and the wild population has increased to approximately 1,700 individuals. Although the golden lion tamarin is still endangered and in need of conservation due to the fragmented landscape, this integrated approach has led to the success observed up to this point and continues to be the backbone for golden lion tamarin conservation.

Introduction

Captive populations can serve a variety of functions including education, research and as a reservoir for wild populations. The role of captive populations in conserving endangered species is not new; in fact, the field of conservation biology was founded in partnership with the zoo community. As wild populations become smaller and more isolated, the tools and science used to manage captive populations can be of value when managing wild populations (Redford *et al.* 2012). This integration between *in situ* and *ex situ* programmes is increasingly important. Recently, the IUCN SSC Conservation Breeding Specialist Group put forth the One Plan approach to conservation planning (Byers *et al.*, this issue). This approach involves creating holistic conservation action plans that integrate, not distinguish, *ex situ* and *in situ* programme strategies for species. There are examples that exist of species where this type of integration is occurring already, such as black-footed ferrets (*Mustela nigripes*) and California condors (*Gymnogyps californianus*). Another example is the golden lion tamarin (*Leontopithecus rosalia*), which has been managed as one metapopulation, integrating *in situ* and *ex situ* programmes (Fig. 1).

The golden lion tamarin is a small, endangered primate endemic to the Atlantic Coastal Forest of Brazil. Living just 70 km northwest of the city of Rio de Janeiro, golden lion tamarins inhabit a highly fragmented forest where less than 7% of the original forest remains (Kleiman & Rylands 2002). Due to deforestation and the pet trade, only a few hundred animals were estimated to be living in the early 1970s when a conservation programme to protect golden lion tamarins began. The primary objective of this programme was to prevent the extinction of golden lion tamarins and further loss of their habitat, the lowland coastal forest. What has unfolded over the past four decades is a holistic conservation programme that includes the integration of wild and captive management and is based on collaborations between biologists, private landowners, governments, zoos and many other stakeholders (Kleiman & Rylands 2002).

Fig. 1
Golden lion tamarins.
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Building a Captive Population

In the 1970s, with less than 90 golden lion tamarins in captivity, the population was small and not self-sustaining (Kleiman & Rylands 2002). Reproduction efforts were unsuccessful, survivorship was poor and the importations from the wild population had been eliminated in order to support the *in situ* conservation efforts. With modifications in husbandry, the captive population of golden lion tamarins increased and in the 1980s began to stabilise (Kleiman & Rylands 2002). At that point, management of the captive population moved to a more genetically based management strategy to maintain genetic diversity. With a healthy captive population and an understanding of the wild population from field research, reintroduction became a real possibility.

A Model for Collaboration and Integration

In 1972, the Saving the Lion Marmoset conference, held at the Smithsonian National Zoo, brought together international biologists working with lion tamarins in efforts to develop a conservation strategy for golden lion tamarins. One focus of that strategy was to develop a healthy captive population capable of supporting reintroduction (Kleiman & Rylands 2002). This meeting was a turning point for the golden lion tamarin and led to long-term international collaborations between biologists whose goals were united in attempting to increase the population *in situ* and *ex situ* and prevent what seemed to be the impending extinction of the golden lion tamarin. The partnerships that developed at this meeting formed the basis for the integration of the *in situ* and *ex situ* programmes.

By the 1980s, due to improved husbandry and management, the captive population was increasing exponentially. Recognising the importance of cooperation between zoos, the International Research and Management Committee (IRMC) was formed in 1981 under the guidance of Devra Kleiman (Kleiman & Rylands 2002). Representatives from several institutions that were at the time holding or owning golden lion tamarins joined this committee with the primary focus on managing the global captive population. This committee established a formal cooperative breeding agreement that all recipients of golden lion tamarins had to sign (and which is still in effect) in order to receive golden lion tamarins.

Overall, the programme has served as an excellent model for AZA's SSP Program. In just a few years, IRMC had morphed into a committee that included national and international experts on all aspects of golden lion tamarin biology and conservation, *in situ* and *ex situ*. In 1990, a decree made this committee the official advisor to the Brazilian government and, in later years, the committee was renamed the International Committee for the Conservation and Management of Lion Tamarins (ICCM) by the Brazilian environmental agency (Kleiman & Rylands 2002). ICCM met annually to review all aspects of golden lion tamarin biology and conservation and made recommendations for actions related to both *in situ* and *ex situ* populations. With the Brazilian government owning captive and wild golden lion tamarins, and one international committee making management recommendations for *ex situ* and *in situ*, there was a clear integration between the two populations under one single set of goals and priorities – a One Plan approach (Byers *et al.*, this issue).

Reintroduction

In 1984, the link between *ex situ* and *in situ* programmes was further strengthened when captive golden lion tamarins were used to augment the wild population. The Golden Lion Tamarin Reintroduction Program began in efforts to increase the number of golden lion tamarins in the population, increase the genetic diversity through careful selection of reintroduction candidates and also increase habitat available for golden lion tamarins (Beck & Martins 2003). Reintroduction ended in 2000 after a total of 147 captive animals and six confiscated animals had been released (Beck & Martins 2003). At this point, the population was growing well on its own and there was no longer suitable habitat within commuting distance. The reintroduced animals have left a descendant population of over 700 individuals of which over 99% are wild-born (Fig. 2; Mickelberg 2011). This population continues to expand and makes up more than a third of the entire wild population.

Through reintroduction, the *ex situ* population became an integrated component of the golden lion tamarin metapopulation. Reintroduction included the careful selection of individuals based on their potential genetic contribution to the reintroduced and captive populations. The best reintroduction candidates would be those individuals that were genetically over-represented in the captive population and under-represented in the reintroduced population; these individuals would have the greatest positive impact on the genetic diversity in both the captive and reintroduced population, if reintroduced. By using this technique for selecting animals, the captive population has served as a demographic and genetic resource for the wild population and has contributed significantly to the overall viability of the golden lion tamarin metapopulation (Mickelberg 2011).

Translating Captive Management to Wild Management

The population of reintroduced golden lion tamarins has been extensively monitored for the last 25 years. A large percentage of the groups living in these areas have been monitored and captured every six months to determine group composition and for the placement of radio telemetry collars, permanent tattoos and temporary dye markings. These historical records provide continuous data on group composition, births, deaths and migrants to and from the study groups. These data are not unlike the data collected for captive populations. In fact, many of the tools used for managing captive populations have been applied for the management of the wild population.

Golden lion tamarins live in highly fragmented habitat with, in some cases, only a few groups living in a forest fragment, not unlike zoo populations with individuals spread out between zoos. For effective conservation and population viability, these populations need to be connected in order to maintain genetic diversity and population viability. One technique the golden lion tamarin programme has used is following the same strategy used for developing captive breeding plans. Using the inventory information, a pedigree database using the software Single Population Animal Records Keeping System (SPARKS) is used to generate and maintain a studbook for the reintroduced and a large component of the wild population. Pedigree analysis using the software PMx has been employed to help assess the status of the reintroduced population as well as direct management strategies to best connect populations (Mickelberg 2011). As the population of golden lion tamarins gets larger, it will become increasingly difficult to obtain reliable pedigree information. However, this provides an example of how pedigree analysis can be a powerful tool for assessing the genetic status of small populations *in situ*.

