Integration of In Situ and Ex Situ Data Management for Biodiversity Conservation Via the ISIS Zoological Information Management System

A Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

by

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DEDICATION

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International Union for Conservation of Nature and Natural Resources	IUCN
Institute of Museum and Library Sciences	IMLS
Instituto de Pesquisas Ecológicas	IPE
Joint Nature Conservation Committee	JNCC
Living Planet Index	LPI
Los Angeles Zoo	LAZ
Lowland Tapir Conservation Initiative	LTCI
Medical Animal Records Keeping System	*MedARKS*
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New Zealand Department of Conservation... NZDOC
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ABSTRACT

INTEGRATION OF IN SITU AND EX SITU DATA MANAGEMENT FOR BIODIVERSITY CONSERVATION VIA THE ISIS ZOOLOGICAL INFORMATION MANAGEMENT SYSTEM

Karin R. Schwartz, Ph.D.

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For conservation action to mitigate biodiversity loss there is an increasing need for a "one plan approach" to develop multi-disciplinary conservation strategies that include the integration of *in situ* (in the wild) and *ex situ* (under human care in zoological facilities) management processes. This integration necessitates collaboration at all levels of conservation action including planning, implementation, monitoring and finally assessment to drive adaptive management processes. Each component of conservation action is fully dependent on the availability and accuracy of data in order to guide the formation of action plans and carry out management processes. The *Zoological Information Management System* (*ZIMS*), managed by the International Species Information System (ISIS), is a centralized Web-based system that pools data on global *ex situ* animal populations including basic information on life history, physiology, behavior, and health to facilitate animal husbandry and breeding management programs.

ZIMS offers a new opportunity to link data management processes for animals that spend a part of their lives under human care and part in their natural environment and potentially for use monitored wild populations.

This dissertation has three main goals: 1) to identify data needed to manage and assess threatened species conservation programs; 2) to identify the data management tools currently in use by both *in situ* and *ex situ* partners for representative species recovery programs; and 3) to develop the framework to expand the use of *ZIMS* by aligning the *in situ* and *ex situ* data needs with *ZIMS* functionality. First, published case studies of conservation translocations for representative invertebrate, fish, amphibian, reptile, bird, and mammal species were reviewed to identify parameters used in management and evaluation of success of the projects. Results showed that for all animal groups, important management and assessment parameters included basic data components on life history attributes, genetic diversity, habitat and resources, health assessments, husbandry and release methodologies, and long-term monitoring. Overriding themes included the lack of evidence-based information on life history, biology and ecology of the species and the need for scientific research for each step of the conservation translocation programs. Second, data collection and management tools were identified for five categories of threatened species programs, each in some way impacted by the integration of *in situ* and *ex situ* research or management. *Ex situ* species coordinators and registrars were consulted to identify data management practices for animals in zoological institutions and field researchers' data collection methods were investigated through direct observation or electronic communication. Overall data management processes included the use of ISIS programs and a combination of database programs (*Access*, *Excel*), *Word* documents, paper forms, and media (photos, videos, diagnostic images) such that compiling data for analysis was inefficient. Communication between *ex situ* and *in situ* partners required duplicate efforts in reporting resulting in lag times that compromised effective conservation action. Third, data requirements and data management tools for each program were aligned with *ZIMS* functionality to illustrate how this information system could integrate *in situ* and *ex situ* data management processes. Acknowledging that *ZIMS* has current functionality to cover many of the collective data management processes, limitations for comprehensive *in situ* data management were identified and recommendations were made for further development. Use of *ZIMS* can facilitate coordination of data management processes between conservation partners, thus improving the efficacy of biodiversity conservation programs.

CHAPTER 1 LINKING IN SITU AND EX SITU DATA MANAGEMENT PROCESSES FOR CONSERVATION OF THREATENED SPECIES

Introduction

The natural world is at great risk from loss of biodiversity due to the burgeoning human population that is perpetuating the unsustainable use of natural resources (Secretariat of the Convention on Biological Diversity 2010). The overall goal of conservation is to mitigate the loss of biodiversity and preserve ecosystem, species, and genetic diversity for future generations (Djoghlaf 2010). Conservation action requires a multi-disciplinary approach to ensure a future for humans as well as species and ecosystems that are now in decline (Westley 2003). In this changing world, there is an increasing need for conservation strategies to include the integration of *in* situ (in the wild) and *ex situ* (within zoological institutions) management processes (Redford *et al.* 2012). This integration necessitates collaboration at all levels of conservation action including planning, implementation, monitoring and finally assessment which drives adaptive management processes.

There are a number of organizations that are working in concert for conservation. The International Union for Conservation of Nature and Natural Resources (IUCN) Species Survival Commission (SSC), one of the six IUCN Commissions, works to provide information on species conservation and the role of species in our ecosystems. The SSC Specialist Groups have an important role in assessing conservation status for threatened species and for facilitating conservation action planning through processes such as Population and Habitat Viability Assessments (PHVA) (IUCN 2008). The SSC is comprised of experts from many disciplines: researchers, educators, government officials, wildlife veterinarians, zoo and botanical institution professionals, and protected area managers. Many zoos and aquariums also provide a role in conservation efforts by providing conservation education and expertise in population management of threatened species. These zoological institutions are involved in *in situ* conservation through such avenues as sharing of information, returning threatened species to the wild, conducting research, funding support for conservation, and contributing expertise to SSC Specialist Groups. It is increasingly evident that in order to stem the tide of biodiversity loss, *in situ* and *ex situ* conservation efforts will need to be combined into a collaborative force for species conservation.

Conservation action planning is fully dependent on the availability and accuracy of data about the threatened species in order to guide the formation of the plans to mitigate population declines. For a PHVA, the planning process involves compilation of data on a species' known ecology and natural life history, conservation status, habitat use, and threats to populate data fields in population viability software such as *Vortex* to estimate extinction risk (Lacy 2010). In order to assess abundance, distribution, and life history parameters, scientists have developed a number of techniques for monitoring natural populations (McComb *et al.* 2010). Within a reintroduction or conservation translocation program, a monitoring program for the released animals must be included in the management plan to assess success of conservation programs (Nichols and Armstrong

2012). When data needed for assessment are lacking or questionable, the uncertainty increases within these processes and is a major impediment to making relevant recommendations for conservation action.

Information technology (IT) to manage populations under human care has evolved to include sophisticated animal records keeping systems as well as IT tools for health care and population management. The International Species Information System (ISIS) is a centralized database system that pools data on animal populations under human care including basic information such as life history, physiology, behavior, and health to facilitate animal husbandry and breeding management processes (Schwartz and Flesness 2014). ISIS has a membership of over 900 zoological institutions worldwide that use ISIS software for data management processes. ISIS deployed the *Zoological Information Management System* (*ZIMS*), a global web-based database system that has increased complexity and functionality from the previous technology used by ISIS members. Zoos and aquariums are involved with *in situ* conservation through many avenues including direct collaboration for returning animals to the wild. Due to the increased need for collaboration and holistic conservation action planning, data sharing between *in situ* and *ex situ* conservation partners is imperative but currently there are no direct links between these two components of conservation programs. *ZIMS* offers an untapped capacity to link data management processes for animals that spend a part of their lives under human care and part in their natural environment as well as the potential for use for managed wild populations.

Status of Biodiversity

Biodiversity is essential for effective ecosystem functioning in changing environments (Loreau *et al*. 2001). The impact of humanity in recent history has altered the balance of natural systems within the biosphere to such a great extent that scientists believe the current species extinction rate is 100 to 1,000 times higher than it would be in a world that was not dominated by humans (Pimm *et al*. 1995). The natural world is in peril as shown by a Global Assessment that for all species assessed (47,677 species), the number of globally threatened or extinct species includes 41% of amphibians, 31% of reptiles, 37% of fishes, 13% of birds and 25% of mammals (IUCN 2012). There are 875 species of vertebrates that have disappeared over the past 500 years in the wild and 65 species now found only in captivity or in cultivation. Such high loss of biodiversity will have severe impacts on the stability of ecosystems if these trends continue (Soulé 2003).

To address the challenges of biodiversity loss, the United Nations Environment Programme (UNEP) convened the Convention on Biological Diversity (CBD) in 1992 with the goal to achieve a significant reduction in the current rate of biodiversity loss at the global, regional and national levels. Article 9 of the CBD called for adopting measures for *ex situ* conservation aimed at recovery of threatened species and reintroduction back to natural habitat. The 10th CBD Conference of the Parties (COP) in 2010 determined that the reduction of the biodiversity loss target agreed upon by the world's governments at the 2002 COP had not been met and agreed on 20 new conservation targets, titled the "Aichi Targets", to form the guidelines for biodiversity conservation through 2020 (CBD 2010). Zoos and aquariums were noted as organizations that could contribute to “Strategic Goal C “ i.e., to “improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity”.

Through the establishment of the Aichi Targets, the stage was set for collaboration of multiple disciplines to contribute to global conservation efforts by working to decrease the loss of biodiversity and ensure a sustainable future for all species. Due to a need for ecosystem-based management and the financial considerations of establishing a global protected area network, the large conservation NGOs such as World Wide Fund For Nature (WWF), Conservation International (CI) and The Nature Conservancy (TNC) moved away from species conservation to focus on ecosystem conservation (James *et al.* 1999; Murdoch *et al*. 2010). Zoological institutions and smaller NGOs that focused on individual taxa thus became the champions of species conservation (Murdoch *et al.* 2010). Zoos and aquariums, as conservation organizations, have long been involved in partnerships to work towards biodiversity conservation and mitigate the loss of biodiversity for a sustainable future.

Zoos and Aquariums and Conservation

Zoos and aquariums evolved from menageries first for entertainment of private individuals or societies and later for the public to institutions with an increased emphasis on conservation (Rabb 1994). Records-keeping was limited prior to the 1980s as many institutions did not individually identify their animals and only kept track of when animals arrived and when they died or were shipped out (Schwartz and Flesness 2014). As the declining status of animals in the wild made acquisition for zoological institutions increasingly difficult, there was a growing awareness of the necessity for conservation measures to mitigate the loss of biodiversity. Cooperative animal management practices became imperative and many zoological institutions became involved in conservation through breeding management programs for endangered species, education programs focusing on conservation, and increased funding support to participate in *in situ* conservation programs. Although the roles for many captive populations were as exhibits and for education and/or entertainment, there were other cases where a captive population was established as a hedge against extinction of the species in the wild (Kierulff *et al.* 2012) or represented the sole survivors for a species extinct in the wild (Cohn 1993). Animal records-keeping became an important part of management as people learned more about successful breeding techniques as well as developing improved husbandry protocols for animal health and well-being.

Beginning in 1981, the Association of Zoos and Aquariums (AZA) developed Species Survival Plans (SSP®) for selected taxa as a cooperative population management and conservation effort in zoos and aquariums in North America. Comparable programs were developed in other regional zoo associations such as European Association of Zoos and Aquariums' European Endangered Species Programmes (EEP), African Association of Zoos and Aquaria's Africa Preservation Programmes (APP), and Zoo and Aquarium Association's Australasian Species Management Programs (ASMP). The World Association of Zoos and Aquariums (WAZA), a global organization that brings together nearly 300 member zoos and aquariums, regional and national associations of zoos and aquariums and affiliate organizations, developed Global Species Management Programs (GSMP) that provided breeding management using a meta-population strategy to include species management for small populations in more than one region (Balmford *et al.* 1995). For a few select endangered species, the captive population was used for reintroduction or supplementation programs, although this was not actually the focus of the captive programs in general (AZA 2014). Accurate and efficient data management processes were critical to track such information as parentage, health, diet, behavior, morphometrics, and husbandry for development of studbooks and use in population management software. With these breeding management programs in place, participating zoological institutions were able to limit collection of animals from the wild thus reducing their impact on wild populations. ISIS reports that in the global animal database of animals currently in ISIS member institutions, 86% of birds, 92% of mammals, 78% of reptiles and 78% of amphibians are captive born (personal communication, Elisabeth Hunt 2012).

In a 2011 study, Conde *et al.* (2011) found that roughly one out of seven known threatened species on the planet can be found in a zoo or an aquarium. The authors stressed that captive breeding in such institutions may be the only practical conservation option left for some species whose habitats are dwindling. Hoffman *et al.* (2010) found that the IUCN conservation status of 68 vertebrate species had improved with 19 of those species benefitting from conservation measures from conservation breeding. With further investigation, Conde *et al*. (2011) showed that 13 species with improved status benefitted from conservation breeding with zoological institutions also contributing substantial logistical, technical or financial support for nine of those 13 species. Yet, thirteen species out of the total number of vertebrate species on the Red List is still only a tiny proportion, illustrating the urgency to increase involvement in conservation programs to benefit wild populations.

In “Building a Future for Wildlife: The World Zoo and Aquarium Conservation Strategy” (WAZACS) , WAZA states that “The major goal of zoos and aquariums will be to integrate all aspects of their work with conservation activities” (WAZA 2005 p.13) and “Zoos and aquariums will make further contributions to conservation in the wild by providing knowledge, skills, and resources through initiatives in zoo breeding, translocations and reintroductions, wildlife health, research, training, education and by funding field activities” (WAZA 2005, p.16). WZACS helped set the stage for zoological institutions to play a role as important conservation organizations (Gipps 2010). Although conservation action is increasing, much more could be done including stepping up financial support for conservation and applying expertise in population management for small populations in zoological institutions to meta-population management of threatened species in the wild (Gusset and Dick 2010). These integrated processes require cooperation, collaboration and communication between *in situ* and *ex situ* efforts for the overall benefit of conservation.

Integration of *in situ* and *ex situ* conservation programs

Conservation and management of animals in the wild can insure not only the survival and recovery of individual taxa but also lead to conservation of their ecosystems. Thus, zoological institutions’ work with umbrella and keystone taxa links conservation for individual species with overall benefits for the habitat and other species required for their survival (Soule *et al.* 1986). Zoological institutions may contribute to conservation directly through different conservation translocation programs including reintroduction, supplementation of threatened populations, head-start programs, or rescue-rehabilitation-release of injured wildlife. As per Reintroduction Specialist Group Guidelines for Reintroductions and Other Conservation Translocations (IUCN/SSC 2013), a conservation translocation is the intentional movement and release of a living organism where the primary objective is a conservation benefit. The goal is to improve the conservation status of the focal species locally or globally, and/or restoration of natural ecosystem functions or processes. A conservation program may include a combination of conservation translocations: population restoration (reintroduction, reinforcement) or conservation introduction (assisted colonization, ecological replacement) (see Appendix I) or incorporate other management tools such as head-starting or rescue/rehabilitation/release protocols.

Head-starting involves collection of eggs from the wild, incubating and then raising the hatchlings under human care until they are old enough and large enough to improve their chance of survival in the wild. Some egg-laying, long-lived species such as turtles and tortoises exhibit a "Type III survivorship curve" where hatchling mortality is very high and those that do survive to adulthood may live a long life (Rockwood 2006). Species such as certain reptiles and amphibians that exhibit limited or no parental care, high fecundity and high juvenile mortality may benefit from head-starting programs for populations under threats such as habitat loss or presence of invasive predators (Heppell *et al.* 1996). Head-starting methodology must be used in conjunction with other conservation measures to ensure survival of adults to realize their breeding potential.

There are many endangered species that benefit from rescue/rehabilitation/release operations facilitated by government authorities, zoological institutions, and rescue and rehabilitation centers around the world. In the United States, there are rescue operations for marine mammal species such as pinnipeds, sea otters and manatees (Moore *et al.* 1996). The Florida Manatee Recovery Plan (U.S.F.W.S. 2001) issued by the U.S. Fish and Wildlife Service includes a rescue, rehabilitation and release program for Florida manatees (*Trichechus manatus latirostris*). Injured or ill manatees are cared for at one of the network facilities, which include government and private licensed rescue centers and a number of zoos and aquariums including Lowry Park Zoo in Tampa, Sea World of Florida in Orlando and the Miami Seaquarium. In 2011, of the 102 manatees rescued, 41 were assisted (after being stranded or entangled) and released back to the wild while 61 were brought into captivity for rehabilitation (USFWS 2013). Of the 61, 41 rehabilitated manatees were released back to the wild within the year.