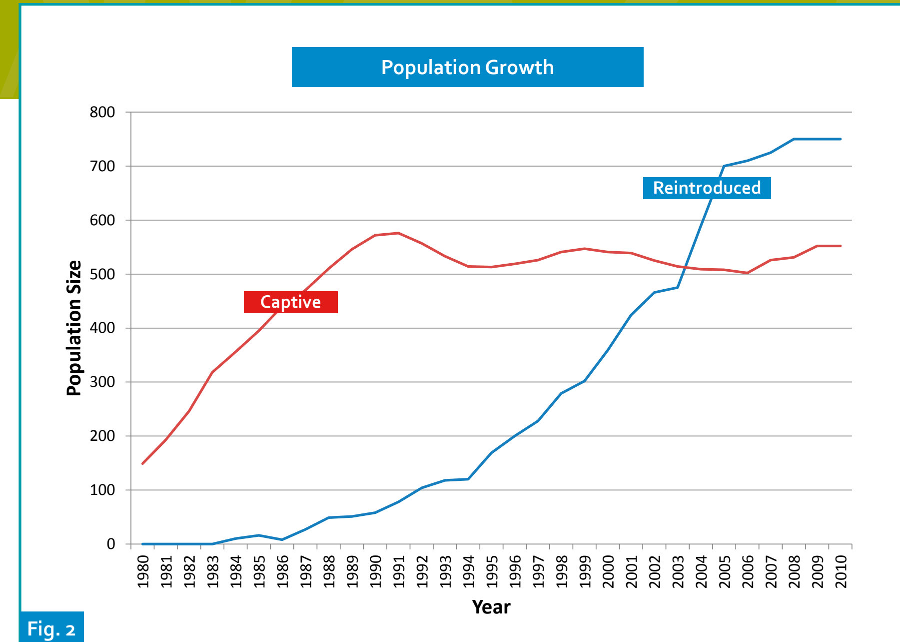

Fig. 2
Population growth in the reintroduced and captive population since 1980. Population numbers for the reintroduced population were estimated based on annual census data.

The cross-pollination of knowledge and tools between *in situ* and *ex situ* programmes has assisted in the recovery of the golden lion tamarin. In 2003, the status of the golden lion tamarin was downgraded from Critically Endangered to Endangered. Currently, there are approximately 1,700 golden lion tamarins living in the wild and about 500 golden lion tamarins living in 150 zoos around the world. While the golden lion tamarin is making a recovery, the battle to save the golden lion tamarin is not over. With the limited forest available, the population will always need close monitoring at the least, but through the integration of *in situ* and *ex situ* programmes, we move closer to protecting this species in perpetuity.

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Conservation Efforts for the Endangered Ozark Hellbender

Summary

The Ozark hellbender (*Cryptobranchus alleganiensis bishopi*) is an endangered aquatic salamander that inhabits cold-water streams in the Ozark Highlands. Due to drastic population declines over the past 40 years, the Ozark Hellbender Working Group was established to develop a recovery plan for the species. It was determined that without intervention, including a captive propagation programme, it was likely that the species would go extinct in the near future. Due to interagency collaboration, significant progress has occurred with refined hatching and husbandry protocols, expansion of rearing facilities, construction of artificial breeding streams, devoted funding and dedicated staff. Along with the world's first captive breeding of Ozark hellbenders in 2011 and subsequent remarkable captive breeding in 2012, together with wild-collected eggs, over 4,000 larvae/juveniles have been produced and/or raised at Saint Louis Zoo. To date, 102 juvenile Ozark hellbenders reared at Saint Louis Zoo have been released into the wild to augment remaining populations. Based on the success of the captive propagation programme, post-release survival and dedicated individuals of various organisations, the future of the Ozark hellbender is looking optimistic.

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Introduction

Hellbenders are large aquatic salamanders that can reach lengths up to 50 cm and are long-lived (25–30 years). There are two subspecies of hellbender: the eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*), which has a distribution from southern New York state south to Georgia and west to Missouri, and the Ozark hellbender (*C. a. bishopi*) (Fig. 1), which only occurs in the Ozark Highlands of south-central Missouri and adjacent north-central Arkansas. Missouri is the only place in the USA where both subspecies occur. The closest relatives of the hellbender are the Chinese giant salamander (*Andrias davidianus*) and the Japanese giant salamander (*A. japonicus*).

Hellbenders inhabit cool, highly oxygenated, fast-flowing streams. They are perfectly adapted for a fully aquatic existence with a dorsal ventrally flattened body and rudder-like tail. The conspicuous folds of skin on the sides of the body and legs are used to absorb dissolved oxygen from the water. While they do have lungs, they are small and primarily used to help with buoyancy. They are primarily nocturnal and spend the daylight hours under large rocks or in bedrock crevices on the river bottom, where they forage principally on crayfish.

Fig. 1
Adult Ozark hellbender.
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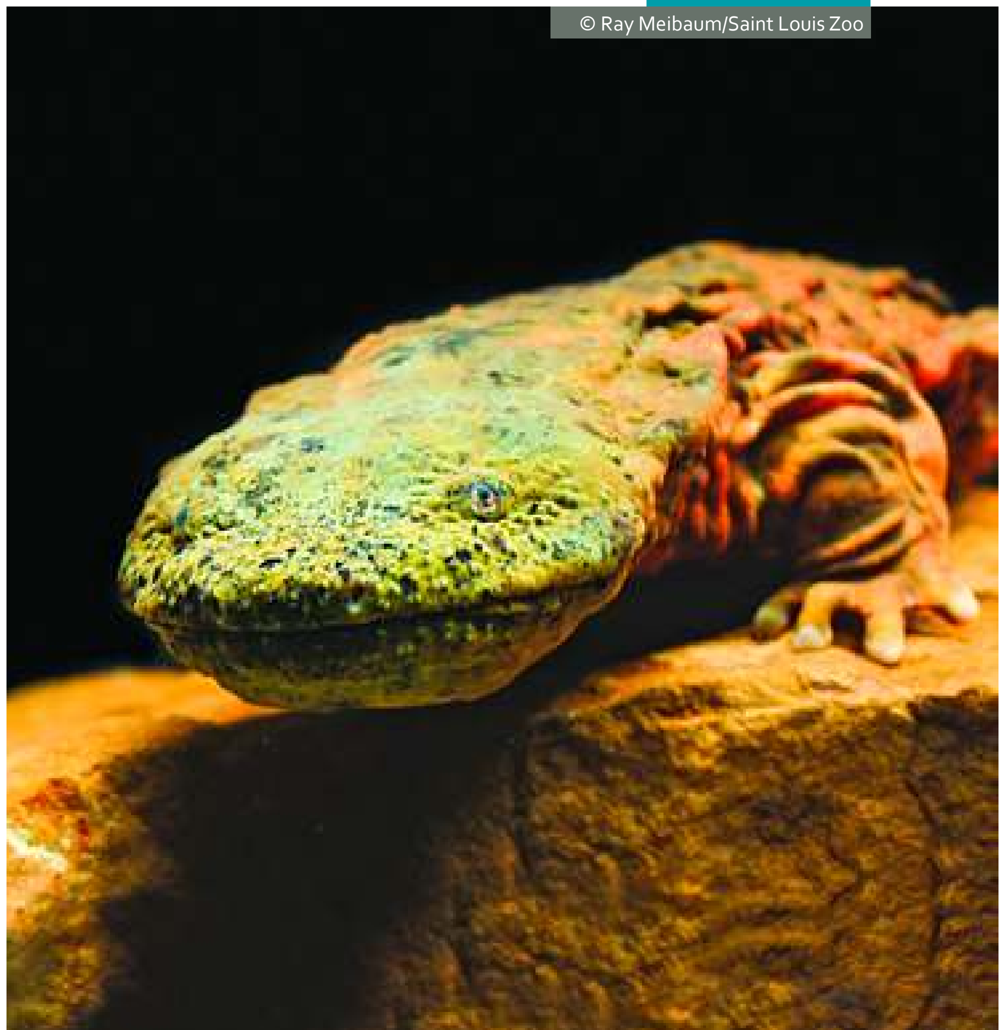

Hellbender populations in Missouri have declined by more than 70% over the past 40 years, with a prominent shift in the age structure where large, mature individuals mostly predominate and young age classes are virtually absent (Wheeler *et al*. 2003; Briggler *et al*. 2007, 2010). While it has been hard to pinpoint a single cause of the population decline, it appears to be a combination of factors including habitat degradation, disease, degraded water quality, over-collection and predation by non-native fish (USFWS 2011). As a result of this decline, both subspecies were listed as critically imperilled and state endangered in Missouri in 2003, and the Ozark hellbender was recently listed as endangered under the Endangered Species Act (USFWS 2011).