A conservation program for langurs in Vietnam goes one step further by combining rescue operations, captive breeding and reintroduction protocols to increase declining populations in the wild (Forster *et al.* 2010). The Endangered Primate Rescue Centre (EPRC) in Cuc Phuong in northern Vietnam, a facility managed by Frankfurt Zoological Society in cooperation with the Cologne Zoo, rescues confiscated IUCN Endangered Hatinh langurs (*Trachypithecus hatinhensis*) and Douc langurs (*Pygathrix nemaeus*). The rescued langurs are entered into a breeding program with the end goal of reintroducing offspring back to a selected site in Phong Nha-Ke Bang National Park in central Vietnam.

Seddon *et al.* (2007) reported that the number of species involved in reintroduction of captive born animals back to the wild increased from 218 in 1998 to 489 by 2005. Data from the Avian Reintroduction and Translocation Database (Lincoln Park Zoo 2013) show that for birds alone, 201 species have been involved in reintroduction or translocation projects with over 2359 release events occurring in the last two decades. For some species extinct in the wild, reintroduction of captive animals offers the only hope of survival and continued intensive management is the only means to ensure the success of these populations. The golden lion tamarin (*Leontopithecus rosalia rosalia*), red wolf (*Canis rufus*) and Arabian oryx (*Oryx luecoryx*) are all examples of species that were literally brought back from the brink of extinction through captive breeding and reintroduction to the wild (Kierulff *et al.* 2012; Beeland 2013; Zafar-ul Islam *et al.* 2010, respectively). All of these programs involve an intersection between care in a zoological institution and life in a natural environment.

Conservation Action Planning

Prior to conservation action, a multi-disciplinary group of specialists go through a conservation action planning process to assess the status of a focal species or taxon in the endemic range, evaluate the threats causing population decline and plan deliberate, specific action steps to mitigate the decline. The Conservation Breeding Specialist Group (CBSG), under the umbrella of the IUCN SSC, conducts PHVA workshops combining face to face meeting of stakeholders with quantitative analysis to evaluate extinction risk through the use of *Vortex* software (Miller and Lacy 1999). *Vortex* is a simulation computer program used to assess extinction risk and help determine the conservation needs of a single species to assist in action planning. Through a modelling approach, *Vortex* simulates the effects of deterministic forces as well as demographic, environmental and genetic stochastic events on a population. *Vortex* also allows trends in human population activities that impact the environment to be factored into the extinction model (Miller and Lacy 2003). In considering the complexity of biological, physical and human systems that impact ecological systems, "MetaModel Manager" (Pollack and Lacy 2013) was designed to link population viability analysis with emerging diseases, landscape changes, climate change and human social factors in order to look at the impact on the probability of extinction of threatened species. "MetaModel Manager" provides an interface between *Vortex*, "Outbreak" software (a modeling program that simulates infectious disease processes in wildlife populations; Lacy *et al.* 2012), and "Spatial" (a spatial data program that collects geographic information system data to track landscape changes due to climate change and/or human impacts; Pollack 2013). The assessment processes are heavily dependent on accessible data to limit uncertainty in the outcome of the analyses.

One Plan Approach – continuum of intensively managed populations

Over the last 30 years the zoo and aquarium community has made significant progress in its cooperative management of *ex situ* populations. Yet, although these programs were considered conservation measures, the effectiveness for conservation was in question (Snyder 1996). Although a few threatened species were saved from extinction through captive breeding and reintroduction methods, overall there were limitations to these methods that precluded them from being the sole solution to species recovery.

These limitations included inability to establish a sustainable population in captivity, potential genetic and behavioral changes, high costs and limited success for reintroductions, and potential for disease transmission.

An assessment of the sustainability of mammal species managed in captivity through AZA SSP®s, EAZA EEPs, and ZAA (previously ARAZPA) ASMPs showed that about half of the species were breeding to replacement and retained the levels of genetic diversity at or above the recommended threshold of 90% (Lees and Wilcken 2009). In an assessment of sustainability in avian species, EAZA avian studbooks were analyzed with results showing that 26% were successful in terms of population size, growth and meeting genetic diversity thresholds but 74% were headed toward increasing difficulties (K. Leus, personal communication 2012). Over time *ex situ* population goals have changed from retaining 90% genetic diversity (GD) for 200 years to 100 years to now 80 or even 50 years (Lees and Wilcken 2009). Priorities were set without complete integration with *in situ* conservation needs.

With the sustainability of *ex situ* populations in question, Conway (2011) suggested that zoos integrate their management strategies with those of wildlife parks and reserves for more holistic conservation action. As the human population grows and habitat disappears, the wild places that persist could very well need some type of management. Thus, the lines will be blurred between management of species under human care and that for animals in the wild. In the "Intensively Managed Populations for Conservation Workshop" facilitated by CBSG in December 2010, international zoological specialists from zoos and aquariums, SSC Specialist Groups, government authorities, universities and conservation NGOs discussed the issues surrounding lack of sustainability for zoo populations and low potential for contributions to biodiversity conservation (CBSG 2011). Participants discussed the need for a paradigm shift towards supporting population management along a continuum from no population management (wild populations) to the most intensive management (regional zoo association population management programs) (see Figure 1.1). Management strategies would change depending on the status of each population and there may be interactions between populations managed through the different strategies. Because of uncertainty for survival of populations in the wild, any *ex situ* population managed for the long term should have the potential to contribute directly to conservation in the wild through the various conservation translocation paradigms including reintroduction or supplementation. This would require exploring new approaches such as coordinated action planning, centralizing expertise and utilizing new tools and strategies for connections along the management continuum.

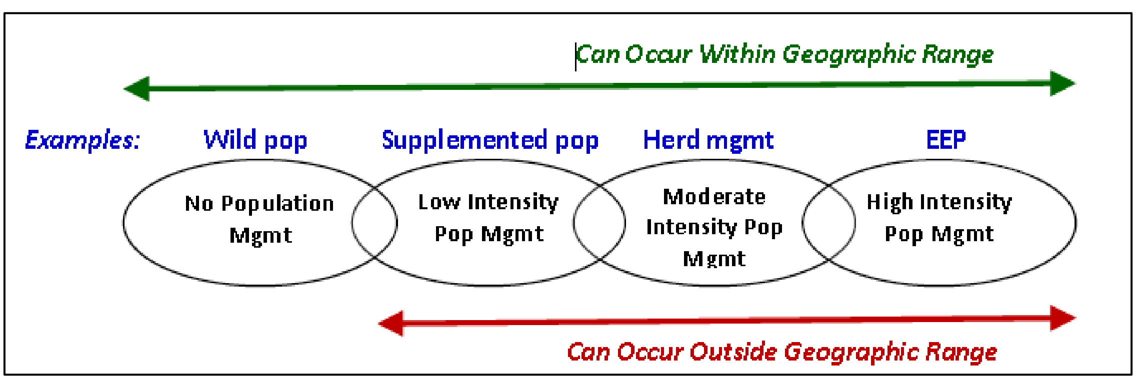


Figure 1.1. Continuum of population management strategies (courtesy of CBSG 2011). EEP – European Endangered Species Programme

There is an increasing need for integration of *in situ* and *ex situ* participation in holistic conservation programs. SSC Taxon Specialist Groups are active in conservation action planning for their focal taxon, producing conservation action plans as a roadmap to future conservation action. The Crocodilian Specialist Group (CSG) has developed Action Plans for 23 individual species of threatened crocodilians that outline a conservation overview (Red List and CITES status, principle threats), ecology and natural history, range listed by country, prioritized projects for protection and monitoring, and a reference list (Crocodile Specialist Group 2013). Zoo professionals are active participants in the CSG and the action plans incorporate *ex situ* components in the overall agenda for conservation of each species (e.g. Tomistoma [*Tomistoma schlegelii*] Action Plan; CSG 2010).

With the increasing need for collaboration between *in situ* and *ex situ* factions for overall conservation, CBSG has proposed a "one plan approach" that incorporates all populations of a species both in the wild and under human care when planning conservation action (Byers *et al*. 2013). Many Taxon Specialist Groups have developed conservation action plans for threatened species in the wild but only a few have incorporated the *ex situ* management plans into their conservation strategies. For many species, *in situ* and *ex situ* conservation action plans have been formed in parallel with a few exceptions (e.g. golden lion tamarin). With anthropogenic factors accelerating the extinction rate of species by a thousand times the natural rate, biodiversity conservation has become mandatory for sustainability of our natural world and natural resources. It is now imperative that species conservation strategies involve both *in situ* and *ex situ* communities for holistic, integrative conservation action planning (Figure 1.2).

Sophisticated records-keeping and population management tools have been developed for use in animal health and breeding management programs for *ex situ* populations. Now, managing critical populations of endangered species in the wild has become important as more conservation translocations of captive-bred or rescue/rehabilitated animals occur. Currently, only a few conservation translocation programs utilize these data management tools for holistic animal management and there is no direct link between the *ex situ* data management processes and databases used in monitoring and managing those animals released to the wild or for intensively managed wild populations. To facilitate the "one plan approach", there is a need for information exchange and standardization between *ex situ* and *in situ* data management practices to link these components for species recovery programs.

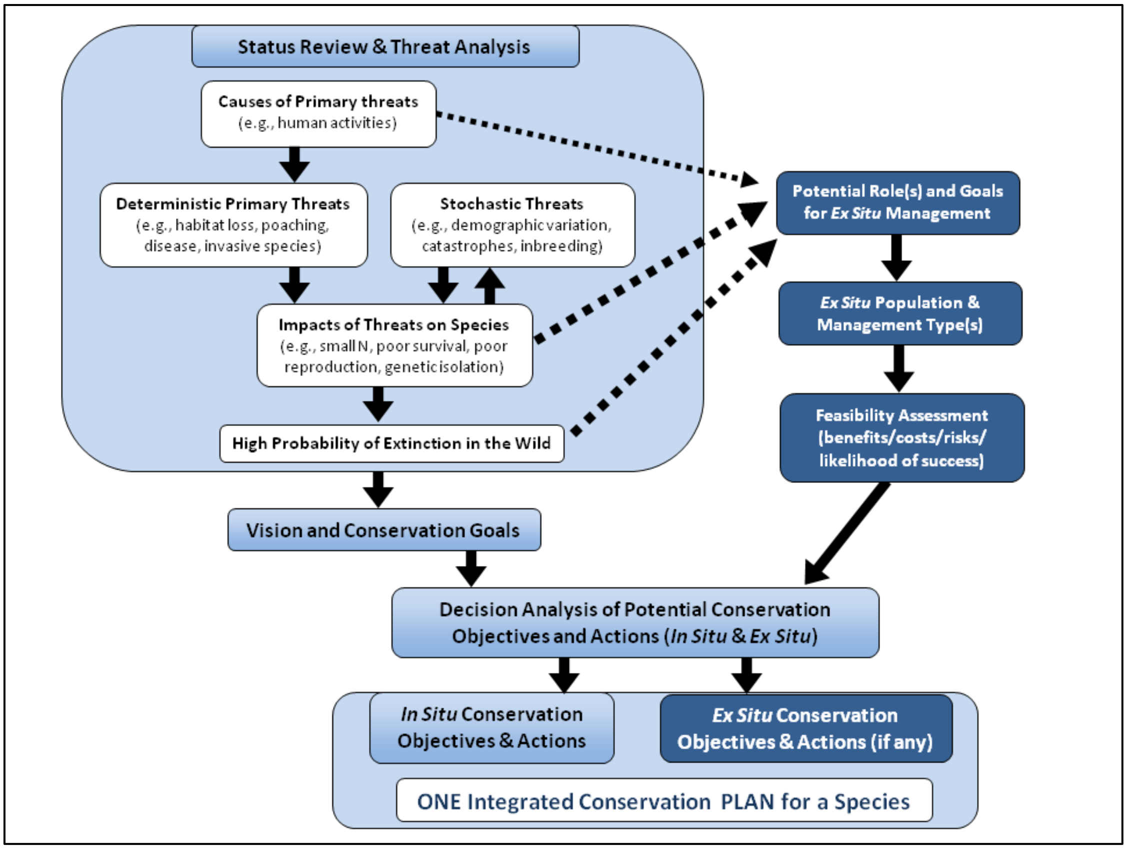


Figure 1.2. Integration of *in situ* and *ex situ* programs for conservation (courtesy of Traylor-Holzer 2013)

Data Management and Data Sharing

Data sharing is a fundamental component of collaboration for any discipline to initiate learning, offer validation and to go forward without duplicating effort. The scientific community depends on shared information to integrate results from different disciplines for holistic understanding in order to build on previous work and progress towards their research goals (Louis *et al*. 2002). Increased collaboration between the *in situ* and *ex situ* conservation communities will be imperative as a single force to address the conservation issues that the world faces. Communication and information exchange will allow progress towards the common conservation goals. Sharing results of determinants for both successful and unsuccessful programs is important to contribute to the body of knowledge through publications in peer-reviewed journals (IUCN 2013). Documentation for all the components of a conservation program will supply the data necessary for robust scientific evaluation to facilitate understanding of the causes for success or failure, allowing for adaptive management.

***Ex situ* data management**

Careful scientific management of *ex situ* populations is required to preserve the genetic and demographic diversity essential for their successful maintenance (Lees and Wilcken 2009). Accurate records are crucial for the long-term management and stability of these populations. Animal records databases contain information used directly for husbandry, population management, regulatory requirements, and strategic planning to help provide the best possible care for animal populations and assist with scientific animal management to ensure healthy populations for the future. Records kept on *ex situ* populations can be compiled for analyses to increase the understanding of basic animal information such as life history, physiology, behavior, and health. For example, research on gray wolf (*Canis lupus*) reproductive physiology using animals in *ex situ* populations has elucidated the basis for social organization and reproductive strategies in this species which helps in understanding social behavior of animals in the wild (Asa and Valdespino 1998). Thus, the big picture of biodiversity conservation is taken into account as knowledge gained on animals maintained under human care contributes to species conservation in the wild.

Careful, cooperative animal record-keeping is a relatively new process that has evolved into a sophisticated global collection of captive animal information. Seal and Makey identified the need for detailed records of zoo specimens worldwide in a global database (Seal and Makey 1973) and Seal founded ISIS in 1973. ISIS is a premier organization that is committed to: “Provide the world’s most current, comprehensive and reliable source of knowledge on intensively managed species and their environments for zoos, aquariums and related organizations to serve institutional, regional, and global animals management (*ex situ*, as well as *in situ*) and conservation goals” (ISIS website 2013). ISIS collectively manages animal records for a membership of over 900 zoological institutions in 85 countries with information on over 3 million animals representing 15,000 species (ISIS 2014). ISIS is centered in Minneapolis, Minnesota with regional offices in Amsterdam, The Netherlands; Bogota, Colombia; Tokyo, Japan; and New Delhi, India. In 1985, the initial version of ISIS’ *Animal Records Keeping System* (*ARKS*) software was made available to members and maintained essential data such as core individual data as well as behavioral observations, reproduction and morphometric data (see Appendix II). The fourth version, *ARKS4* could be used in any of 14 languages (English, Finnish, French, German, Hungarian, Italian, Japanese, Norwegian, Portuguese, Russian, Slovak, Spanish, Swedish and Ukrainian). In March 2010, ISIS issued the web-based Zoological Information Management System which would replace previous ISIS software and contained more complex functionality as a comprehensive information management system.

An animal's medical record was kept through the use of *MedARKS* (the *Medical Animal Records Keeping System*, a DOS program). The medical record in *MedARKS* was linked to the animal's *ARKS* record through the animal's institutional ID number and included anesthesia, clinical pathology, parasitology, prescription, and clinical notes modules, as well as medical history, inventory, and cryptopreservation/serum bank modules. Unlike *ARKS* records, individual animal medical records were not compiled within the central ISIS database, although there were physiological normal values and anesthesiology libraries developed through collective contributions of medical information from ISIS member institutions. Only 91 institutions used *MedARKS* in conjunction with their *ARKS* records, possibly due to the language limitations of this program that was only in English (J. Andrew Teare, personal communication).