While the carrying capacity of Ozark streams has been estimated at 11,000 specimens, current estimates of Ozark hellbenders remaining in the wild are less than 600 individuals. The results of a Population and Habitat Viability Assessment (PHVA), facilitated by the IUCN SSC Conservation Breeding Specialist Group, indicate that all hellbender populations have a high risk of extinction (above 96%) over the next 75 years, unless populations can be bolstered (Briggler *et al*. 2007). A comprehensive conservation strategy, to ensure the long-term survival and recovery of the Ozark hellbender, was developed by the Ozark Hellbender Working Group, which is comprised of state and federal agencies, universities, zoos, non-governmental agencies and interested individuals (Briggler *et al.* 2010). While addressing the reasons for the decline in the wild, it was determined that captive propagation and head-starting were essential to the long-term recovery of the Ozark hellbender.

Captive Propagation and Head-starting

A captive propagation and head-start programme for the Ozark hellbender was initiated by the Saint Louis Zoo's WildCare Institute Ron Goellner Center for Hellbender Conservation and the Missouri Department of Conservation in 2002 (Briggler *et al.* 2011). The programme was designed to rear individuals for increasing wild populations through augmentation and, if necessary, reintroduction. While recruitment is limited in the wild, some egg clutches have been discovered annually in recent years. Portions of these clutches have been brought to Saint Louis Zoo and/or the Missouri Department of Conservation Shepherd of the Hills Fish Hatchery for hatching and head-starting efforts. Currently, over 1,500 Ozark hellbenders hatched from wild-collected eggs are being raised at Saint Louis Zoo for future releases.

Although these head-started individuals are essential to the recovery efforts for the Ozark hellbender, the larger goal is captive reproduction, a feat that had never been achieved. To help reach the goal of captive reproduction, Saint Louis Zoo constructed an indoor stream (9.7 × 1.7 × 0.6 m) in 2002 and two outdoor streams (11.3 × 1.5 × 1.4 m and 11.7 × 1.8 × 1.4 m) in 2011. Breeding stock was obtained from three genetically distinct Missouri Ozark rivers: the North Fork of the White River, Eleven Point River and Current River. These three populations are each housed separately in one the aforementioned artificial streams. Simulation of natural habitat (i.e. gravel bottom, shelter rocks and artificial nesting chambers) and seasonal environmental conditions (i.e. photoperiod, water temperature, precipitation patterns and water quality parameters) were mimicked to induce breeding activity. Every year since 2007 hellbenders have laid eggs, but were not being fertilised by the males. However, a milestone was achieved on 18 October 2011 when two clutches of fertilised eggs (Fig. 2) from the Eleven Point River population were discovered in one of the outdoor streams. This was the world's first captive breeding of the species, thus resulting in approximately 150 larvae.

An even greater achievement occurred the following year with breeding success in all three streams. Between 22 September and 1 October 2012, eight Ozark hellbenders laid eggs: three clutches from the Current River, three clutches from the North Fork of the White River and two clutches from the Eleven Point River. There were approximately 2,800 fertile eggs from the combined clutches, from which 2,500 larvae hatched. The significance of this second breeding was that all three river populations of Ozark hellbender reproduced, including the North Fork of the White River population that has been maintained indoors for the past eight years. These successes have paved the way for bolstering wild populations through augmentation.

Augmentation of Wild Populations

Success of any propagation effort is to eventually release animals back into their native habitat. The first release of captive-raised Ozark hellbenders occurred in 2008 in the North Fork of the White River. Thirty-six juveniles that had been hatched from eggs collected in 2002 and raised at Saint Louis Zoo were released at two locations with varying rock composition. Over the next year to year and a half, these individuals were tracked using radio-telemetry to determine the feasibility of head-starting juvenile hellbenders. The results of the study demonstrated that these captive-reared hellbenders had high survivorship (75% and 48%), had established home ranges, were growing and were demonstrating reproductive cycling at the same time as the wild population (Briggler *et al*. 2012).

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Fig. 2
Well-developed Ozark hellbender embryos.
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The success of this first release suggests that augmenting wild populations with captive, head-started animals can be successful and that they can survive in the wild (Briggler *et al*. 2012). This has led to subsequent releases in 2012 of an additional 66 Ozark hellbender juveniles in the North Fork of the White River. These animals will be monitored long-term to not only evaluate survivorship and acclimation to the wild, but also to gain a better understanding of the factors contributing to their decline (i.e. amphibian chytrid fungus infection rates, abnormality rates, heavy metal accumulation, reproductive and stress hormones, etc.). With less than 600 Ozark hellbenders estimated to remain in the wild, the 4,000 larvae and juveniles currently being raised at Saint Louis Zoo will make a substantial contribution to the long-term recovery of the species over the next five years.

Conclusions: Hope for Hellbenders

The success of this conservation programme is due to the dedication and resourcefulness of many individuals, institutions and organisations, including (but not limited to) Saint Louis Zoo (keepers, veterinarians, life support staff), Missouri Department of Conservation, US Fish and Wildlife Service, US Forest Service, National Park Service and Arkansas Game and Fish Commission. Through teamwork and persistence, the aforementioned partners and several universities, which constitute the Ozark Hellbender Working Group, are making great strides towards the recovery of the Ozark hellbender through active research, including monitoring of populations, investigating abnormalities, exploring potential interactions with predators, assessing health conditions and sperm quality, and evaluating the frequency and distribution of diseases (e.g. amphibian chytrid fungus, ranavirus). As well as the remarkable achievements of the propagation efforts at the Ron Goellner Center for Hellbender Conservation, WildCare Institute, Saint Louis Zoo. These achievements will not only buy time to further address the decline of this species, but will likely be the "safety net" needed to save this unique native of the cold-water streams of the Ozark Highlands.

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The Western Pond Turtle in Washington: Crawling Back from Extirpation

Summary

The western pond turtle (*Actinemys marmorata*) was once abundant throughout the lowland areas of British Columbia and Washington's Puget Sound, through western Oregon, California and into the northernmost areas of Baja California. Historically, this turtle was only one of two native freshwater turtles in the Pacific Coast states of the USA. Today, the turtle is in decline throughout its range from threats including habitat alteration and presence of invasive species to emerging disease. In Washington, because of particularly dramatic population declines, the species was listed by the state as endangered in 1993. Over the past two decades, stakeholders in Washington have worked to save this species from extinction through a two-pronged *ex situ* and *in situ* approach, combining head-starting and reintroduction, habitat improvement, control of predators and invasive species, and population monitoring and research. The 20th anniversary of the listing was an opportune time to systematically examine progress to date and employ science-based methods to assess population viability and set management priorities for this intensively managed programme. An IUCN SSC Conservation Breeding Specialist Group-facilitated Population and Habitat Viability Assessment workshop, held in late 2012, aided the recovery team in accomplishing this goal.