To evaluate the species and specimens in terms of demographic and genetic goals, evaluations rely on a studbook, a single species database. *SPARKS* (*Single Population Analysis and Record Keeping System*) developed in 1987 by ISIS has become the zoo and aquarium standard endorsed internationally by the World Association of Zoos and Aquariums (WAZA); this studbook program supports data management of single species populations through compilation of basic demographic and genetic information and has some population analysis reporting capabilities. The dataset in *SPARKS* comes from the institutional records, many of which are in the ISIS global database or from the institutions' animal record system for non-ISIS members. Studbooks document a species pedigree; the lineage of each individual is recorded with dates of birth, death, and transfer. *PopLink*, developed by the AZA Population Management Center (PMC) at

Lincoln Park Zoo in Chicago, Illinois, was released in 2006 as an alternative program to *SPARKS* for development of a species studbook. *PopLink* datasets can be imported into population management software for population analysis. However, *PopLink* is not an ISIS product, output is not ISIS standard and the PMC does not offer international support, thus *SPARKS* remains the WAZA endorsed studbook program at the global level.

Demographic and genetic datasets from *SPARKS* are imported into *PMx* (Ballou *et al.* 2011), a population management program that analyzes the data to come up with various population management parameters to assist in the management process. Information includes life tables for males and females showing the average survival and reproductive rates over a selected time period, the population growth rate (lambda- the finite rate of increase or r – the intrinsic rate of increase) for a stable population as well as generation length (T), current number of males or females and projected numbers for a period of time in the future. This information leads to the analysis for reproductive planning, or how the population can be maintained for a projected growth rate. The genetic analysis produces a picture of the genetic health of the population by summarizing the founder representation, the amount of gene diversity present in the captive population relative to the wild population, the number of founder genome equivalents (how many wild-caught animals would have the same gene diversity as the captive-born population) and the mean inbreeding coefficients of the population.

At the ISIS Futures Search Workshop in 2000, the vision for “one global, accurate, comprehensive, Web-enabled, real-time animal and collection information system" was initiated leading to the development of the *Zoological Information Management System*. *ZIMS* is a comprehensive information management system that encompasses individual animal records (previous records are migrated from *ARKS*) and medical records (migrated from *MedARKS*) with future releases incorporating studbooks and population management functionality all within a single web-based system. *ZIMS* has increased the scope for data collection and analysis for *ex situ* populations as well as having great potential for linking *ex situ* and *in situ* data management processes.

***In situ* data management**

Conservation programs directed at species recovery may involve reintroductions or other conservation translocations with animals that for a portion of their lives were in *ex situ* facilities. The objective of such programs is to re-establish a self-sustaining population within its historic range or an alternate appropriate habitat. Beck *et al*. (1994) found a success rate of 11% when assessing 145 reintroduction projects involving captive animals, reporting that only 50% of the programs investigated had documentation to back up their ratings. With the low success rate of reintroduction programs noted, the IUCN Reintroduction Specialist Group formulated the Guidelines for Reintroductions (IUCN, 1998) to improve the reintroduction processes. Use of the Reintroduction Guidelines have improved pre-release planning, selection of founders, release protocols and post-release monitoring processes and the overall success of these endangered species conservation programs (Soorae 2008). Pre- and post-release monitoring of the re-established population was determined to be extremely important in order to assess the success of the program as well as plan for the future. In 2013, the Reintroduction Guidelines were updated and contained a guideline for incorporating data management into conservation program design (IUCN/SSC 2013). Data management for the translocation program should be planned in advance so that there is no question as to what data should be collected and the methods that should be used for monitoring the animals in the wild.

A structured decision making (SDM) process will provide a logical approach to identify the best options for managing a program and includes objectives, potential management actions, modeling the potential results and a monitoring program for input of results (Nichols and Armstrong 2012). Objectives for monitoring programs can be classified into two categories: scientific and management (Yoccoz *et al*. 2001). Scientific research objectives may include an understanding of the biology and ecology of the species, associated status in the ecosystem under the presence of threats, and health assessments of the population. Management objectives include assessing population viability and sustainability using monitoring data to evaluate parameters within the program. Both scientific and management objectives may be integrated within the overall conservation program plan. The objectives for each program will dictate the type of monitoring that should occur - what data should be collected, where and when, to provide evidence to measure progress towards program goals and to facilitate adaptive management of the program if objectives are not being met. Developing an *a priori* data management plan will help to ensure that the monitoring program has a sampling design that will enable robust analysis to impact the decision making process.

Various types of data are collected for a range of techniques that are used to monitor the progress of the programs (see Appendix III). Depending on the species, their life history traits, the habitat, the ease of detectability and the overall objectives of the program, the population may be observed and assessed as a whole or through identification of individuals that are closely monitored. Monitoring programs produce complex datasets that should be standardized yet flexible to changes as the programs are adapted. There are six essential descriptors that accompany each component (field) of the data management system (McComb *et al*. 2010):

1) what organism (species);

2) how many (units of detection);

3) where (location where the organism was recorded);

4) when (date and time);

5) how (details of data-collection protocol); and

6) who (person recording the data).

Details on monitoring data will be discussed in Chapter 3.

Currently, the data management processes for *in situ* programs are not linked with the ISIS animal records system that is used (for ISIS members) or an in-house records-keeping system (for non-ISIS members) while animals are within a zoological institution. It is advantageous to integrate data management for information while animals are under human care and information on those animals after release in a single system to learn about the entire process and identify variables that impact the success of the conservation program.

Justification

Although zoological institutions have made contributions to conservation through captive breeding of endangered species for potential conservation translocations, conducting research on the species in captivity, offering expertise and capacity building for range country programs, and funding support, the full potential for conservation action has not been realized (Fa *et al*. 2014). Applying technologies and methodologies that facilitate *ex situ* animal management to integrated conservation programs would contribute to overall management processes. Currently, there is no direct method for exchange of information on the animals between zoological institutions and wildlife managers working with these species in the wild. Animal records for animals in zoological institutions are kept in ISIS or other database programs and data on these same animals released to the wild are kept in various project-specific databases developed for capturing monitoring data. As such, there is no direct link between the captive animal records in ISIS and those databases used in monitoring and managing reintroduced and wild populations. This disconnect is detrimental to the successful conservation of these species.

Fischer and Lindenmayer (2000) looked at trends affecting success of reintroduction and relocation programs through an assessment of case studies and theoretical papers published over the last 20 years. The assessment confirmed that reintroductions and relocations are important conservation tools but success could be improved through better planning, rigorous testing of methods, establishing widely used and accepted criteria for assessing the success of the program, better monitoring of the post-release population and greater effort to report the level of success of the program through publishing of results. The number of reintroductions/relocations has increased, yet the literature on these programs largely consists of descriptive accounts or retrospective analyses of post-reintroduction monitoring (Seddon *et al*. 2007). Armstrong and Seddon (2007) advocate that reintroduction programs develop key questions prior to the release of the animals to the wild to focus monitoring at the population, meta-population and ecosystem levels. Thus, the data management plan for both pre- and post-release processes will be focused to provide answers to those key questions that will inform the adaptive management process. A strong link between databases used for records-keeping on the animals while under human care and on those same animals after release to the wild would facilitate this management process.

Likewise, knowledge of a reintroduced animal's pedigree in captivity can help mitigate genetic problems after reintroduction. Pedigree analysis has been used extensively to manage animals in captivity but has rarely been used by field biologists to manage populations in the wild (Haig and Ballou, 2002). With a need to manage populations over a continuum of intensively managed strategies, pedigree analyses of both the captive and reintroduced populations assist in managing the species as a meta-population resulting in elucidating genetic costs and benefits of movement of animals between captivity and the wild (as in supplementation). Capturing pedigree data for both captive and reintroduced populations in a single database will facilitate pedigree analysis for species meta-population management.

Data on captive animals in *ZIMS* may offer benefits that begin with the conservation management planning for a reintroduction program. Information used in *Vortex* calculations for a PHVA includes demographic and biological data on the species that may not be available for the wild population. Information captured in *ZIMS* on such parameters as longevity, age specific reproductive and mortality rates, reproductive life-span, and susceptibility to inbreeding would contribute to more precise estimates for use in *Vortex* modeling and thus improved guidelines for reintroduction.

In summary, expansion of *ZIMS* to include post-release data will help to evaluate reintroduction programs by retaining a single record on an individual throughout its life, both while in captivity and after release. Survivability of the released animal could then be linked with husbandry practices, behavior, social climate and health while in captivity prior to release as well as measured parameters after release. Genetic and demographic data collected in *ZIMS* could be used as a link between information on animals in captivity and animals in the wild in managing these populations as a meta-population.

Objectives

The overall objective of this study was to develop scientific-based recommendations for establishing a global database system that would provide a direct link between information collected on animals in captivity and their wild populations in order to enhance integration of *ex situ* and *in situ* conservation of threatened species. As data management processes for animals under human care using ISIS are well standardized (Schwartz and Flesness 2014), integration will depend on identifying the information important for monitoring and management of populations in the wild and identifying information system technologies that are in current use to ensure that the new system would cover these capabilities. Results of this study will be used to contribute to further utilization and development of *ZIMS* and increase its capacity for collection of information on captive animals that have been released to the wild and/or for facilitating management of wild populations.

This dissertation has three components:

Project 1 - Parameter Assessment

Identify the information (parameters) important for managing and/or assessing the status of reintroduced or wild populations. This will be accomplished through:

1) Literature review on factors impacting success for conservation translocations.

2) Literature review on parameters used in assessment and management of conservation translocation programs.

3) Reviewing case studies for reintroduction programs to identify parameters that were used in managing and/or assessing success of the projects. The resources for the case studies were the IUCN Reintroduction Specialist Group publications of Global Reintroduction Perspectives, Reintroduction Case-Studies From Around the Globe (Soorae 2008, 2010, 2011). A database was compiled in a Microsoft database program to contain life history and program management (both *in situ* and *ex situ*) parameters for the species in the case studies that would identify trends for important parameters for different categories of programs. The trends are defined as patterns in the data that identify the parameters that are used in assessment for each component of the programs for that particular taxa, region, or ecosystem.

4) Review CBSG published PHVA reports for those species in the case study dataset to identify whether there were data gaps for parameters required for *Vortex* modelling of extinction risk. Note the use of captive animal data (parameters including biological values, life history, reproductive biology, demography) to fill in for data deficiencies and identify the impact on PHVA processes.

Project 2 – Technology - current tools used in data collection

The objective of this study was to identify tools that are currently in use for data collection on animals released to the wild or in wild population management programs. It is important to know about the tools that are in current use in order to gain an understanding of the requirements for data collection and to ensure that a newly developed system will have the capacity to either encompass the range of data collection needs or to be able to work in conjunction with auxiliary programs that will cover the needs. This was done by identifying data collection and data management tools currently in use for management of threatened species with different characteristics. Each category is an example of a species that in some way is impacted by the integration of *in situ* and *ex situ* research or management programs. Programs for representative species in each category were investigated for *in situ* and *ex situ* data management processes – data captured, types of databases or programs used, how data were analyzed, and how data were integrated between *in situ* and *ex situ* components of the program.

Five categories of threatened species were identified:

A. Endangered species whose wild population became dangerously low and captive breeding program was implemented for purposes of release for reintroduction.

American burying beetle (*Nicrophorus americanus*)

Takahē (*Porphyrio hochstetteri*)

Western pond turtle (*Actinemys marmorata*)

B. Last remaining individuals of an endangered species brought into captivity due to threat of extinction in the wild. Species was once listed as IUCN Extinct in the Wild. Reintroduction program is well developed through captive breeding or rearing with managed release and established monitoring program for assessment.

Kakapo (*Strigops habroptilus*)

Kihansi spray toad (*Nectophrynoides asperginis*)

Red wolf (*Canis rufus*)

C. Endangered species that does not currently have a reintroduction program but future conservation efforts include such a program. Current *ex situ* programs contribute data to PHVA for the species and integrated plan is developed for overall conservation.

Lowland tapir (*Tapirus terrestris*)

D. Endangered species that has a rescue/rehab/release program but no current reintroduction program of captive born animals to the wild.

Cheetah (*Acinonyx jubatus*)

E. Endangered species with a research program for the wild populations but no current reintroductions from the captive population (if present). Data exchange is critical for understanding of the species, benefitting both wild and captive populations.

Giant armadillo (*Priodontes maximus*)

Armenian viper (*Montivipera raddei*)

Project 3 – Align data needs with *ZIMS* functionality

The objective of this project was to review the current capacity of *ZIMS* as a database tool to collect information on *ex situ* and *in situ* populations. Using information from Projects 1 and 2, *ZIMS* functionality was identified that could cover the data needs for the different categories of conservation programs. Limitations of *ZIMS* to cover *in situ* data were identified to highlight the areas that would need further development. This would form the framework for *ZIMS* to provide the tools needed to enhance the connectivity of information on captive and wild/reintroduced populations and outline a future direction to improve the integration of *in situ* and *ex situ* data management processes.

References

Asa, C.S. and C. Valdespino. 1998. Canid reproductive biology: An integration of proximate mechanisms and ultimate causes. American Zoologist 38(1): 251-259

Ballou, J.D., R.C. Lacy, and J.P. Pollak. 2011. PMx: software for demographic and genetic analysis and management of pedigreed populations (version 1.0). Chicago Zoological Society, Brookfield, IL, USA

Balmford, A., G.M. Mace, and N. Leader-Williams.1995.Designing the ark: setting priorities for captive breeding.Conservation Biology 10(3): 719–727

Beeland, T.D. 2013. The Secret World of Red Wolves: the Fight to Save North America's Other Wolf. University of North Carolina Press, Chapel Hill, North Carolina, pp. 256

Byers, O., C. Lees, J. Wilcken, and C. Schwitzer. 2013. The One Plan Approach: the philosophy and implementation of CBSG's approach to integrated species conservation planning. WAZA Magazine 14: 2-5

Cade, T.J. and W. Burnham. 2003. Return of the Peregrine. The Peregrine Fund, Boise, Idaho

Caughley, G. 1994. Directions in conservation biology. Journal of Animal Ecology 63(2): 215-244

Cohn, J.P. 1993. The flight of the California condor. Bioscience 43(4): 206-209

Conde, D.A., N. R. Flesness, F. Colchero, O.R. Jones, A. Scheuerlein. 2011. An emerging role of zoos to conserve biodiversity. Science 331(6023): 1390-1391

Conservation Breeding Specialist Group (ed.). 2011. Intensively Managed Populations for Conservation Workshop Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN

CBSG. 2012. One Plan Approach to Conservation Planning: *Ex situ* programs as part of an overall species conservation strategy. CBSG News 23. January 2012

Convention on Biological Diversity COP Decision X/2.2010.The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets

Convention on Biological Diversity.2010. Global Biodiversity Outlook 3. Montréal, pg. 94

Crocodile Specialist Group. http://www.iucncsg.org/pages/Publications.html. Accessed 18.June.2013

Crocodile Specialist Group. 2010. Action Plan for Tomistoma (*Tomistoma schlegelii*). http://www.iucncsg.org/365_docs/attachments/protarea/22_T-e88f8a45.pdf. Accessed 18.June.2013

Dickie, L.A., J.P. Bonner, C. West. 2007. *In situ* and *ex situ* conservation: blurring the boundaries between zoos and the wild. In: Zimmerman, A., M. Hatchwell, L. Dickie and C. West (eds.). Zoos in the 21st Century: Catalysts for Conservation? 2007. Zoological Society of London, London, UK

Djoghlaf, A. 2010. Convention on Biological Diversity: conservation of biodiversity through 2010 and beyond. pp. 17-20. In: Dick, G. and M. Gusset (eds.). Building a Future for Wildlife: Zoos And Aquariums Committed To Biodiversity Conservation. WAZA Executive Office, Gland, Switzerland

Estes, L.D.2006.Reintroducing a large herbivore: a remote sensing and modeling approach to determine the mountain bongo's (*Tragelaphus eurycerus isaaci*) past and present critical habitat: a report on the first field season's progress. Gnusletter 24(2): 3-4

Fa, J.E., M. Gusset, N. Flesness and D.A. Conde. 2014. Zoos have yet to unveil their full conservation potential. Animal Conservation 17(2): 97-100

Forster, B., M. Vogt, T. Zeigler, D. Schrudde, M. Raffel. 2010. Langurs in Vietnam: rescued at the very last minute? pp. 133-138. In: Dick, G. and M. Gusset (eds.). Building a Future for Wildlife: Zoos and Aquariums Committed to Biodiversity Conservation, WAZA Executive Office, Gland, Switzerland

Gipps, J. 2010. The world zoo and aquarium conservation strategy: where do we go from here? pp. 35-38. In: Dick, G. and M. Gusset (eds.). Building a Future for Wildlife: Zoos and Aquariums Committed to Biodiversity Conservation, WAZA Executive Office, Gland, Switzerland

Griffiths, C. J., C. G. Jones, D, M. Hansen, M. Puttoo, R. V. Tatayah, C. B. Muller, and S. Harris. 2010. The use of extant non-indigenous tortoises as a restoration tool to replace extinct ecosystem engineers. Restoration Ecology 18(1**):** 1–7

Gusset, M. and G. Dick. 2012. Editorial. WAZA Magazine. 13: 1-2

Gusset, M. and G. Dick. 2010. 'Building a future for wildlife'? Evaluating the contribution of the world zoo and aquarium community to *in situ* conservation. International Zoo Yearbook 44: 183–191

Hedrick, P.W. and R.J. Fredrickson. 2008. Captive breeding and the reintroduction of Mexican and red wolves. Molecular Ecology 17(1): 344-350

Heppell, S., L.B. Crowder and D.T. Crouse. 1996. Models to evaluate headstarting as a management tool for long-lived turtles. Molecular Ecology 6 (2): 556-565

Hoffman, M. *et al.* 2010. The impact of conservation on the status of the world's vertebrates. Science 330(6010):1503-1509

ISIS. http://www2.isis.org/AboutISIS/Pages/About-ISIS.aspx. Accessed 21.June.2014

IUCN/Species Survival Commission.2005. 2004 Red List of Threatened Species: A Global Assessment. Baillie, J.E.M., C. Hilton-Taylor and S.N.Stuard (eds.). Gland, Switzerland and Cambridge, UK

IUCN/Species Survival Commission. 2008.Strategic Planning for Species Conservation: An Overview. Version 1.0.Gland, Switzerland: IUCN. pg. 22

IUCN. 2013. http://iucn.org/about/work/programmes/species/who_we_are/about_the_species_survival_commission_/. Accessed.17.June.2013

IUCN. 2012. The IUCN Red List of Threatened Species. Version 2012.2. http://www.iucnredlist.org. Accessed 9.December.2012

IUCN/SSC .1998. Guidelines for Reintroductions. IUCN Species Survival Commission. Gland, Switzerland

IUCN/SSC .2013. Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission, viiii + pp. 57

James, A.N., K.J. Gaston and A. Balmford. 1999. Balancing the Earth's accounts. Nature 401(6751): 323-324

Jimenez, J. A., K.A. Hughes, G. Alaks, L. Graham, R.C. Lacy, 1994. An experimental study of inbreeding depression in a natural habitat. Science 266(5183): 271-273

Kierulff, M.C.M., C.R. Ruiz-Miranda, P.Procópio de Oliveira, B.B. Beck, A. Martins, J.M. Dietz, D.M. Rambaldi and A.J. Baker. 2012 The golden lion tamarin *Leontopithecus rosalia*: a conservation success story. International Zoo Yearbook. 46: 36-45

Keller, L.F., P. Arcese, J.N. M. Smitt, W.M. Hochachka, S.C. Stearns.1994. Selection against inbred song sparrows during a natural population bottleneck. Nature 372(6504): 356-357

Lacy, R.C. 1993. Impacts of inbreeding in natural and captive populations of vertebrates; implications for conservation. Perspectives in Biology and Medicine 36: 480-496

Lacy, R.C. 2010. *Vortex* version 9.99. Chicago Zoological Society, Chicago, IL

Lacy, R.C., J.P. Pollak, P.S. Miller, L. Hungerford, and P. Bright. 2012. Outbreak version 2.0. IUCN SSC Conservation Breeding Specialist Group. Apple Valley, MN, USA

Lackey, L. B. ISIS staff, personal communication, 2012

Lees, C. and J. Wilcken. 2009. Sustaining the Ark: the challenges faced by zoos in maintaining viable populations. International Zoo Yearbook 43: 6-18

Lincoln Park Zoo. Avian Reintroduction and Translocation Database. http://www.lpzoo.org/ARTD. Accessed on 9.June.2013

Loreau, M., S. Naeem, P. Inchausti, J. Bengtsson, J. P. Grime, A. Hector, D. U. Hooper, M. A. Huston, D. Raffaelli, B. Schmid, D. Tilman and D. A. Wardle.2001. Biodiversity and ecosystem functioning: current knowledge and future challenges. Science 294 (5543): 804-808

Mace, G.M., A. Balmford, N. Leader-Williams, A. Manica, O. Walter, C. West, and A. Zimmermann. 2007. Measuring conservation success: assessing zoos' contribution. pp. 322-342. In: Zimmermann, A., M. Hatchwell, L. A. Dickie, and C. West, (eds.). Zoos in the 21st Century: Catalysts for Conservation. Cambridge University Press, Cambridge, United Kingdom

McComb, B., B. Zuckerberg, D. Vesely, C. Jordan. 2010. Monitoring Animal Populations and Their Habitats. CRC Press. Boca Raton, FL. pp. 277

McComb, B., B. Zuckerberg, D. Vesely, C. Jordan. 2010. Chapter 10. Database management. pp. 179-188. In: Monitoring Animal Populations and Their Habitats. CRC Press. Boca Raton, FL

Miller, P.S. and R.C. Lacy. 1999. *VORTEX*: A stochastic simulation of the extinction process. Version 8 User's Manual. Conservation Breeding Specialist Group (SSC/IUCN). Apple Valley, Minnesota

Miller, P.S. and R.C. Lacy. 2003. Chapter 3: Integrating the human dimension into endangered species risk assessment. In: Experiments in Consilience, F.R. Westley and P.S. Miller, editors, Island Press, Washington, D.C. pp. 41-63

Moore, M., G. Early, K. Touhey, S. Barco, F. Gulland, R. Wells. 2007. Rehabilitation and release of marine mammals in the United States: risks and benefits. Marine Mammal Science 23(4): 731-750

Murdoch, W., M. Bode, J. Hoekstra, P. Kareiva, S. Polasky, H.P. Possingham and K.A. Wilson. 2010 Trade-offs in identifying global conservation priority areas. In: Leader-Williams, N., W.M. Adams and R.J. Smith (eds.). 2010. Trade-offs in Conservation: Deciding What to Save. Wiley-Blackwell Publishing Ltd., Chichester, West Sussex, UK

Nichols, J.D. and D.P. Armstrong. 2012. Monitoring for reintroductions. pp. 223-255. In: Ewen, J.G., D.P. Armstrong, K.A.Parker, P.J. Seddon (eds.). Reintroduction Biology. Wiley-Blackwell Publishing, Chichester, West Sussex, UK

Pimm, S. L., G. J. Russell, J.L. Gittleman and T. M. Brooks.1995.The future of biodiversity. Science 269(5222): 347-350

Pollak, J.P. 2013. Spatial model of animal movements on landscapes. J.P. Pollak, New York, NY

Pollak J.P. and R.C. Lacy. 2013. MetaModel Manager. Version 1.0. Brookfield, IL: Chicago Zoological Society

Pramuk, J., F. Koontz, M. Tirhi, S. Zeigler, K. Schwartz, and P. Miller (eds.) 2013. Western Pond Turtle (*Actinemys marmorata*) Population and Habitat Viability Assessment: Workshop Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN

Rabb, G. B. 1994. The changing roles of zoological parks in conserving biological diversity. American Zoologist 34(1): 159-164

Raboy, B.E. and R.C. Lacy. 2013. Metamodel Manager.User's Manual. Brookfield, IL: Chicago Zoological Society

Ralls, K. and J.D. Ballou. 2004 Genetic status and management of California condors. Condor 106(2): 215-228

Redford, K.H., D.B. Jensen, and J.J. Breheny. 2012. Integrating the captive and the wild. Science 338(6111): 1157-1158

Rocamora, G. and E. Henriette-Payet. 2008. Conservation introductions of the Seychelles white-eye on predator free rehabilitated islands of the Seychelles archipelago, Indian Ocean. pp. 121-129. In: Soorae, P. S. Global Reintroduction Perspectives: Case studies from around the globe. IUCN/SSC Reintroduction Specialist Group, Abu Dhabi UAE

Rockwood, L. 2006. Introduction to Population Ecology. Blackwell Publishing Ltd., Malden, MA. pg. 81

Schwartz, K and N. Flesness. 2014. On the origin of species information systems: an evolutionary perspective. pp. 86-91. In: McGregor Reid, G. and G. Moore (eds.). History of Zoos and Aquariums: From Royal Gifts to Biodiversity Conservation. The North of England Zoological Society, Chester, UK

Seal, U.S. and D.G. Makey. 1973. Computer usage for total animal and endangered species inventory systems: a specific proposal. pp. 178-188 . In: Research in Zoos and Aquariums. National Academy of Sciences, Washington, D.C.

Seddon, P. J., D. P. Armstrong, and R.F. Maloney. 2007. Developing the science of reintroduction biology. Conservation Biology 21(2): 303-312

Seddon, P.J., W.M. Strauss, and J. Innes. 2012. Animal translocations: what are they and why do we do them? In: J.G.Ewen, D.P. Armstrong, K.A.Parker, P.J. Seddon (eds.). Reintroduction Biology, Wiley-Blackwell Publishing, Chichester, West Sussex, UK

Snyder, N.F.R., S.R. Derrickson, S.T. Beissinger, J.W. Wiley, T.B. Smith, W.D. Toone, B. Miller.1996. Limitations of captive breeding in endangered species recovery. Conservation Biology 10(2): 338 - 348

Soorae, P.S. (ed.). 2008. Global Re-introduction Perspectives: re-introduction case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Soorae, P.S. (ed.). 2010. Global Re-introduction Perspectives: additional case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Soorae, P.S. (ed.). 2011. Global Re-introduction Perspectives: more case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Soulé, M.E., J.A. Estes, J. Berger, and C. Martinez Del Rio. 2003. Ecological effectiveness: conservation goals for interactive species. Conservation Biology 17(5): 1238-1250

Soulé, M., M. Gilpin, W. Conway, T. Foose. 1986. The millenium ark; how long a voyage, how many staterooms, how many passengers? Zoo Biology 5(2):101-113

Stanley Price, M.R. 1989. Animal Re-introductions: the Arabian Oryx in Oman. Cambridge University Press, Cambridge, UK

Traylor-Holzer, K., K. Leus, and P. McGowan. 2013 Integrating assessment of *ex situ* management options into species conservation planning.WAZA Magazine 14: 6-9

U.S. Fish and Wildlife Service. http://www.fws.gov/northflorida/Manatee/Rescue-Rehab/Manatee_R3_Program_Reports.html. Accessed 20.Oct.2013

U.S. Fish and Wildlife Service. 2001. Florida Manatee Recovery Plan, (*Trichechus manatus latirostris*), Third Revision. U.S. Fish and Wildlife Service. Atlanta, Georgia. pp. 144. + appendices

Westley, F.R. 2003. The story of an experiment: integrating social and scientific responses to facilitate conservation action.pp. 3-20. In: Westley, F.R. and P.S. Miller (eds.). Experiments in Consilience. Island Press. Washington, D.C.

World Association of Zoos and Aquariums (WAZA). 2005. Building a Future for Wildlife: The World Zoo and Aquarium Conservation Strategy, WAZA Executive Office, Bern, Switzerland

Yoccoz, N.G., J.D. Nichols, T. Boulinier. 2001. Monitoring of biological diversity in space and time. Trends in Ecology & Evolution 16(8): 446-453

Zafar-ul Islam, M. A. Boug, K. Ismail, E.R. Robinson, Y. bin Saleh al Hafedh. 2010. Over 20 years of re-introducing the Arabian oryx in fenced and free-range protected areas of Saudi Arabia. pp. 269-273. In: Soorae, P.S. (ed.). Global Re-introduction Perspectives: 2010. Additional case-studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi. 2010

Zimmermann, A. and R. Wilkinson. 2007. The conservation mission in the wild: zoos as conservation NGOs. pp. 303–321. In: Zimmermann, A., M. Hatchwell, L.A. Dickie, and C. West (eds.). Zoos in the 21st century: Catalysts for Conservation. Cambridge University Press, Cambridge, United Kingdom

CHAPTER 2 IDENTIFYING IMPORTANT PARAMETERS FOR MANAGEMENT AND ASSESSMENT OF THREATENED SPECIES RECOVERY PROGRAMS

Introduction

Conservation translocation programs contribute to the overall conservation of threatened species by restoring populations to historical ranges, supplementing small populations, or filling an available ecological niche in a new location when the original range becomes detrimental to the sustainability of a population (Seddon *et al*. 2012). These conservation programs fit within the bigger picture of biodiversity conservation as outlined in the Convention on Biological Diversity (CBD) whose aim is to achieve significant reduction of biodiversity loss at the global, national, and regional levels (Convention on Biological Diversity 2010). The Aichi Targets for 2020, established by the CBD, outline international goals for reducing biodiversity loss (CBD 2010). In Decision VII/30 of the CBD, the Conference of the Parties (COP) agreed on a provisional list of global indicators, to assess progress at the global level towards the 2010 targets (CBD 2010). In a review of reports from 83% of the Parties to the CBD, only 36% included evidenced indicators backed up by data and figures (Bubb *et al*. 2011). Reports showed that there were only 4 evidenced relevant indicators for Aichi Target 12 (Preventing Extinctions), although they had 31 non-evidenced indicators, showing that there were few data sets available, a lack of capacity for reporting on these indicators, or that these are low priorities. Thus, in spite of available modern digital technology, there is a paucity of data for assessment of conservation action.

Historically, conservation practices consisted of *ad hoc* data collection and retrospective analysis and many times conservation action was evaluated through evidence based on anecdote and personal experiences (Pullin *et al*. 2004). Up until the 1990s, conservation programs were managed with little attention to research focusing on program objectives and outcomes (Seddon *et al*. 2007). Early reintroduction programs were afflicted by poor planning, lack of resources and release of inappropriate founders (confiscations, exotic pets or surplus animals from captive breeding programs) and limited or no post-release monitoring. Conservation practitioners could not learn about variables important for success since the methodologies and post-release results went undocumented, with many failures going unreported. Beck *et al*. (1994) found a success rate of merely 11% when assessing 145 reintroduction projects involving captive animals and stated that complete documentation on written procedures and post-release monitoring was found, moreover, for only 50% of the programs investigated. The authors highlighted the importance of incorporating research strategies for planning and documentation of pre-release experience, training, and medical screening as well as post-release methodologies and monitoring to be able to assess success and apply adaptive management for improving the outcomes of these programs.

As conservation issues point towards increased need for integration between *in situ* and *ex situ* processes, that integration includes data management for these processes in order to provide the evidence-based science required for assessment, management and implementation of the programs. There are studies that identify parameters that are used for assessment of success for specific translocated species (Gusset 2009; King *et al*. 2012; Palomares *et al*. 2011); for different classes of taxa (Fischer and Lindenmayer 2000; Germano and Bishop 2008; Griffiths and Pavajeau 2008; Wolf *et al*. 1998); for *ex situ* populations prior to release (Jule *et al*. 2008; Maloney and McLean 1995; McFee 2004; Reading *et al*. 2013; Robert 2009; Stoinski *et al*. 2003); data required for monitoring populations in the wild (Conroy and Cooper 2012; Mccomb *et al*. 2010); data required for PHVA (Lacy 2005; CBSG 2010); and general guidelines for data requirements (IUCN/SSC 2013; Sutherland *et al.* 2010). There are no comprehensive studies that identify parameters required for the continuum of a conservation action process that includes initial assessment, planning, implementation, and ongoing adaptive management of the programs covering both *in situ* and *ex situ* components.

Considering the overall objective of integrating *in situ* and *ex situ* data management processes, the aim of this chapter is to identify the parameters and methodologies used for holistic management and evaluation of conservation programs for translocated and/or wild populations. This will form a framework for required data for an integrated data management system that will cover all components of a threatened species conservation program.