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Introduction

Populations of the western pond turtle (*Actinemys marmorata*), a medium-sized aquatic species that at one time ranged from British Columbia to Baja California, are declining throughout their range (for a species review, see Ernst & Lovich 2009). Lowland prairie wetlands, the environment type required by the turtle, is the most endangered habitat in Washington state, having been largely converted to agriculture and housing. By 1990, the species in Washington was close to becoming extirpated with fewer than 150 turtles surviving, primarily from decades of uncontrolled habitat alteration and commercial collecting for food, but also from an unknown respiratory disease that was causing a rapid decline in one of the two remaining populations state-wide, both located in the Columbia River Gorge.

In 1990, in response to the disease outbreak and low population numbers, Woodland Park Zoo and the Washington Department of Fish and Wildlife (WDFW) partnered in a triage effort to bring a founder population into captivity for treatment and establishment of an *ex situ* programme. At the same time, WDFW initiated an *in situ* plan for species recovery that included habitat improvement, control of predators and invasive species, and population monitoring and research. From the onset, the initiative has been a collaborative one, involving many organisations and individuals, too numerous to list here. Key agencies, in addition to WDFW, include the US Fish and Wildlife Service, US Forest Service, Washington State Parks and The Nature Conservancy. Since 2000, Oregon Zoo has supported and participated significantly in both *in situ* and *ex situ* activities; Point Defiance Zoo and Seattle Aquarium have assisted in the past. Frank Slavens (former reptile curator at Woodland Park Zoo) and Kate Slavens (former WDFW biologist) have played key roles, as have WDFW biologists David Anderson, Michelle Tirhi and Jeffrey Skriletz.

Fig. 1
Since 1991, 1,300 western pond turtles have been head-started and released, growing the wild population from 150 to an estimated 1,500 turtles.
© Ryan Hawk/Woodland Park Zoo

Western Pond Turtle Recovery in Washington State

The *Washington State Recovery Plan for the Western Pond Turtle* (Hays *et al*. 1999) provides the framework that guides recovery actions for the species. Recovery goals, objectives, strategies and tasks are outlined in the plan, as well as a primer on the species' biology. The goal of the programme is to re-establish self-sustaining populations of western pond turtles in two regions of the state: Puget Sound and the Columbia River Gorge. Complete recovery is defined as requiring seven established populations (three in Puget Sound and four in the Columbia River Gorge) of more than 200 turtles comprising no more than 70% adults sustained through natural recruitment. In addition, recovery will ensure that both the associated wetlands and upland nesting habitat at all sites are secure from excessive human development and disturbance.

Recovery strategies include the following goals: survey and monitor populations; enhance numbers through captive breeding/head-starting, creating new populations, controlling invasive bullfrogs and other predators and minimising human disturbance; improve habitat; conduct research; manage data and information; conduct public conservation education; and evaluate and enforce relevant wildlife regulations. In 14 years, significant progress has been made in all of these areas. Each year, the recovery team meets to review progress and set plans for the coming field season.

Today, primarily through head-starting and habitat acquisition, the number of western pond turtles in Washington has grown from 150 (1990 census) to an estimated 1,500 (Fig. 1). The number of populations has increased through reintroduction from just two Columbia River Gorge locations in 1990 to six sites, two in Puget Sound and four in the Columbia River Gorge today. Since 1991, head-starting each year uses wild-collected eggs and hatchlings, which are maintained at the zoo for 10 months until the turtles are large enough to avoid being eaten by non-native bullfrogs. In mid-summer, the team collects morphometric data on the hatchlings – they are permanently identified with transponders and shell notches – and released into the wild. In the past 22 years, more than 1,300 hatchlings have been released to the wild and reintroduced at all six population sites. Also essential has been the acquisition or permitted use of 735 acres of habitat at the field sites, including locations in four different state counties.

Other significant *in situ* and *ex situ* actions, besides habitat acquisition, have included: efforts to control invasive North American bullfrogs (*Lithobates catesbeianus*) through egg mass collection and adult removal at Sondino, the only site currently with more than 200 turtles; removal of invasive plants at several sites to improve upland habitat; nest site enhancement through grass plantings and soil improvement; population monitoring through annual assessments; research on survivability (Vander Haegen *et al*. 2009); and public education and interpretation at Woodland Park Zoo and Oregon Zoo, including significant local media each year on hatchling release days.

PHVA: A Planning Tool for Intensively Managed Species

Integrating *in situ* and *ex situ* approaches within any one species recovery programme is complex and requires synchronous management practices. In the case of the western pond turtle in Washington, the recovery challenge has been exacerbated by the slow reproduction and concomitant population recovery of a long-lived reptile, and the other significant threats still facing the species. Recently the team has observed yet another threat: an emerging condition known as Ulcerative Shell Disease. This disease of yet unknown cause affects the turtles by eroding the underlying bone of the carapace and plastron, with advanced cases affecting the spine and leading to lowered fitness, paralysis and even death. All of these threats combined require the team to optimise its *in situ* and *ex situ* resources.

In 2012, the team sought the assistance of the IUCN SSC Conservation Breeding Specialist Group (CBSG) to conduct a Population and Habitat Viability Assessment (PHVA) workshop (Fig. 2). The purpose was to investigate the present and future state of the western pond turtle in Washington and bring together relevant stakeholders, including WDFW, partnering zoos and others working on similar recovery efforts for the species in California. The PHVA was designed to address four specific goals: employ science-based methodology, including Vortex modelling to evaluate the current population status; identify optimal management alternatives to enhance species viability (e.g. determine the relative efficacy of continued head-starting, habitat management and efforts to reduce bullfrog populations); prioritise future research; and identify ways to improve communication and programme implementation. Workshop funding was provided by Woodland Park Zoo, Oregon Zoo, Northwest Zoo and Aquarium Alliance and WDFW.

The PHVA workshop process is designed to optimise productivity over a short time frame while accommodating a diversity of stakeholders with often vastly different backgrounds and opinions. This three-day workshop, attended by 30 participants, was held in Olympia, Washington from 13 until 15 November 2012 and was expertly facilitated by three representatives from CBSG. The workshop process is initiated with a discussion of threats facing the recovery species and development of a threat diagram. This interactive activity engages the participants and provides a starting point to aid the collective understanding of threats to species recovery.

Following this initial exercise, the participants are divided into working groups according to their expertise. These working groups participate in brainstorming sessions to tackle specific issues confronting species recovery. For example, the working groups were assembled to address current western pond turtle population status, habitat, population viability analysis and *ex situ* conservation and husbandry. Working groups prioritise problem statements relating to their identified issues and then assemble data, and prepare short and long-term goals for addressing problems. Plenary sessions then serve to provide a report out to the larger group during which the facilitators encourage and lead discussions on the groups' findings. The facilitators also provide a thorough explanation of the Vortex software and population viability assessment analyses, key to understanding the current and future states of the recovery species and for informing workshop proceedings. These analyses are performed on data provided by workshop participants and gathered from published literature prior to the meeting.

The PHVA report is in preparation and when complete will be available through the CBSG website. Many actions and important observations were identified, with the following subset deemed of highest priority: the epidemiology, prevalence and effects of Ulcerative Shell Disease are poorly understood and require immediate attention and research; there is a greater need for *in situ* and *ex situ* data and information sharing between stakeholders; an additional population site should be added within the next five years; low juvenile recruitment and the threat of invasive bullfrogs were determined as key factors influencing population viability; adult females are critically important to the long-term survivability of the wild population; and habitat restoration for salmon could be negatively influencing turtle recovery at some sites and should be evaluated.

Conclusions

For more than two decades, a combined *in situ* and *ex situ* species recovery programme in Washington for the western pond turtle has shown promising results. While the species is not fully recovered, it is no longer on the brink of extinction. The programme's collaborative public–private partnership between state agencies, federal agencies, non-governmental organisations and zoo-based conservation organisations has demonstrated the effectiveness of combining the expertise of multiple stakeholders and facility resources. A continuing impediment to progress has been how to best organise and manage such complex efforts, especially in a challenging fiscal environment. To this end, we recommend the importance of a well-conceived recovery plan, regular communication among team members and periodic population-level analyses to inform management planning.

Fig. 2
A Population and Habitat Viability Assessment workshop conducted in 2012 helped the recovery team assign priority *in situ* and *ex situ* management actions.
© Fred Koontz/Woodland Park Zoo

Based on our PVHA experience, we recommend it as a tool for improving population-level analyses of intensively managed threatened species. In addition to the analyses, we found that a surprisingly important benefit of the PHVA was that it provided a forum for summarising collective knowledge and discussing prioritised threats and needed actions. In preparation for the PHVA, for example, stakeholders for the first time were required to collate demographic and genetic data from each recovery site in order to perform the modelling exercises. Also, prior to the workshop, little communication existed between the California and Washington *ex situ* western pond turtle programmes, but now these organisations are sharing their husbandry data and expertise and are working towards streamlining best practices.

An important team-building outcome of the PHVA was forming thematic subgroups that are expected to continue addressing action plans and timelines. For example, an effort is underway to quantify the prevalence and epidemiology of Ulcerative Shell Disease. Another product of the workshop has been the development of new Internet-based tools (website and listserv) that will aid communication efforts among stakeholders.

In summary, efforts to recover the endangered western pond turtle in Washington will continue with a mix of *in situ* and *ex situ* approaches, which bring together the resources of multiple government agencies and conservation organisations, including zoos of the region. The team also aims to build on its two-decade historical foundation of cooperation and adaptive management. Programme partners expect that momentum and products resulting from the PHVA will greatly aid these efforts.

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Saving the Devil: One Species, One Plan

Summary

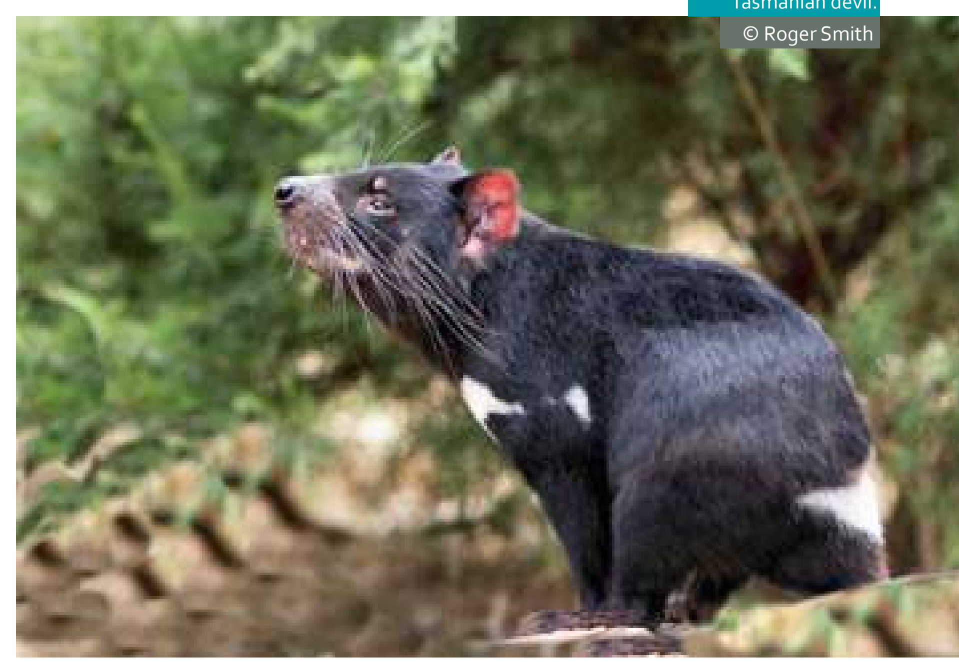
Tasmanian devils (*Sarcophilus harrisii*) are at risk of extinction from a disease known as Devil Facial Tumour Disease and, at current rates of spread, species extinction is predicted in 25 to 30 years. An insurance population has been established, which is designed to take the species through this extinction event and provide for full ecological recovery. This programme comprises a metapopulation of captive, free-ranging and wild populations, linked through strategic animal movements. The development of this approach to recovery closely follows the One Plan approach advocated by CBSG, in its careful inclusion from the outset "of all populations of the species, inside and outside their natural range, under all conditions of management, engaging all responsible parties and all available resources from the very start of the species conservation planning process". To date, this programme has achieved a number of significant milestones and is now moving from insurance to ecological recovery.

Devil Facial Tumour Disease

Tasmanian devils (*Sarcophilus harrisii*) were once common across mainland Australia, but are now confined to the island of Tasmania (Fig. 1). Although considered common in the wild until the 1990s, they are now at risk of extinction due to a previously unknown Devil Facial Tumour Disease (DFTD). DFTD is a transmissible cancer, passed between individuals through biting, which is common around social feeds and the breeding season. Since first observations of DFTD in the mid to late 1990s, the disease "front" has continued to move across the island, reducing some affected populations by up to 90% (DPIPWE 2013).

In 2003, regional zoo representatives, along with interested field researchers, ecologists, disease specialists and relevant non-government organisations, were invited to a government-organised workshop in Tasmania, aimed at building a shared understanding of the disease issue, what was known about it, what could or should be done, and who might be willing and able to help. Little was known about the disease at that time: there was no diagnostic test, incubation times were uncertain, modes and rates of transmission were largely unknown and, consequently, there was no agreed prognosis for long-term impact on species survival. In response to this, and in close collaboration with the Tasmanian wildlife agency, the zoo community agreed to revamp its regional captive population, which at the time was for educational display, into a short-term insurance programme designed to span a period during which further research and monitoring would evaluate the nature and likely impact of the disease. Depending on the outcomes of this, the captive population could either be wound down or ramped up to provide more substantial support.

Fig. 1
Tasmanian devil.
© Roger Smith



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A Short-term Insurance Population

Through the Australasian zoo association, a 10-year insurance programme was established, aimed at retaining 90% of wild source gene diversity for 10 years. Analyses indicated that this would require around 30 wild-caught founders, sufficient carrying capacity for 150 individuals and a programme of close genetic management. Four core breeding centres were designated, one in each of four Australian states. Each comprised a primary breeding zoo, with other local zoos supporting as satellite breeding and holding facilities. Restricted animal exchanges between these "silos" in the early stages provided an additional layer of biosecurity, facilitated inbreeding management and smoothed logistics. Devils had proved in the past to be a challenging species to work with. To provide the necessary regional up-skilling, Trowunna Wildlife Park, the only institution to have demonstrated long-term successful management of the species, established an on-site training course in devil management and breeding, to which all participating institutions sent keeping staff before receiving programme animals. By 2007, founders had been received and two seasons of litters produced.