The objectives of this study are to:

1) Identify and confirm the information (parameters) and methodologies used all along the continuum for threatened species recovery programs (for both *ex situ* and *in situ* components) for managing and assessing the status of translocated or wild populations.

These identified parameters and methodologies will determine the data needed for management and assessment of the programs.

2) Determine the level of participation and identify methodologies used by *ex situ* institutions and if they are currently using International Species Information System (ISIS) software as members. This will establish the current role of ISIS as a data management methodology for *ex situ* populations involved in conservation translocation programs and the potential for further integration of data management systems.

3) Identify how the ratings for different levels of success were determined. This will show what indicators were used to assess success and identify data needed for that assessment.

4) Identify the major difficulties that were faced and the important lessons learned. This may elucidate issues that can be rectified by improved data management processes.

5) Identify data gaps for required parameters for the PHVA process through review of CBSG published PHVA reports for those species in the case study dataset. Note the use of captive animal data (parameters including biological values, life history, reproductive biology, demography) to fill in for data deficiencies on animals in their natural habitat and identify the impact on PHVA processes. This will show the value of an integrated database system that will facilitate compilation of data for animals both in captivity and in the wild to assist in assessment and projections of risk of extinction.

Determination of Important Factors for Conservation Planning, Management and Assessment

The overall objective for any conservation program is the conservation benefit for the species with an establishment of a viable population in the wild (IUCN 2013). Conservation science involves selecting actions to achieve objectives in a system that is constantly changing, involving factors that may be unpredictable (Conroy *et al*. 2009) and documenting such action for review. It is important to understand the difference between collection of any data just because it might be useful and the systematic collection of data to increase knowledge. Armstrong and Seddon (2008) promote a strategic approach to conservation action planning and implementation focusing on key research questions that need answering to improve conservation outcomes. The questions focus on assessing success at three levels: the population level, meta-population level and ecosystem level. At the population level, the important key questions focus on establishment of a genetically diverse and demographically stable population (effect of release methodologies and pre- and post-release management on post-release survival) and persistence (habitat conditions needed and how genetic makeup affects persistence). At the meta-population level, the focus is on meta-population management (optimal allocation of translocated individuals between sites, use of translocations for isolated sites, and harvesting from source populations). At the ecosystem level, questions target whether a species and its parasites are native to the ecosystem, effects on the ecosystem by the introduced species and its parasites and how the introduction affects ultimate species composition of the ecosystem. Using this framework focused at the three levels to address questions identified *a priori* will increase the knowledge and inform for adaptive management. These broad questions dictate the data necessary for planning, management and assessment of the programs.

The process of conservation planning determines strategies needed to attain the goal of a viable population that will persist in spite of effects of demographic, environmental, and genetic stochasticity, and natural catastrophes (Shaffer 1981). Population Viability Analysis (PVA) is a quantitative analysis process that evaluates the extinction risk of wildlife under current or future conditions using information on life history, population dynamics, ecology, and genetics along with environmental factors and threats that affect the population (Vredenburg and Westley 2003). A Population and Habitat Viability Assessment (PHVA), the extinction risk assessment process designed by CBSG, uses PVA for the quantitative analysis and also incorporates use of structured tools to involve stakeholders from a broad range of disciplines in the process (CBSG 2010). Thus, important factors for conservation planning include the science behind the quantitative analysis as well as the multi-disciplinary input from a variety of stakeholders.

Conservation translocation programs should be evaluated along a continuum of objectives having both short and long term components (Gusset 2009). Time frames for evaluation will depend on the focal species' life history traits and the length of time that the program has been in existence. Seddon (1999) identified a sequence of three objectives for assessment of reintroduction programs: survival of the release generation; breeding by the release generation and their offspring; and persistence of the re-established population as projected through use of population extinction probability modelling. Post-release management through monitoring and in many cases interventions (supplementary feedings, veterinary care, predator control) are needed to ensure population persistence over the long term. King *et al*. (2012) performed an assessment of success of a reintroduction program for Western lowland gorilla (*Gorilla gorilla gorilla*) in Congo and Gabon, following the framework for assessment of survival, reproduction and persistence. The released gorillas consisted of confiscated young wild-born gorillas orphaned by the bushmeat trade and a small group of young captive-born gorillas at an institution in the UK. The authors assessed success through survival and reproduction parameters for the reintroduced groups of this long-lived species and determined that the post-release age-specific survival and reproduction rates were comparable to wild gorillas. The most important factor for higher post-release survival rates seemed to be the experience of personnel involved in the planning and implementation of the programs since gorillas released prior to 2000 had a slightly lower survival rate. This may reflect the changes that occurred in pre-release and release protocols, however this remains speculation. The extensive monitoring data to capture demographic information and population dynamics were used to determine the probability of population persistence and thus long-term reintroduction success.

Factors impacting success

In order to make assessments on conservation programs for adaptive management, it is important first to identify the definition of success. It is then possible to identify the parameters that are necessary to measure the outcomes of the conservation programs in terms of success or failure. Evaluating a program as a success using the overall objective of establishing a self-sustaining population as the single criteria implies an end point to the program with further releases or monitoring unnecessary. The criteria for success are used for evaluation at a given point in time and thus there is a sequence of objectives that can be evaluated throughout the program to measure success (Seddon 1999). The assessment is ongoing since demographic and environmental stochastic events may change the status at any point in time. New threats may occur that affect the success of the program. For example, the Arabian oryx (*Oryx leucoryx*), extinct in the wild by 1972, was brought back by a reintroduction program initiated in 1982 to return this species to the wild in Oman (Jahdami *et al.* 2011). The wild population grew to 400 individuals in the mid-1990s but intensive poaching over a three year period led to an eventual wild population collapse. A captive breeding program was once again initiated and along with establishment of the Al Wusta Wildlife Reserve, the population has almost returned to previous population size.

A number of reviews have been done to determine factors that are important in assessing translocation programs (Griffiths and Pavajeau 2008; Wolf *et al.* 1998; Germano *et al.* 2008; Fischer and Lindenmayer 2000). Results of a study on intentional release programs of native bird and mammals to the wild in Australia, Canada, Hawaii, New Zealand and the United States showed that larger founder populations were more successful, habitat quality was important and those avian species that were early breeders with larger clutch sizes were more likely to persist (Griffith *et al*. 1989). Programs for herbivores were more successful than carnivores or omnivores. Wolf *et al.* (1998) reviewed 181 case studies and confirmed the results that showed habitat quality, number of animals released and release into the core of the species' historical range were predictors of success for these conservation translocation programs. Further analysis was done using a phylogenetically based statistical method of independent contrasts to include the influence of phylogenetic relationships, and in this study, results of comparisons between species of different trophic levels (carnivore, herbivore, omnivore) showed that omnivores were more likely to persist than those of the other two categories.

Fischer and Lindenmayer (2000) reviewed 180 case studies and additional theoretical papers on animal translocations published over a 20 year period to identify trends in factors that impacted relocation success. In agreement with Griffith *et al.* (1989), the authors found that there was an increase in success when a larger number of animals were released (>100) and also when the source population was wild rather than captive born. In addition, the translocations were more likely to succeed if the initial threats causing the decline were removed.

There is a bias in taxonomic representation in translocation programs as the greatest percentage of programs concentrate on mammal and bird species (Fischer and Lindenmayer 2000; Seddon *et al.* 2005). Germano and Bishop (2008) noted the increased importance of proactive conservation for amphibians and reptiles due to the precipitous decline of these taxa worldwide and reviewed translocation programs to evaluate the suitability for translocations. The authors reported that amphibians and reptiles show a number of traits that make them suitable candidates for captive-release programs such as high fecundity, lack of parental care, and cost-effectiveness for breeding small sized species. Other factors found to be important for success included consideration of the appropriate life stage for release (larval or juvenile stages), the quality of the habitat and whether the habitat was located within the historic range of the species.

Habitat quality is of prime importance for successful conservation translocation programs (Osbourne and Seddon 2012; Cook *et al*. 2002; Bartel and Sexton 2009). Section 5.1.2 of the IUCN SSC Reintroduction Specialist Group Guidelines for Reintroductions and other Conservation Translocations (IUCN 2013) state that “suitable habitat should meet the candidate species’ total biotic and abiotic needs through space and time and for all life stages”. Cheyne (2006) stressed the importance of planning for both pre-release and post-release phases of a reintroduction program for agile gibbon (*Hylobates agilis albibarbis*). In this study, the author assessed the fruit abundance, fruit productivity, tree density and diversity of an island in Central Kalimantan, Indonesia for suitability as a release site for agile gibbons. Habitat monitoring was also important post-release since habitat quality might change over time and no longer meet the requirements of the species.

Gusset *et al*. (2008) performed an extensive evaluation of African wild dog (*Lycaon pictus*) reintroductions to test factors that impacted the survival of the released animals for this endangered species. A meta-population management approach was adopted through recommendations from a PHVA where African wild dogs, a highly social species, were reintroduced into several conservation areas in the fragmented landscape (Mills *et al.* 1998). The authors concluded that two factors were predominant for survival success for the reintroduced populations: wild dogs need to be socially integrated pre-release and released into securely fenced protected areas. The framework for this study encompassed parameters used to assess success at all three levels: the population level, meta-population level and ecosystem level.

Factors that impact success for programs with *ex situ* components

Several studies of reintroduction programs have shown that wild born animals have better survival rates than captive born animals after release (Beck *et al*. 1994; Griffith *et al*. 1989; Fischer and Lindenmayer 2000). There are a number of factors specific to captive environments that impact survival success of the released animals and thus must be taken into consideration when planning a reintroduction program. Populations may undergo genetic, physiological, and behavioral changes while in captivity that can impact their survival and persistence in the wild (Lacy 1994).

The aim of captive breeding management for eventual release to the wild is to minimize loss of genetic variability and minimize evolutionary change due to loss of alleles through genetic drift or through selection for adaptations to captivity. In small populations, allele frequencies may fluctuate just by chance and rare alleles which may encode for traits important for survival in the wild, may not be passed on to the following generation (Frankham *et al*. 2005a). In a population with a very small founder base, or in the absence of proper population management, a captive population may suffer from inbreeding depression that compromises adaptability to novel environments and lowers reproductive success (Ralls *et* al. 1988). In a reintroduction program for Mexican wolf (*Canis lupus baileyi*), a species that had gone extinct in the wild, researchers found that the small captive population was highly inbred due to only a few founding individuals, causing significant inbreeding depression characterized by poor sperm quality and limited reproductive success (Asa *et al.* 2007). Thus, genetic management in captivity focuses on maximum retention of genetic diversity of the initial founding population with equal representation of founders (Frankham *et al*. 2005b). Genetic diversity is important for the released population as well in order to establish a sustainable population, thus a large number of breeding adults, a balanced sex ratio and a source population that is genetically diverse will limit inbreeding in the released population (Favé *et al*. 2008). When continued supplementation occurs from the captive source population, the genetic diversity of both the source population and wild population must be considered in determining which individuals will be released in order to benefit both populations (Earnhardt 1999).

After a number of generations in captivity, certain species may exhibit a phenotypic change in body type that compromises survival in the wild (Connolly and Cree 2008). Connolly and Cree (2008) compared body sizes of wild and captive Otago skinks (*Oligosoma otagense*), an endangered, long-lived viviparous species in southern New Zealand that soon may require integration of *in situ* and *ex situ* conservation programs. The captive-born skinks, maintained up to three generations by private herpetologists, showed significantly heavier body mass, a wider tail base, faster growth rate and much slower sprint speed than those from the wild. The phenotypic differences may impact captive-born skinks if released to the wild by compromising predator avoidance and ability to capture prey.

Animals under human care live in a benign environment where food is provided, predation is restricted, and health care reduces parasite loads and disease transmission

(Robert 2009) and thus may not be prepared to live without supplemental care. Captive-born animals that are released to the wild may lack certain behavioral skills such as predator avoidance and effective foraging strategies. Jule *et al*. (2008) found that wild-born carnivores had higher survival rates when reintroduced to the wild than captive-born animals. The captive-born animals were much more likely to succumb to starvation and predation and less likely to resist disease.

Minimizing adaptation to captive conditions is another goal for these breeding programs. Natural selection will inadvertently favor animals that have adapted to the captive environment and that breed well under those conditions. Animals such as antelope and kangaroos that depend on a quick flight response to survive in the wild may react to a disturbance in captivity by running into a wall causing instant death. Inadvertent selection occurs when those antelope or kangaroos that are calmer survive and are able to reproduce. The longer a population is kept in captivity, the greater chance of genetic adaptation to captivity (Williams and Hoffman 2009; McPhee 2003). Certain behavior types that may be beneficial for one species may be detrimental to another. Bremner-Harrison *et al*. (2004) demonstrated that boldness in released captive-bred swift fox (*Vulpes velox)* reduced survival rates when those animals were reintroduced to the wild since bolder foxes moved greater distances and were more likely to be subjected to predation. Sinn *et al*. (2014) showed that boldness in captive-raised, orphaned Tasmanian devils (*Sarcophilus harrisii*) was beneficial for survival in the wild as devils that survived were 3.5 more bold than those that did not survive. While swift foxes are monogamous, omnivorous and have many predators (coyotes, *Canis latrans*; golden eagles, *Aquila* *chrysaetos*; badgers, *Taxidea taxis*; bobcats, *Lynx rufus*), Tasmanian devils are solitary, carnivorous and have no predators except humans. Thus boldness would be a beneficial trait for devils that fight each other for access to mates, rely on capturing prey or feeding on carrion (chase other species off of their kills) and have no other natural predators. For swift foxes, boldness would be a liability in avoiding predation, competition for mates is less costly, and foraging does not always depend on predation of other species. Thus, the life history characteristics of a species must be taken into account when factoring in appropriate behavior types for reintroduction to the wild.

Returning an endangered species to the wild requires genetic and behavioral management for that species early in the program development in order to facilitate success of that population once in the wild. Environmental enrichment, defined as changes in management strategies to improve the welfare of animals in *ex situ* facilities, is important to prepare animals for reintroduction to the wild (Reading *et al.* 2013). Reintroduction success is dependent on behavioral traits that are required for survival such as locomotion skills, predator avoidance, foraging, interaction in social groups, habitat selection and avoiding conflicts with humans. Enrichment must provide an environment that mimics the natural environment as much as possible. Thus, both negative and positive enrichment is needed such as exposure to predators (or surrogate models) to learn predator avoidance (New Zealand robin *Petroica australis* - Maloney and McLean 1995; masked bob-white *Colinus virginianus ridgwayi* - Carpenter *et al*. 1991), availability of preferred foods (as well as the opportunity to forage for food or kill prey species) for food recognition (thick-billed parrot *Rhynhopsitta pachyrhyncha* -

Wiley *et al.* 1992; black-footed ferret *Mustela nigripes* - Biggins *et al.* 1999), development of natural social groups (African wild dog *Lycaon pictus* - Gusset *et al.* 2006) and enclosures with appropriate natural habitat that will be encountered in the wild for development of proper locomotive skills (golden lion tamarin *Leontopithecus rosalia* - Stoinski *et al*. 2003). The reintroduction program for the endangered golden lion tamarin made use of all of these pre-release training techniques to prepare these small primates for release back to their natural range in Brazil (Beck *et al*. 1994; Castro *et al*. 1998; Stoinski *et al*. 2003). Results from extensive monitoring of the initial released population showed that survival was affected by lack of motor skills to traverse the natural habitat (difficulty in traveling between trees on thin, flexible substrates for foraging). Pre-release protocols were developed where animals were released in natural social groups within an area of forest in the natal zoo (or the center of the program - the National Zoo in Washington, D.C.) and carefully monitored. This protocol provided experience with natural substrates (tree branches and ropes simulating vines), training in predator avoidance (avoiding hawks) and foraging. The reintroduction project was designed to test the different management protocols pre- and post-release and the effect on subsequent survival and reproduction of the released population. Thus through careful records-keeping and monitoring of all components of the program, variables contributing to the success could be determined.

Conservation translocations carry a risk of disease transmissions between the source population and the wild populations in the area of release with the risk especially high when the translocations involve animals from captivity. For animals that have been in captivity for multiple generations, there may be inbreeding and thus loss of immunogenetic major histocompatibility complex (MHC) genes (Boyce *et al*. 2011). MHC genes are important for resistance to parasites and pathogens (Hedrick and Kim 2000), for mate choice (Setchell and Huchard 2010) and in maternal-fetal interactions (Lokki and Laitinen 2001). With the additional issue of limited exposure to pathogenic organisms that occur in nature, immune responses will be compromised, affecting resistance to disease and thus survival and reproduction once released to the wild. Zhang *et al*. (2006) demonstrated that a reintroduced population of the endangered crested ibis (*Nipponia nippon*), an Asian species that had undergone a severe population bottleneck, had low variability in MHC genes and suffered a high incidence of mortality due to disease. Thus the authors suggested that founders for reintroduction include individuals containing most of the different MHC allele genotypes (Zhang *et al.* 2006). They also stressed the importance of monitoring the release site for pathogens and parasite-host relationships in local species within the same class.

Unique to the captive environment, animals may have limited exposure to native parasites or be exposed to exotic diseases from other species. Comparison studies between parasites of captive and wild populations are helpful in a risk assessment process prior to release (Frölich *et al*. 2005). For Sumatran orangutans (*Pongo abelii*), similar intestinal parasites were found in free-ranging, semi-captive and captive populations in Sumatra, Indonesia (Mul *et al*. 2007). For the Cuban iguana (*Cyclura nubile*), a higher prevalence of intestinal coccidia was present in the wild population than the captive population (Alberts *et al*. 1998). When a lack of an infectious agent or disease exists in either the captive or the wild population and the disease exists in the other, a decision must be made to mitigate the risk of transmission of that disease, whether or not to reintroduce that captive population or to change release sites that don't hold such a risk (Ewen *et al*. 2012).

Methodologies for conservation translocations

Health assessments are critical for all components of a conservation translocation, including pre-release assessments with health care and vaccinations (if warranted) and ongoing health monitoring after release (Beck *et al*. 1994). Preparation for release may include vaccinations for diseases that may be prevalent in the release area or in domestic stock that live in adjacent areas. Prior to release in a reintroduction program, captive-bred red wolves (*Canis rufus*), a species once extinct in the wild, receive vaccinations against rabies, distemper, canine parvovirus, hepatitis, corona virus and parainfluenza, which are diseases prevalent in the reintroduction area of North Carolina (Bartel and Rabon 2013). The reintroduction program has ongoing disease prevention and surveillance protocols due to the threat of disease transmission from domestic hunting dogs and coyotes that have moved into the area.

One challenge for conservation translocations is determining the best method for releasing the animals to ensure the most positive outcome in terms of transitioning from captivity to the wild. A "soft" or delayed release method is a technique to confine the animals to an enclosure within the release area for a period of time to allow acclimation to the habitat and sometimes including additional supplementation of natural foods that will be found in the area (Parker *et al.* 2012). A "hard" or immediate release is the technique to release the individuals directly into the wild without an acclimation period. The type of release method used will depend on the species, the released animals' prior experience, and the management objectives for the program. A large-scale reintroduction program to return large mammalian predators to Eastern Cape Province in South Africa was undertaken to boost the ecotourism trade and restore ecological integrity to an area where predator populations had declined (Hayward *et al*. 2007). African lions (*Panthera leo*), African wild dogs (*Lycaon pictus*), cheetah (*Acinonyx jubatus*), spotted hyenas (*Crocuta crocuta*), leopard (*Panthera pardus*) and serval (*Leptailurus serval*) were reintroduced to 11 different sites using a soft release method where the animals were kept in a boma (an enclosure) at the release site for varying periods of time. The soft release method exposed the predators to electrified fencing, habituated them to tourist vehicles, monitored/treated them for disease and parasite loads, and established social groups. The authors stressed the importance of understanding and sharing the causes of successes and failures of the programs through documentation of methodologies employed as well as post-release monitoring to assess survival and population growth or decline.

Soft release protocols may be beneficial in terms of outcome but also can be costly in terms of funding and staff time to develop the release enclosure as well as delaying the release to the wild (Somers and Gusset 2009). Hardman and Moro (2006) demonstrated that a soft release method did not impact success for reintroduction programs for rufous hare-wallaby (*Lagostrophus hirsutus*) and banded-hare-wallaby (*Lagostrophus fasciatus fasciatus*) when compared to use of a hard release protocol. The authors stressed the importance for reintroduction programs to use evidence-based information to explore cost/benefit analysis to make the determination on soft or hard releases.

Important Parameters for Managing and Monitoring Wild Populations

The Aichi Targets for 2020 (CBD 2010) outline action needed to reduce biodiversity loss on an international scale. Pereira *et al*. (2013) noted that although it is important to monitor biodiversity change in order to assess status of species and ecosystems in order to reach the Aichi Targets, there is no current standardized global observation system to deliver regular, timely data on biodiversity change. The Group on Earth Observations Biodiversity Observations Network (GEO BON) is working on a biodiversity monitoring system that identifies Essential Biodiversity Variables (EBV) that would offer consistent national or regional monitoring standards for collection of data for global sharing (Pereira *et al*. 2013). GEO BON defines an EBV as "a measurement required for study, reporting, and management of biodiversity change" (GEO BON Website). The EBV framework is organized into six classes that can be used across taxa and terrestrial, freshwater and marine realms. The classes, as they relate to wild populations, include:

1. Genetic composition – co-ancestry, allelic diversity, population genetic differentiation

2. Species populations – abundances and distributions, population structure by age/size class, population demography, survival, and sustainability

3. Species traits – phenology (plant and animal life cycle events and impact of variations in climate and habitat factors), natal dispersal distance, migratory behavior, demographic traits, physiological traits

4. Community composition – taxonomic diversity, species interactions

5. Ecosystem structure – habitat structure, ecosystem extent and fragmentation, ecosystem composition by functional type
6. Ecosystem function – net primary productivity, secondary productivity, nutrient output/input ratios, disturbance regime

The EBV classes align with Armstrong and Seddon's strategic approach in assessing success at the population, meta-population and ecosystem levels (Armstrong and Seddon 2008) and candidate EBVs identify specific values that are required for capturing essential measurement of biodiversity change (Pereira *et al*. 2013).

The EBV framework to assess impact of biodiversity change can be important for identifying success for a conservation program through analyses of survival, reproduction and persistence parameters of the translocated species. These parameters may relate to assessment of the population after release, but are also relevant to consider for the *ex situ* component (if applicable) of the conservation programs. Understanding of the species' biology and ecology is essential for any translocation to determine habitat and resource requirements as well as identify optimum pre- and post-release management strategies. Population modelling using a PVA process can be used to initiate a program to predict extinction risk and also to assess a program to project population growth, sustainability, and population persistence (Armstrong and Reynolds 2012). Within this organizational framework, parameter values along the continuum of processes for conservation translocations can be identified for pre-release, release and post-release stages as well as projections for the future, to assess success for survival, reproduction and population sustainability.

Parameters along the Conservation Translocation Cycle

Sutherland *et al.* (2010) recognized the importance of standardizing documentation throughout reintroduction programs for avian species in order to assess effectiveness of different methods and improve success. The authors suggest nine main principles that include documenting the planning for each program prior to release of the animals, clearly specifying objectives and monitoring plans to establish quantifiable measures of success, document publishing plans, documenting release methods in a standardized way, monitor the reintroduced population at standardized time intervals, monitor the estimated population size as well as age and sex classes, distinguish the outcome for reintroduced individuals versus those in the existing wild population, and finally, make the results available through publishing. There is a need to document the process, methodologies, and outcomes for each conservation translocation such that this information can be shared to increase the knowledge required for other successful programs.

The Reintroduction Specialist Group's (RSG) Re-introduction Guidelines (IUCN 2013) outline a process labeled the Conservation Translocation Cycle that depicts the different components of a conservation translocation program (Figure 2.1). Each component of a conservation translocation program has specific parameters that can be identified that will enable assessment and inform for adaptive management for a particular taxa. The need for a program starts with a conservation situation where a species population declines due to various threats and requires conservation measures to reverse the decline or mitigate the risk of extinction. IUCN Red List assessment evaluates taxa for the probability of extinction using parameters on population dynamics and genetics, habitat resource requirements, threats and probability of stochastic events that will affect the population. Once a conservation issue has been established, a goal to mitigate the issue can be identified with quantifiable targets for population size, mitigation of threats and decreasing rate of decline.

Taking the species ecology and biology into account, population size and available habitat resources, a feasibility assessment of the program would identify potential benefits or negative impacts on the environment as well as social and economic impact on the local communities. A risk assessment should be done to take into consideration extinction risk under current conditions, ecological risk on other species or on ecosystem functions, risk of disease transmission, and socio-economic risks of harmful impacts on people and their livelihoods. A PHVA makes use of computer simulation models to represent real systems and predict extinction risk or project growth of a population under current conditions or for differing management strategies. Demographic parameters that affect population growth (birth, death, immigration, emigration) are combined with threats as well as genetic and environmental stochastic events to make a quantified assessment for extinction risk. Parameters used in PHVA modeling will be identified and uncertainties in parameter estimates will be discussed in terms of sensitivity analysis later in the chapter.

Program partners are gathered to analyze the feasibility and risk assessments and consider the staff time, costs and methodologies to be incorporated into the program. The design of the program includes development of a data management plan to assure that there is foresight in gathering evidence to assess the program. The data management plan should contain the standards for data collection on released individuals or groups as well as methodologies used prior to release (in the case of those programs with an *ex situ* component or for soft releases), at release and for monitoring data.

The design phase will include decisions for selection of the source of animals for the translocation (either captive or wild born/hatch). Species traits that are important include required habitat and resources, trophic level, social grouping, mating system, and fecundity. For captive-born/hatch animals, individual data will include individual identification (tags, bands, transponders, etc.), age, development milestones, life stage, sex, health status, weight, measurements; population management parameters including parentage (pedigree), reproductive status, behavior; husbandry methodology parameters including incubation methods (egg-laying species), rearing, diet; enrichment experience parameters including socialization, feeding, locomotive skills, predator avoidance. For wild born/hatch animals (for translocations, head-starting, and rescue/rehab/release) individual data will include individual identification, age, social group, life stage, sex, health status, length of time in captivity, extent of exposure to humans.

For the implementation phase, it is very important to record the methodologies used before release, for the release and after release. This documentation will facilitate research to determine the methods that bring the greatest success for each translocation and assist in adaptive management at each step in the process. Pre-release methodologies include population management analysis to ensure genetic and demographic stability of the source population, husbandry methodologies for reproduction, rearing, care, feeding, and pre-release training. Release methodologies include determination of best life stage at release, optimal numbers to release, optimal social groups to release and soft or hard release protocols. Post-release methodologies would include any supplemental protocols (food, nest boxes or denning areas), ongoing predator control and habitat restoration measures. The methodologies for ongoing monitoring are critical to document as well as the monitoring data that will be collected in order to assess the program.

Ongoing monitoring is critical to assess each step in the continuum towards establishing a viable population in the wild. In Section 4.2 of the IUCN SSC Reintroduction Specialist Group Guidelines for Reintroductions and other Conservation Translocations (IUCN 2013), guidelines for designing a monitoring program include direct reference to the need for data collection and management to provide evidence to measure progress (see Box 1).

Guidelines

Section 4

Planning a translocation

4.2 Monitoring programme design

Monitoring the course of a translocation is an essential activity (Guidelines Section 8). It should be considered as an integral part of translocation design, not to be merely added on at a later stage.

The effort invested in developing realistic goals and objectives is the starting point for a monitoring programme; its design should reflect the phases of translocated population development - Annex 4 - and answer at least the following:

- What evidence will measure progress towards meeting translocation objectives and, ultimately, success or failure?
- What data should be collected, where and when, to provide this evidence, and what methods and protocols should be used?
- Who will collect the data, analyse it and ensure safe keeping?
- Who will be responsible for disseminating monitoring information to relevant parties?

Box 1. Guidelines for data requirements in monitoring program design for conservation translocations (IUCN 2013)

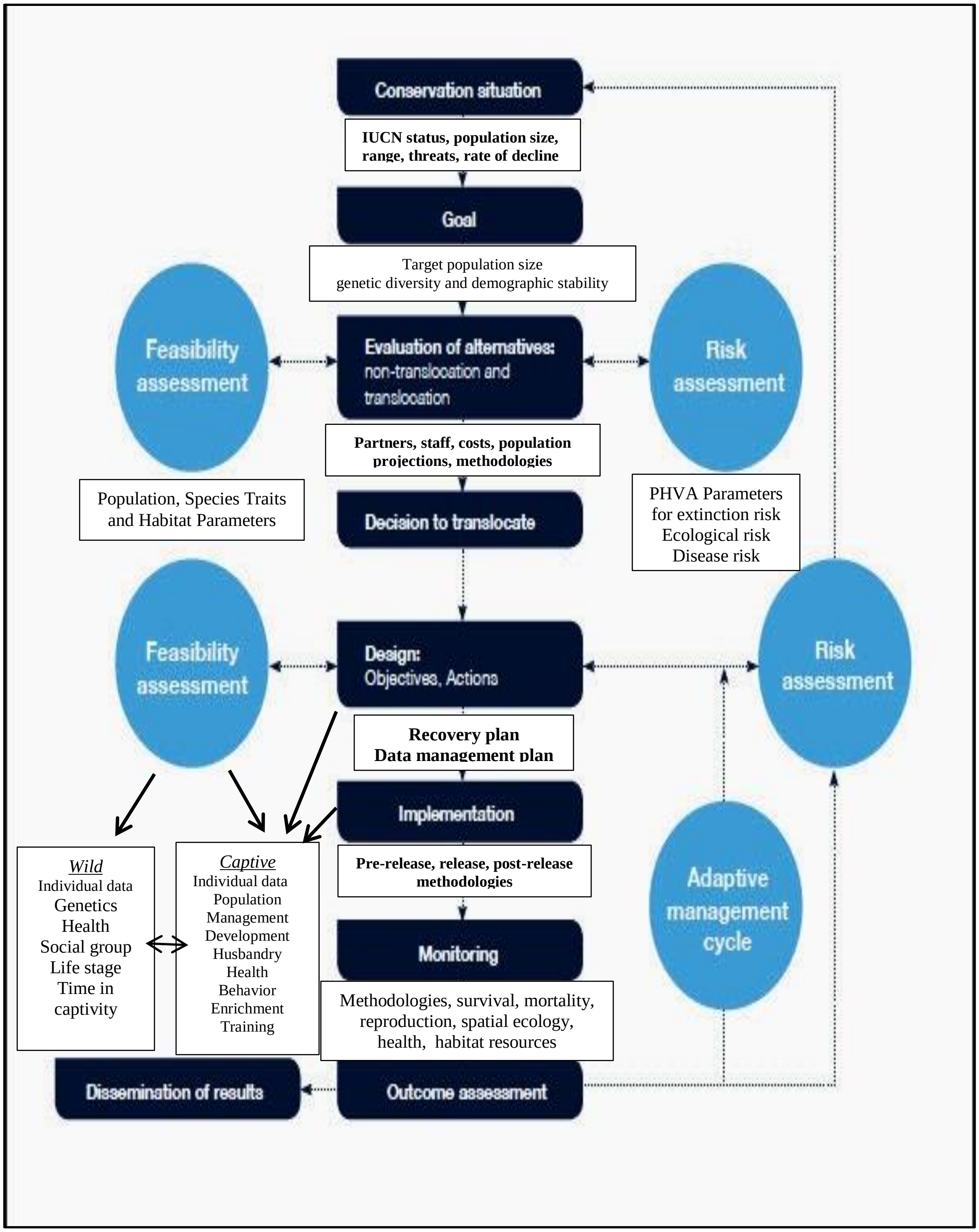


Figure 2.1. Conservation Translocation Cycle – Parameters (white boxes) required for components (black and blue shapes) for planning, design, implementation, and assessment of translocations. (Original figure courtesy of IUCN/SSC 2013).