A Change of Plan

In 2007, the Tasmanian government called a meeting of scientists to consolidate what had been learned since 2003 about DFTD and its impact. The conclusions of this meeting were stark. The disease had moved swiftly across the devil's range, with up to 90% of animals lost in affected populations. No resistance in the wild had been encountered, with unusually low levels of gene diversity across the species cited as a likely reason for the apparently undifferentiated response between individuals. Species extinction was predicted in 25 to 30 years. It was immediately apparent to zoo community representatives that the existing insurance population would be inadequate to cater for the predicted extinction event. Tasmanian wildlife agency authorities were notified and work began to reshape the programme around more ambitious goals better suited to the species' predicament. The IUCN SSC Conservation Breeding Specialist Group (CBSG) was consulted and a programme was developed that would be capable of sustaining the species through an extinction event and into full ecological recovery. The following goals were agreed (for 50 years):

- to be free of DFTD;
- retention of 95% of a representative sample of wild gene diversity;
- retention of wild behaviours;
- retention of devil-associated flora and fauna (commensal, symbiotic and parasitic); and
- the ability to generate a harvest for release.

Application of population genetics theory, consideration of the opportunities and constraints around founder collection presented by the species' unique predicament and discussions of what wild and captive resources might be mobilised through Tasmanian, Australian and international networks, led to a new insurance programme strategy. The new model (Fig. 2.) was of a metapopulation comprising a mix of the following management styles:

Intensively Managed Captive Populations (Baker *et al.* 2011). Those in which population size, structure and pairings for breeding are closely controlled to maximise stability and retention of genetic diversity. Animals do not normally share the same space throughout the breeding season. Natural selection is not assumed and selection of any kind is actively avoided. For a given population size, retention of genetic diversity over generations is expected to be relatively high.

Free-range Enclosure Populations. These have an intermediate level of management. Groups of animals are housed together, occupying the same enclosure space throughout the breeding season. Stocking densities are higher than those reported for wild populations. Natural selection is not assumed but may operate to some extent. For a given population size, retention of genetic diversity is expected to fall in between that for captive and wild populations.

Isolated Wild Populations. These occupy large and/or relatively inaccessible natural areas within the former range of Tasmanian devils. Boundaries may be human-made or natural (e.g. water). Management is minimal and there is limited ability to track population parameters. Natural selection is expected to be operating. Retention of genetic diversity is expected to be lower than that of the other two management styles.

It was envisaged that these components would articulate through centralised monitoring and management of demographic and genetic characteristics, and by the strategic movement and management of animals to optimise these towards agreed goals. An increased founder base of 150 wild-caught individuals was agreed on (based on Marshall & Brown 1975), reflecting more ambitious genetic goals both with regard to retained

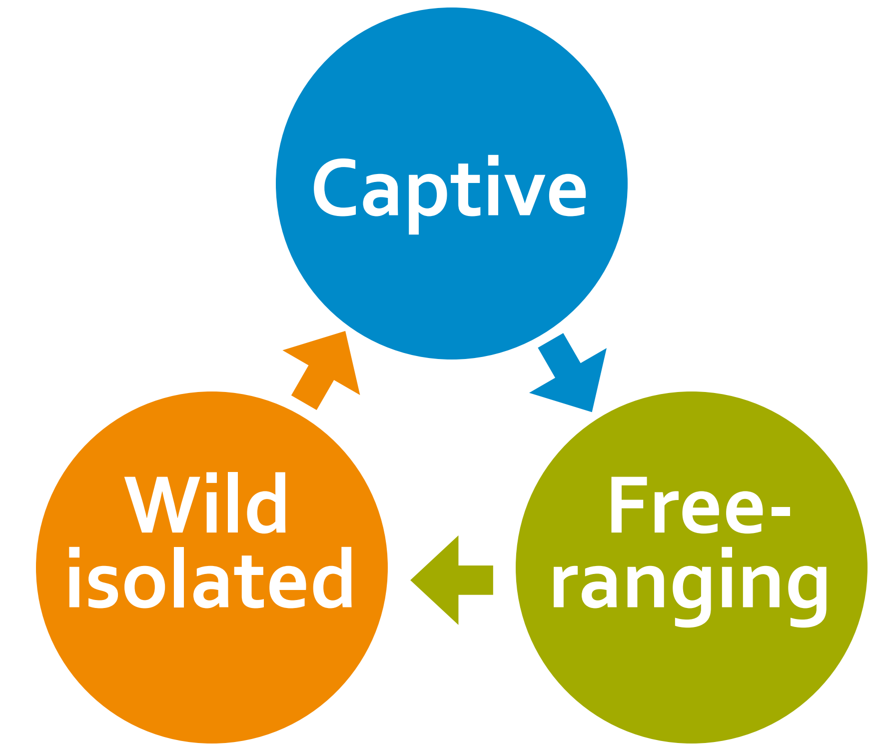

Fig. 2
Target profile of the Tasmanian devil insurance metapopulation: founders = 150, total effective size N_e = 500, total census size (variable) N = 1,500–5,000.

heterozygosity and sampled allelic diversity, and taking into account the negligible impact that this extraction would have on the prognosis for wild stocks. It was anticipated that the new long-term genetic goals could be met with an effective population size of N_e = 500, expected to equate to an actual size of approximately 1,500 captive, 2,500 free-ranging or 5,000 wild animals (due to the differential gene retention abilities of the three management styles), or to some intermediate number reflecting a combination of these three categories. It was agreed that this size would need to be reached only once it became no longer possible to collect devils from the wild to supplement gene diversity.

This three-pronged approach to management capitalises on the strengths and compensates for the weaknesses of each individual management style (Table 1). Once all three components are in place, and of sufficient size, all insurance population goals should be met and the species should be moving towards ecological recovery.

Table 1 Relative strengths and weaknesses of metapopulation components (comparisons are based on populations of equal size): ■ = not provided for, ■ = partially provided for, ■ = provided for (DFTD = Devil Facial Tumour Disease).

Intensively managed captive populations	Free-range enclosure populations	Isolated wild populations
Secure from DFTD	Secure from DFTD	Secure from DFTD
High gene diversity retention	High gene diversity retention	High gene diversity retention
100% wild behaviour	100% wild behaviour	100% wild behaviour
Associated flora and fauna	Associated flora and fauna	Associated flora and fauna
Natural selection enabled	Natural selection enabled	Natural selection enabled

In 2008, after assisting with the redesign of the programme, CBSG was invited to convene a planning workshop aimed at moving the new strategy to implementation. The workshop, sponsored by Taronga Zoo and the Tasmanian Department of Primary Industries, Parks, Water and Environment, brought together 40 field staff, researchers, zoo community leaders, cultural leaders and policy makers to work out how and where the new programme would be deployed, and who would be involved. Working groups considered: which Tasmanian islands and peninsulas might be suitable for housing disease-free animals; what the local and international zoo community could provide in terms of space and resources; where the strengths and weaknesses in biosecurity might be in such a metapopulation and how best to manage this; and how the proposition of large, free-ranging populations could be tackled. Importantly at this meeting, a proposal for a free-ranging facility on mainland Australia was unveiled and developed (CBSG 2008). The resulting blueprint for large-scale, cost-effective devil management has since been realised as Devil Ark, a project operated through Gosford Reptile Park that is proving to be a highly successful management model.

The CBSG planning workshop gave the insurance population its current shape and catalysed its implementation. It currently comprises approximately 500 individuals, with around 75% held in intensively managed captive facilities, 20% in free-ranging enclosures and 5% recently released to a protected island site. This release signals a new phase in the project: in addition to this initial island release, wild peninsulas are beginning to be isolated through fencing, cleared of diseased devils and restocked with disease-free animals. Although the areas that can be isolated in this way in the immediate future are a small proportion of the devil's range, this development begins to shift the project from insurance into ecological recovery, securing a future for devils in Tasmania.