Through monitoring, data are collected to answer specific questions that point towards specific goals in the action plan for the species. Parameters to measure population sustainability and growth include survival, mortality (occurrence and cause), reproduction, location (remain or disperse from release site), health, and status of habitat resources. Methodologies may include intensive monitoring of individuals through individual identification, radio-telemetry, visual observation, audio observation, non-invasive genetic techniques, camera trap photos, capture-mark-recapture methods for health assessments or other methods to track the status of individual animals. Methods for less intensive monitoring of a population may be done through survey counts, aerial surveys, camera trap photos to determine presence or other methods that are employed for species that are difficult to monitor at the individual level. Individual monitoring is much more expensive in staff time and funding and although this method may yield more useful information, it is not always feasible, especially for the long term.

Each program requires documentation all along the continuum of the process in order to learn or confirm best methods for positive outcomes for the translocated species. The outcomes should be published for adoption of adaptive management strategies and to inform future conservation planning for that taxon as well as for other taxa.

Parameters for PHVA

A PHVA may be incorporated in various stages of a conservation translocation program to make an initial assessment of threatened status and extinction risk, to assess human impact on the population, to analyze impact of management strategies for adaptive management, and to project future population growth or decline (Akçakaya and

Sjögren-Gulve 2000). PVA, as the quantitative analysis component of a PHVA, uses computer simulation models that are constructed with two goals: to understand the underlying processes at the landscape, meta-population, population and individual levels that impact the population sizes and distribution in space and time; and making projections of the effect of human activities (either management or detrimental activities) on population abundance and distribution (Conroy 1995). *Vortex* (Lacy 2005), the computer software package widely used for PVA modelling, models individual animals in a population or a number of populations, following the fate of each throughout their lifetime in each population to generate an overview for the species. This requires a large amount of species and population-specific data. Required input data (Table 2.1) includes biological (reproduction and genetic) parameters as well as demographic events (birth, sex ratio, mating, dispersal, death). In addition, parameters include frequency and severity of catastrophes (environmental, disease epidemics) and how population size changes from harvesting or supplementing (adding animals to the population through translocations).

For many PHVAs, data are unavailable for biological and demographic parameters if the species has not been adequately studied in the wild. Information is collected from all possible sources and many times, information comes from studies of the animals in captivity. For the Baird's tapir (*Tapirus bairdii*), a PHVA was conducted in 2005 in the range country of Belize, Central America (Medici *et al*. 2005). There were limited data on ecology and biology as well as on density and abundance in certain regions of the range, and a lack of knowledge about effect of biological and chemical hazards (parasites, bacteria, toxic substances) on survival. The baseline input reproductive parameters for simulation modeling with *Vortex* came from studies of Baird's tapirs in captivity. One benefit of having a PHVA workshop is that it brings together stakeholders from both the *in situ* and *ex situ* communities to identify what information is unknown and can direct action to specific research needed for further assessment of the population.

Table 2.1. Input data required for *Vortex* (CBSG 2010)

Category	Parameter
Population	Scientific name
	Geographic range
	Current population size
	Number of populations
	Migration between populations
Habitat	Carrying capacity of habitat
	Habitat loss or gain
Reproduction	Breeding system
	Age at first reproduction - males & females
	Maximum breeding age
	Percentage of males that are potential breeders
	Sex ratio of offspring at birth
	Maximum litter/clutch size
	Proportion of adult females that produce a litter/clutch
	Variation in number of females that breed
	Is reproduction density-dependent?
	Number of offspring per litter/clutch
Survival	Age specific survival of females with variation across years
	Age specific survival of males with variation across years
Genetics	Include inbreeding depression
	Number of lethal equivalents in population
	Proportion of lethal equivalents due to recessive alleles
Catastrophes	Number of catastrophes. May include any disaster that will kill many individuals or cause major breeding failure
	Probabilities of occurrence for each catastrophe
	Severity of catastrophes
Harvest	Number of animals removed to captive stocks, by translocation, by hunting
	Age class and sex of animals harvested
	Interval for removal of animals (annually or number of years)

Vortex can incorporate uncertainties in the model caused by poor data, variable data or lack of data. When good quality data are lacking, parameters are expressed as a range of values to incorporate into the model. Different models can be constructed to simulate the best-case and worst-case scenarios. Combining the results for both models will give a range of estimates for the assessment (Akçakaya and Sjögren-Gulve 2000). Good quality data will decrease the uncertainty in the analysis and make the results more reliable. Sensitivity analysis can identify parameters or life history stages that will have the most effect on the trajectory of the population and thus inform management decisions (Mills and Lindberg 2002). It can also identify how parameter uncertainty can impact the resulting estimates of extinction risk and thus highlight the importance of acquiring better data.

Data Management

Threatened species conservation programs are long-term entities and as such, collected datasets are to be used, shared, analyzed and built upon for re-use as time goes on. The RSG Reintroduction Guidelines have formed a framework for management and implementation of conservation translocations that include the need for data management all along the continuum of the programs. Due to the collaborative nature involving many stakeholders, standardization is needed in collection, compilation and use of data from each sector of the program. Since the personnel and the program itself may change, it is important to include definition and recording of descriptive meta-data (data about the data) such as where the data came from, experimental parameters, and data standards used in the collection process (Lynch 2008). Thus, data management is an important component of any conservation program and critical for documenting each step in data collection, storage and usage as well as changes in staff, program methodologies, and adaptive management strategies (McComb *et al*. 2010). Information from different programs can be compiled to learn about strategies for a particular taxa or region that provide successful results for species conservation.

Data management can be considered a methodology parameter and for *ex situ* components of conservation programs, may consist of use of the *Zoological Information Management System* (*ZIMS*) for ISIS members and use of other database applications for both ISIS members and non-members. As an international web-based system, *ZIMS* offers a comprehensive, standardized records-keeping system for husbandry and medical records for management of *ex situ* populations. The great advantage of a web-based system is that records can be shared in real time which is critical for breeding management programs that involve regional or global collaborations. Thus the membership in ISIS and use of *ZIMS* as a factor in the effectiveness of data management processes may be considered in the assessment of conservation programs as well as point towards the potential for use in integrating *ex situ* and *in situ* components.

Parameter Assessment Study

The overall objective of this study was to gain an understanding of the parameters and methodologies that are required for managing and assessing conservation translocation programs from both *ex situ* and *in situ* components.

Methods

Parameters and methodologies used in management and assessment of reintroduction and other conservation translocation programs were identified for all components along the conservation translocation cycle – feasibility and risk assessment, design (objectives and actions), implementation (pre-release, release and post-release), monitoring, and outcome assessment (Figure 2.1).

Data sources

Three data sources were used. First, case studies in three volumes of the IUCN Reintroduction Specialist Group (RSG) Global Re-introduction Perspectives: Re-introduction Case-Studies From Around the Globe (Soorae 2008, 2010, 2011) were accessed to identify frequency of use for parameters and methodologies for different taxa (see Appendix IV for species list for each issue of RSG Global Re-introduction Perspectives). Each case study included program goals, project summary, major challenges, major lessons learned, and reasons for success or failure (as defined by each program). Second, published literature was reviewed for additional information on basic life history traits and program management parameters for each species (Appendix IV). Third, *ZIMS* was accessed for *ex situ* data management parameters in use (*ZIMS* 2014).

Data management and analysis

Data from these three sources were compiled in Microsoft *Access* 2010. The variables in the database included life history and program management (both *in situ* and *ex situ*) parameters for 168 animal species represented in 153 case studies to be used for analysis that would identify trends for important parameters for different categories of programs.

The trends are defined as patterns in the data that identify the parameters used in assessment for each component of the programs for that particular taxon, region, or ecosystem. Parameters identified in publications by Wolf *et al.* (1998) and Fischer and Lindenmayer (2000) on assessment of translocation programs formed the basis of the variables in the database. Categories for the parameters included (see Appendix V for complete list of parameters):

1. Taxonomy and status: Common and scientific name, animal group, IUCN Red List Status, World Region (see 3). Note: the IUCN Red List status is from the most recent assessment for the species and may differ from the status in the case study.
2. Life history traits: Trophic level, life span, social and mating systems, reproductive information, parental care, activity type
3. IUCN World Regions: IUCN Statutory Regions 1-8 as per article 16 and 17 of the Statutes and Regulation 36 of the Regulations
4. Program management: Program name, partners, captive/wild animal source, life stage at release, hard/soft release, supportive measures, monitoring type (see 6), CBSG PHVA, program success, difficulties and lessons learned
5. IUCN Habitat Types: Designated habitat types as per IUCN Habitat Classification Scheme (IUCN website 2014)
6. *Ex situ* management: *Ex situ* facility, ISIS member, ISIS record, pre-release management, incubation, rearing, pre-release training (see 7)

7. Pre-release training – habitat use, feeding, predator avoidance, migration, physical conditioning, and social structure

8) Monitoring types: monitoring techniques

Frequencies of each collected variable were determined in *Excel*, *Access*, or *SPSS* to assess parameters along each component of the conservation translocation cycle for each of six taxa: invertebrates, fish, birds, mammals, amphibians, and reptiles.

The dataset of case studies was characterized to determine overall representation between the different animals groups, in the eight world regions, and by IUCN status. For each animal group (invertebrate, fish, amphibian, reptile, bird, mammal), the data were analyzed to answer the following questions:

1) For each component of the programs, what parameters were important in assessing the outcomes?
2) For the implementation and monitoring stages, what methodologies were used for pre-release, release, post-release and monitoring components? Documentation on methodologies is needed in order to relate
3) How many programs had zoological institution partners that were ISIS members; that kept records in ISIS; that had *ex situ* partners that were not ISIS members but were included on the ISIS institution list?
4) What factors were used to assess success? What were the main difficulties faced and lessons learned for each animal group?

PHVA Evaluation

The PHVA process is an assessment tool for the risk of extinction and plays an important role in the conservation planning process. Each PHVA requires comprehensive data input in order to produce a reliable assessment of risk and produce a guideline for conservation action. There were PHVAs for 17 of the programs in the case study dataset. The PHVA publications were accessed from the CBSG Document Library (CBSG 2014) and references are listed under each species in Appendix IV. PHVAs for species investigated in the research (Chapter 3) were omitted in this portion of the study as they will be discussed along with the results from that study. The PHVAs were reviewed to:

1) Determine whether programs had to incorporate uncertainty due to unknown or incomplete data into the modeling process. Identify top priority actions and sources of or data gaps in demographic and genetic parameters needed for the assessment process. This would determine the need for more comprehensive data collection in order to inform for modelling analyses that would affect management of the programs.
2) Evaluate the extent to which *ex situ* data were used for input into *Vortex* as well as the extent of involvement in the PHVA process by zoological institutions. This would determine the value of participation from the *ex situ* community in contributing to conservation action planning or adaptive management.

Results

Overview of trends for all taxa

The RSG (Reintroduction Specialist Group) Global Re-introduction Perspectives targeted 184 case studies of conservation translocations implemented between 1960 and the date of publication (Soorae 2008; Soorae 2010; Soorae 2011). For this study, analyses were done for 153 case studies including animal groups only and omitting those for plants. There were 16 case studies for invertebrates, 24 for fish, 13 for amphibians, 23 for reptiles, 35 for birds and 42 for mammals. There were more than one species included in some of the programs (e.g. 8 species of giant clams within the giant clam re-introduction program in the Indo-Pacific) and also more than one program for certain species (e.g. 6 programs for Arabian oryx in 5 different countries). The programs involved different types of conservation translocation paradigms including reintroduction, supplementation, rescue/rehabilitation/release, head-start/release, conservation introduction, translocation (see Appendix I) or a combination of two or more paradigms (Figure 2.2). The majority of the case studies reported reintroductions as the conservation translocation type in concert with others (109) or solely as the type implemented (77). There were 41 programs that used more than one translocation type in the process of moving or returning animals to the wild. For example, a program might include translocation, supplementation and reintroduction by capture of juveniles from a population in a different region for translocation to an area where the species is now extinct plus augmentation from a captive breeding program.

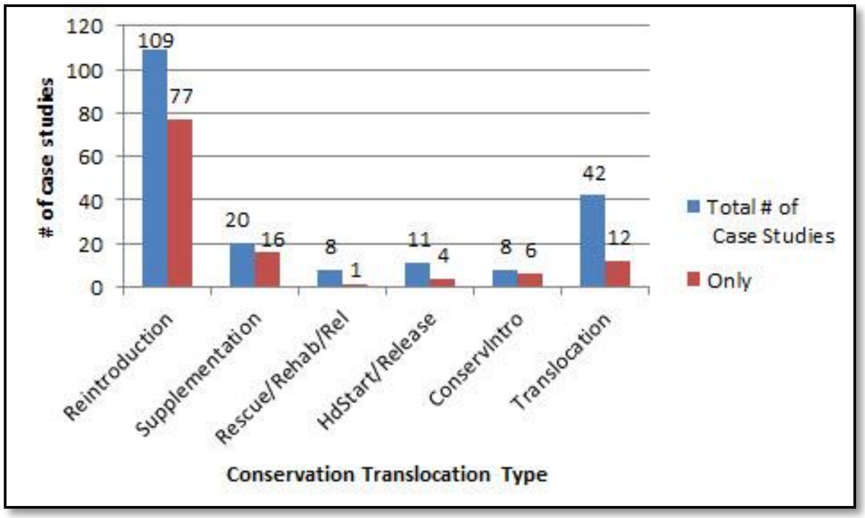


Figure 2.2. Number of case studies that implemented the different conservation translocation types. Total # indicates the overall number that included each conservation translocation type whereas Only designates the number that used only that particular type.

The 153 case studies included programs that were located in all 8 IUCN World Regions, with 13.7% in Africa, 3.9% in Meso and South America, 15.7% in North America and the Caribbean, 13.1% in South and East Asia, 11.1% in West Asia, 3.9% in East Europe, North and Central Asia, 19.0% in Oceania, 19.6% in West Europe (Figure 2.3).

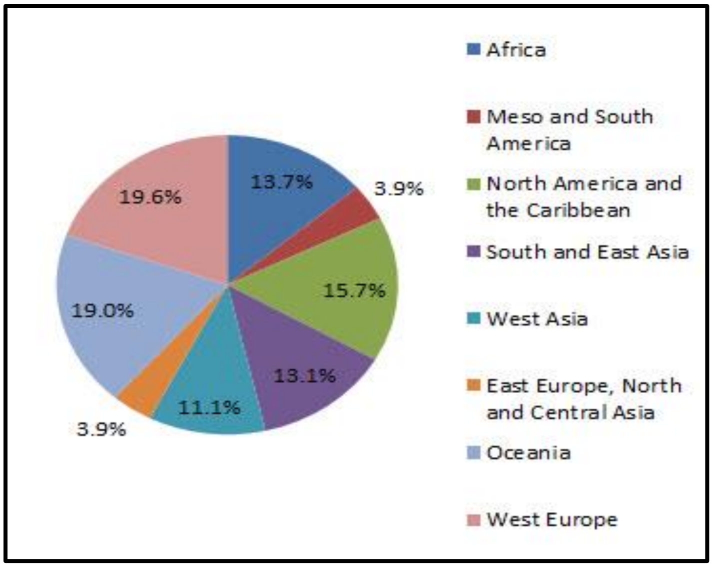


Figure 2.3. Percentage of case studies implemented in each IUCN World Region

Over 73% of species programs for all taxa were implemented under a published recovery plan with amphibian and reptile programs topping the list with over 92%, showing that the majority of programs targeted specific objectives and goals to aid in assessment of the programs. A smaller percentage of programs incorporated a PHVA which more specifically targets status, threats and management actions for conservation of the species. Over 46% of the mammal programs had PHVAs done, topping the list with amphibian programs coming in second at 20%. The percentages for programs for invertebrates, reptiles and birds all were under 9% and there were no PHVAs done for fish species (Table 2.2).

Table 2.2. Conservation situation and program design - percentage of species in each animal category listed on IUCN Red List, percentage listed within IUCN threatened categories (EX, EW, CR, EN, VU), with Recovery Plans and PHVAs.