This programme has required and received an outstanding level of commitment, investment and participation from the zoo industry. It has also challenged government and other agencies to embark on activities that were novel and in many ways conflicted with current thinking and wildlife management practices. Gaining approval for these activities has required commitment and persistence from project staff, which was underpinned by an unyielding confidence in the science, process and effort that went into the development of the insurance metapopulation plan. The success can be attributed to the integrated One Plan approach adopted by the Save the Tasmanian Devil Program, widely advocated by CBSG and discussed elsewhere (Byers *et al.*, this issue). Features of the project that illustrate the practice and benefits of a One Plan approach, and in particular the effective articulation of zoo, CBSG and wildlife agency strengths, are:

- The captive community was invited into discussions as soon as it became evident that the species was in trouble.
- The captive community responded by evaluating and reshaping its existing captive programme towards conservation goals: new targets, new founders, new facilities and centralised up-skilling for animal management staff.
- As part of the recognised stakeholder group, the team for captive programme coordination was made aware immediately of the dramatic change in status and prognosis for wild populations four years into the programme.
- The team understood and responded to the change by initiating an immediate redesign of the programme in collaboration with *in situ* partners and CBSG.
- *Ex situ* and *in situ* stakeholders, regulatory and resourcing bodies understood and supported the redesign and collectively moved it towards its current level of implementation. Key to this was the 2008 CBSG-facilitated Population and Habitat Viability Assessment (PHVA) workshop, outcomes from which continue to guide management strategy.
- Representatives from the zoo and field communities continue to meet regularly with government representatives to review progress and challenges across the mosaic of management that constitutes the Tasmanian devil recovery effort. CBSG serves as an independent and neutral advisor on small population management strategy across the management continuum.

Although Tasmanian devils are far from secure in the wild, this exceptional level of investment in a disease-free metapopulation of wild, free-ranging and captive populations, underpinned by a One Plan approach, is not only buying time for the species but is actively contributing to its re-establishment in the wild.

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Restoring African Wild Dogs in South Africa: A Managed Metapopulation Approach

Summary

Over the past 15 years, the number of endangered African wild dogs (*Lycaon pictus*) in South Africa has increased by nearly 50% through the active reintroduction of animals into suitable state-protected areas and private reserves. These new, isolated populations are managed collectively as a managed metapopulation, linked through artificially mediated dispersal. Founding stock for reintroductions has comprised both wild-caught and captive-bred animals and this has unearthed some useful lessons about the *in situ-ex situ* interface. Chief among these is the need for an a *priori* strategy for *ex situ* support of the programme, essential to avoid uncoordinated and *ad hoc* use of captive-bred animals, and to ensure the long-term demographic and genetic viability of this nationally important wild dog population.

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Introduction

The managed metapopulation approach to African wild dog (*Lycaon pictus*) conservation in South Africa is an innovative restoration programme to increase the population size and distribution range of this endangered canid (Fig.1). The programme makes use of South Africa's unusual conservation landscape – unique among African nations for its preponderance of private fenced reserves. The approach was formulated in 1998 on the back of recommendations emanating from a Population and Habitat Viability Assessment (PHVA) workshop, facilitated by the IUCN SSC Conservation Breeding Specialist Group, which emphasised the importance of establishing a second viable population of wild dogs in South Africa, in addition to the only large contiguous population occurring in Kruger National Park (Mills *et al.* 1998).

The absence of suitably large areas to support another viable population led to the decision to establish a network of small populations in private and state-owned fenced reserves across the country. These populations, although not viable individually, would be connected through artificially mediated dispersal, with the goal of establishing at least nine packs in 10 years. The Wild Dog Advisory Group South Africa – a network of conservation authorities, managers, researchers and other stakeholders – was set up to achieve this goal by identifying metapopulation sites, coordinating reintroductions and guiding subsequent population interventions.

Fig. 1 African wild dogs. © Rob Till

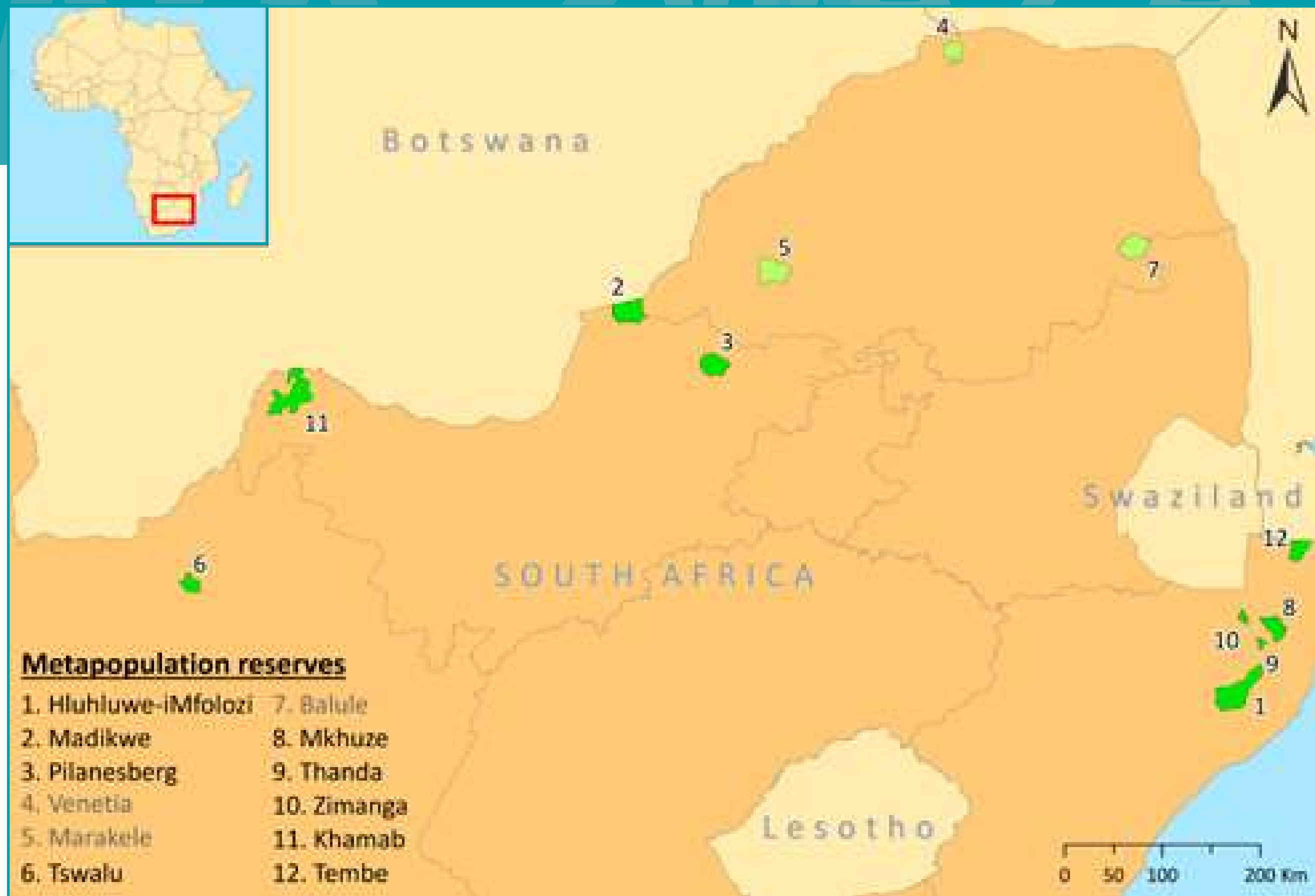

Fig. 2 Map of South Africa showing the reserves participating in the managed wild dog metapopulation, 1998–2012 (grey legend entries indicate reserves that have withdrawn from the programme).

Wild dogs are highly social canids, living in packs of two to 30 adults that consist of a dominant breeding pair and their young and non-breeding helpers. Litters are typically produced annually and until the pups are a year old, they depend on older pack members to provide them with meat from kills. Hunting is cooperative, and this allows capture of larger prey than would be possible by individuals hunting alone. New packs form when single-sex dispersing groups (of either sex) leave their natal packs and meet up with unrelated dispersing groups of the opposite sex. This process of new pack formation, and the wild dogs' inherent sociality, have both contributed to the ease in which new packs for reintroduction and population augmentation are artificially created.

The Use of Captive-bred Animals in Wild Dog Conservation Management

Between 1998 and 2012, the number of reserves participating in the managed metapopulation fluctuated between two and nine (Fig. 2). Total wild dog numbers peaked at more than 230 individuals in 2005, and have maintained above 150 individuals in more than 12 breeding packs since September 2009.

Although reintroduction may not be a high priority in the wild dog conservation toolbox, wild dog reintroductions had taken place throughout the region long before the formal adoption of the managed metapopulation approach in South Africa. These included sites in South Africa, Namibia, Zimbabwe and Kenya. These early interventions were not part of a coordinated programme, and many of them failed for biological and/or non-biological reasons. The former included lack of social integration within artificially assembled packs leading to pack dissolution or fission following release, as well as the use of captive-bred animals that lacked the social and hunting behaviours necessary for survival in the wild (Gusset *et al.* 2006). The latter included anthropogenic mortality as a result of inadequate sensitisation to the process among neighbouring communities.

Partly as a result of these early failures, it was initially intended that wild-caught founding stock for managed metapopulation reintroductions would be obtained from the free-ranging population in Kruger National Park. However, as time went by, it became apparent that there were other, more readily accessible sources of founding animals, and that it was not necessary to risk the potential impacts on the source population of wild dogs in Kruger National Park (Davies-Mostert *et al.* 2009). Only two of the 96 founding individuals (2%) were sourced from Kruger National Park; the remainder comprised wild-caught animals relocated from unprotected areas following conflict with game and livestock farmers (49%), captive-bred animals from facilities in South Africa and Botswana (24%), and pups from litters born in holding enclosures while their parents were awaiting translocation and/or release (25%).

Lessons Learned About the *In Situ–Ex Situ* Interface

In the 15 years since initiation of the managed metapopulation approach, captive-bred animals have made a more significant contribution than was first anticipated, and some key lessons have emerged about the integration of *in situ* and *ex situ* management (Gusset *et al.* 2008). These relate to the relevance of a strategic direction for the *in situ–ex situ* interface, the variety of technical skills acquired for intensive *in situ* management, the identification and uptake of cross-cutting population management tools, and the potential long-term contribution of captive facilities to metapopulation persistence.

A Significant Contribution in the Absence of Strategy. Although captive-bred animals comprised almost a quarter of all founder animals in the managed metapopulation, this was largely by chance rather than due to a particular *ex situ* breeding and release strategy. There has never been a coordinated breeding plan for *ex situ* wild dogs intended for release; partly because the frequency of augmentation of *ex situ* animals was relatively low (and has become lower) and because there was an understanding that sourcing wild-caught animals from subpopulation reserves was preferable. However, there were a number of occasions when suitable wild-caught individuals were not available to resolve demographic issues within subpopulations, and in these instances there were always facilities that could be relied upon to provide animals, free of charge. So was a strategy necessary? Given the need to ensure both demographic and genetic viability in the long term, and the increasing complexity as the number of individuals and subpopulations has grown, there is an argument to be made for formally incorporating *ex situ* facilities to ensure a supply of genetically suitable founders in the future.

Building Technical Competencies. In order to achieve the goal of establishing and maintaining at least nine wild dog packs outside of Kruger National park, wild dog populations have been re-established or augmented on at least 33 occasions. These experiences have provided a fruitful testing ground for fine-tuning our technical capacity to mimic wild dog dispersal and new pack formation, and some clear lessons have emerged (Gusset *et al.* 2006). Chief among these is the importance of strong social cohesion among members of artificially formed packs, now widely recognised as a principle driver of pack persistence. Wild dogs are obligate social animals, with hunting and pup provisioning (including guarding) highly dependent on pack members working closely as a team. Bonds can be tested and strengthened during a holding period, in which new pack mates are kept together in an enclosure for several weeks or months prior to release. This has been a boon for the recovery programme: by bonding captive-bred individuals with few life skills to hunting- and predator-savvy wild-caught animals, the programme has been able to bolster the number of animals available for release. There are many examples of how captive-bred animals have learned the requisite skills for survival from their wild-caught pack mates.

Ex Situ *Tools for Better* In Situ *Management*. In many ways, the managed metapopulation closely parallels a managed captive population: animals are moved among subpopulations based on demographic and genetic criteria and translocations are conducted to optimise these (Gusset *et al.* 2009). The only major difference is that the adaptive forces of selection (including predation, disease and mate choice) operate more influentially on the one than the other. There are a number of *ex situ* population management tools that are widely used in the management of animal collection across the world; however, these tools were not identified or adopted from the initiation of the programme. In the first few years, the population size was small enough and monitored closely enough to keep track of individuals, and translocation decisions were based on informal expert judgements about relationships between individuals and populations.

However, as the metapopulation grew in size (individuals, packs and subpopulations), and there was turnover among management personnel, it became more challenging to implement this "seat of the pants" methodology. A key lesson from this is the importance of formal population management tools to improve population management efficiency, and reduce the possibility of poor judgements due to lack of robust data on population structure. Recent genetic studies suggest that the "seat of the pants" approach has been adequate to maintain levels of gene diversity higher than those in the free-ranging population in Kruger National Park, which means it is not too late to implement tools for future management.

The Real Role of Captive Facilities. Many captive breeding facilities in South Africa justify their existence with claims that they are breeding animals for release into the wild. This is sometimes a smoke-screen for generating entrance fees and even donations from misinformed members of the public. This is illustrated by the fact that the number of wild dogs in captivity in South Africa is unknown: even properly registered facilities have a poor record of submitting population records to studbooks, and unregistered facilities are a complete black hole. While one or two facilities have made a meaningful contribution to *in situ* conservation efforts through the provision of wild dogs when necessary (see above), captive breeding is not the panacea for wild dog conservation that so many claim it to be. Rather, facilities have an important advocacy and awareness role to play in educating members of the public about the real threats facing wild dogs and other large carnivores (primarily habitat loss and fragmentation, and direct persecution). It is a role that should be emphasised.

The Way Forward for Metapopulation Management of Large Carnivores

South Africa has a chequered past in terms of large carnivore conservation: there exist huge expanses of land where cheetahs (*Acinonyx jubatus*) and wild dogs have been completely extirpated, and lion (*Panthera leo*) populations only occur in a handful of fenced protected areas. However, this unfortunate situation has given rise (out of necessity) to the development of innovative restoration programmes that have recovered extirpated range for large carnivores through reintroductions into fenced reserves throughout the country. The motivation for these reintroductions differs widely among species: cheetahs and lions have typically been reintroduced to generate income from ecotourism, whereas the wild dog programme met a strategic conservation need. However, many of the lessons learned are transferrable across species (Gusset 2009), and this is true for the integration of *in situ* and *ex situ* approaches for large carnivore management. Unfortunately, the uptake of these lessons is likely to become more urgent as human population growth and associated pressures on natural resources put the squeeze on large carnivore populations (particularly wide-ranging species) across the globe, and intensive management becomes increasingly inevitable.

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Southern yellow-billed hornbill (*Tockus leucomelas*) in the Okavango Delta.

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