	Conservation situation				Feasibility/risk assessment		Design		
Animal Group	IUCN Listed		IUCN Threatened		PHVA		Recovery Plan		Tota l N
	Species	%N	Species	%N	Species	%N	Species	%N	
Invertebrate	17	70.8%	10	41.7%	2	8.3%	19	79.2%	24
Fish	20	87.0%	17	73.9%	0	0.0%	19	82.6%	23
Amphibian	14	93.3%	11	73.3%	3	20.0%	14	93.3%	15
Reptile	24	85.7%	18	64.3%	2	7.1%	26	92.9%	28
Bird	36	97.3%	21	56.8%	2	5.4%	32	86.5%	37
Mammal	41	100%	32	78.1%	19	46.3%	30	73.2%	41
Total	151	89.9%	108	64.3%	28	16.7%	137	81.6%	168

Assessment of parameters by taxa

Each case study was categorized by taxa of the focal species. Results are compilations of use of parameters or methodologies at each level of the conservation translocation program cycle (see Figure 2.1) for the case studies of each taxon. There will be further discussion on the data captured by each methodology in Chapter 3. The levels include: conservation situation/feasibility/risk assessment (population and life history traits, IUCN status, PHVA), design (recovery plan, data management plan), implementation (pre-release, release and post-release methodologies and use of ISIS for animal records), monitoring (methodologies and data), and outcome assessment (success or failure, lessons learned, adaptive management).

Invertebrates

Conservation situation/feasibility/risk assessment

For the 24 species of invertebrates in 16 programs, 70.8% had been assessed and assigned an IUCN Red List status with 41.7% listed in the IUCN threatened categories (Table 2.2). Only 2 of the 15 invertebrate programs had a PHVA done (American burying beetle, *Nicrophorus americanus* and Karner blue butterfly, *Lycaeides melissa samuelis*) using more specific parameters to project extinction risk. For those species that were not listed by IUCN (and thus not evaluated), assessments were done on specific populations elucidating the need for conservation measures (e.g. mottled grasshopper, *Myrmeleotetti maculatus*, not evaluated for the Red List, had a wide range in mainland Britain but was not common in any area).

Design

Over 79% of the programs had a published Recovery Plan outlining specific objectives and actions to reach their conservation goals. Few Recovery Plans included a detailed data management plan although some such as the Miami Blue Butterfly Management Plan (Florida Fish and Wildlife Conservation Commission 2003) included the objective of developing a comprehensive database to accommodate monitoring data and track the status of individual populations within the meta-population. The terrestrial species that were not included in a Recovery Plan were listed as Near Threatened or were not evaluated so extinction risk had not been previously assessed. The other two species without a Recovery Plan were corals involved in a translocation program in India where the program was overseen by the national government.

Implementation

There were 10 species in programs with wild individuals as the source population. Prior to capture and release, research was done to assess habitat, identify population sizes, population structure, reproductive behavior (e.g. San Francisco forktail damselfly, *Ischnura gemina*), and in some cases estimate genetic diversity of the source populations (e.g. southern damselfly, *Coenagrion mercurial*). Some programs involved restoration and establishment of habitat (e.g. mottled grasshopper, *Myrmeleotetti maculatus*). For other species that hadn't been well studied, researchers tested capture and translocation techniques (e.g. giant Gippsland earthworm, *Megascolides australis*).

Fourteen of the 24 invertebrate programs involved releasing captive-hatched individuals into the wild. For five of these programs, the *ex situ* population was managed in a formal breeding program to retain maximum genetic diversity for those that would be released as well as for those that were maintained in the breeding colony (see Appendix VI). The American burying beetle is managed through the AZA American Burying Beetle SSP® and is the only breeding program of the five that is facilitated through a regional zoo association breeding management program. The other four were in breeding programs within one institution and include Lord Howe Island phasmid (*Dryococelus australis*) and field cricket (*Gryllus camprestris*) both managed by the London Zoo, Karner blue butterfly managed by the Toledo Zoo, and Miami blue butterfly (*Cyclargus thomasi bethunebakeri*) managed by the University of Florida. For all the captive breeding programs, health assessments were an important part of the pre-release protocols, ensuring that the released individuals were not transmitting disease into the wild and also boosting the chances of survival. For the field cricket program, health inspections confirmed the presence of gregarine parasites in the captive population thus preventing releases to the wild early in the program (1996-1997). Basic animal records were maintained in ISIS for four of the five species captive bred within an institution (all but the Miami blue butterfly). Eight species of giant clam (6 from genus *Tridacna* and 2 from genus *Hippopus*) and the pine hoverfly (*Blera fallax*) were captive-bred but there were few details of the breeding programs.

For the programs using wild individuals, three species were involved in reintroductions, five were translocations, one was a combination of translocation and reintroduction and one species was involved in a conservation introduction. For the captive-hatched individuals, the program for giant clams was a supplementation of the wild population whereas all the other programs involving captive-hatched individuals were reintroductions. All conservation translocations programs incorporated a hard release method except for the giant clam reintroduction where the individuals were placed in simple mesh cages off the bottom of the ocean to protect against large predators. Nine of the 15 hard-released species required supportive measures after release ranging from providing housing (e.g., hollowed out blocks of wood for Banks Peninsula tree weta, *Hemideina ricta* and leaf-vein slug, *Pseudaneitea maculate*) or breeding sites (e.g., holes bored in stumps for pine hoverfly), to supplemental feeding (e.g. American burying beetles were buried with a quail carcass, with continued provisioning as needed) to predator control (removal of rodents for flax snail, *Placostylus ambagiosus* and leaf-vein slug) and habitat restoration (e.g., regulated grazing and scrub clearances for large blue butterfly, *Phengaris arion;* clearing aquatic overgrown vegetation for San Francisco forktail damselfly). The life stage at release includes the whole range from eggs, larvae, and juveniles up to adults depending on the life history traits and resource requirements for each species.

Monitoring

Various types of monitoring methodologies were employed for the different programs. For the marine species such as coral (*Acropora* sp. and *Pocillopora* sp.) and giant clams, monitoring consisted of simple surveys of measurements of linear increase and branch formation for coral and growth in the clams as well as mortality and recruitment. Simple surveys were also used for Karner and large blue butterflies, field cricket, tree weta and southern damselfly which consisted of counts and evidence of reproduction. For the large blue butterfly, a species that is dependent on a species of ant (*Myrmica sabuleti*) for larvae survival, the population of ants was also closely monitored. For mottled grasshopper, visual counts were augmented by audial observations to assess population size. American burying beetles were monitored by trapping as many beetles as possible within an area and comparing the number of beetles captured to the previous year's number to estimate population size increase or decrease. For the Miami blue butterfly, genetic markers were developed and used along with relatively non-invasive wing fragment sampling to monitor the genetic diversity in both wild and captive populations. Regular monitoring was done to assess trends in population numbers, reproductive success, patch occupancy and habitat conditions. The most intensive monitoring program for an invertebrate species was for the San Francisco damselfly where each released individual was identified with a number marked on a wing. The released damselflies were monitored daily to estimate survival and movement patterns as well as to observe normal reproductive behavior.

Outcome Assessment

For the 24 invertebrate species in 16 programs, 63% were indicated as partially successful with 29% as successful and 4% each for highly successful and for failure (Figure 2.4). Success was rated in relation to the objectives for each program by its authors. The leaf-vein slug program was rated highly successful as surveys showed substantial numbers as well as signs of reproduction (eggs) after three years even though predatory house mice (*Mus musculus*) were present. On the other end of the spectrum was the failure of the Miami blue butterfly reintroduction. In spite of reintroductions of more than 7000 captive-bred individuals at three release sites, there was no evidence of population establishment at any of the sites. The researchers stated that due to the emergency listing of this species as endangered, management decisions had to be made quickly prior to scientific research that could better inform the management of the program. Through lessons learned and greater collaboration, the program will now target basic and applied research in population ecology, conservation genetics and effect of mosquito control insecticides to complement captive breeding and reintroductions.

Programs evaluated as successful had high survival rates or the establishment of a sustainable (breeding) population after a certain number of years (generations). For example, the large blue butterfly population was securely re-established after it had gone extinct in its natural range in the UK. This has been a long term program, with the first transfers in 1982 and now two populations have thrived without further supplementation for 20 generations. For the giant Gippsland earthworm, the conservation translocation was deemed a success due to evidence of survival and breeding 4 years post-release. Scientists stated that these programs would be considered highly successful only after long-term sustainability was determined or if a meta-population was established.

Programs rated as partially successful may have been successful at various levels of the program but the outcome did not meet objectives set for the population in the wild. The program to reintroduce giant clams (*Tridacna gigas, T. derasa, T. squamosa, T. maxima, T. crocea*, *T. tevoroa, Hippopus hippopus* and *H. porcellanus*) in the Indo-Pacific region showed success in the hatching and rearing processes with documented husbandry manuals produced for these methods. A soft release paradigm using mesh cages is employed to allow growth and protection from large predators. Although the larvae production has been successful within the hatcheries, there has been high juvenile mortality when released to the ocean even when protected within mesh cages. Thus, recruitment may be poor for various sites. Poaching of broodstock is another issue that has impacted success of the program. Success for this program will depend on further management of the current wild populations to prevent overfishing and integration of improved husbandry practices into current methodology for the program.

“Major difficulties faced” included lack of scientific research on ecology and biology of the species or on proven methodologies for invertebrate translocations (31% of the programs); habitat issues including loss of ecological processes, unsuitable water flow, difficulty in managing habitat or predators partially due to permitting issues (31%);

lack of funding for monitoring and frequent changes in land managers (19%); stochastic environment events such as drought, hot or freezing weather (19%). “Lessons learned” included importance of standardized release and long-term monitoring protocols and research on methodology (13% of programs), importance of long-term collaboration of multi-disciplinary group of stakeholders (31%), benefits of testing translocation program techniques including captive breeding protocols (25%) and importance of post-arrival and pre-release health screening (12%).

Fish

Conservation situation/feasibility/risk assessment

For the 23 species of fish in 24 programs, 87% had been assessed and assigned an IUCN Red List status with 73.9% listed in the IUCN threatened categories (Table 2.2). There have been no PHVAs for fish species. Feasibility assessments included assessment for suitable habitat and identifying suitable source populations that lived in comparable environmental conditions and could withstand the removal of individuals. For the reintroduction of Atlantic salmon (*Salmo salar*) to the River Rhine System in Germany, researchers mapped and used GIS to reference more than 100 ha of suitable habitat in preparation for the program.

Design

Over 79% of the programs were listed in a Regional or National Biodiversity Strategy or had a published Recovery Plan. Species in seven out of these 19 programs (37%) were listed as in need of conservation action in Regional or National Biodiversity

Action Plans or Strategies for the UK, Japan, and Australia but did not have a specific recovery plan for each species. The United States Fish and Wildlife Service (USFWS) developed specific Recovery Plans for each of 5 threatened fish species in their region and species specific Recovery Plans were also completed for a fish species in Spain and one in Israel. One species was covered under an international Migratory Fish Program which covered a particular river system that spanned a number of countries. These plans in general did not include specific data management protocols. The USFWS Bull Trout Draft Recovery Plan (2004) showed that for 8 core areas in need of bull trout (*Salvelinus confluentus*) conservation action, 7 had no or limited long term monitoring data. There was no mention of a data management protocol although they did identify the need to develop a standardized survey protocol as part of the plan.

Implementation

There were three species in programs with wild individuals as the source population for reintroduction. For Atlantic salmon, different life stages were identified and collected from a number of locations (Norway, Scotland and Ireland) for the reintroduction. Fry of bull trout (*Salvelinus* confluentus) were at first translocated but monitoring showed high mortality and thus the fry were collected for rearing prior to release. Berg-Breede River whitefish (*Barbus andrewi*) adults were collected for their reintroduction program into their historic previous range.

There were 21 species in programs with captive-hatched individuals as the source population. All species were bred and/or raised in a fish hatchery, wildlife research center, aquarium or museum (see Appendix VI). Pre-release protocols would include incubation and rearing techniques as well as health assessments prior to release. Only one zoological institution, the Tennessee Aquarium, was also an ISIS member. Three institutions – Lake Biwa Museum, Gifu Fresh Water World Aquarium and Dept. of Zoology, Tel Aviv University are not ISIS members but are on the *ZIMS* Institution List. The Tennessee Aquarium Conservation Institute (TACI) was involved with the program for lake sturgeon (*Acipenser fulvescens*). Initially, eggs were gathered from the wild in Wisconsin during the spawning season and taken to USFWS hatchery for hatching. Fingerlings were reared until fall and then after undergoing a health assessment (screening for known pathogens including sturgeon iridovirus), some were released in the French Broad River in Tennessee while some were retained for further growth at the TACI. Later releases include individuals at yearling, sub-adult and adult life stages. The Tennessee Aquarium tracks lake sturgeon in their collection in ISIS but it is unclear if those individual fish are involved in the reintroduction program.

Five of the programs involved a head-start paradigm where eggs were collected from the wild for incubation, hatching and rearing at an institution until reaching a size where they would be more likely to survive in the wild. All five head-start programs were for reintroductions. Eleven additional programs were for reintroduction programs alone and five programs were for supplementations. All programs used a hard release paradigm and there were no supportive measures taken for any of the programs.

Monitoring

Seventeen of the 24 programs (71%) used a combination of monitoring techniques to assess the progress of the programs. Monitoring methods for tracking fish included surveying by visual counts of different life stages (snorkeling or visual counts at the surface), capturing fish through electrofishing (applying an electrical current to stun and net the fish-freshwater only), netting (hoop net, seine or gill nets, trawling), and radio-tracking. Six programs used a simple survey method alone, consisting of monitoring the counts of the population. For the striped bitterling (*Acheilognathu cyanostigma*), a species that is dependent on a mussel species for reproduction, the monitoring included not only counting of surfacing larval fish but also surveying the mussels to see if they contained bitterling eggs or embryos. For the Azraq killifish (*Aphanius sirhani*), the monitoring program included surveys of alien species population sizes that had impacted killifish population decline. Thirteen of the programs (54%) utilized a recapture paradigm in combination with other monitoring methods in order to assess not only numbers, but to evaluate growth and assess health of the individuals. Chemical or physical marking of individuals before release was done in three programs (e.g., trout cod, *Maccullochella macquariensis*) to aid in identification upon recapture and identify released fish from those recruited from the wild. Three programs utilized genetic sampling and analysis to monitor the genetic diversity of the reintroduced population. Age classes were determined for some species through examination and measurement of otoliths - fish ear bones located behind the brain (trout cod and burbot, *Lota lota*) however this method could only be used on dead animals (Thoresson 1996). The most intensive monitoring was done for lake sturgeon and Adriatic sturgeon (*Acipenser naccarii*) where, in addition to using recapture, health assessment and survey methods, some individuals were individually identified using PIT tags and radio-tracking to identify movements as well as monitor growth and survival.

Outcome Assessment

For the 23 fish species in 24 programs, 28% were indicated as highly successful with 40% as successful, 28% for partially successful and 4% for “too soon to tell” (Figure 2.5). Those rated as “highly successful” were determined to have well-established populations with individuals of different age classes present in the absence of reintroduction events for a number of years and have expanded ranges (yellowfin madtom, *Noturus flavipinnis*; smoky madtom, *Noturu baileyi*; Citico darter, *Etheostoma sitikuense*) or had evidence of large population size where the majority of juveniles captured were from natural reproduction processes (North Sea houting, *Coregonus oxyrinchus*). One of the programs for bull trout was planned and initiated shortly before publication of the case study and thus was rated as “too soon to tell”. There were no programs for fish species that failed.

There were different criteria used between programs for a “successful” rating. For Spanish toothcarp (*Aphanius iberus*), the captive breeding program was deemed a success and the species had increased its range with the establishment of reserves. For lake sturgeon, success meant the program reached target numbers of individuals for the annual releases for this long-lived species. Lake sturgeons do not reach sexual maturity until 12 years old and the oldest released individuals were 10 years old. The lake sturgeon program would not be rated as “highly successful” until natural reproduction occurred in the wild. For the oily bitterling (*Tinakia limbata*), the release sites were restored ponds that were carefully managed by the local community, with exclusion of invasive species and monitoring of the reintroduced oily bitterlings as well as management of the obligatory mussel population required for bitterling reproduction. The bitterling reintroductions and reinforcements resulted in evidence of breeding for the bitterlings as well as the mussels. Since this was just the beginning of an adjacent sustainable agrochemical-free soybean cultivation program that would not impact the water quality of the ponds and also there were some issues with the illegal release of predatory largemouth bass, this program was rated as “successful” rather than “highly successful”.

Programs rated as “partially successful” may have been successful at various levels of the program but the outcome did not meet objectives set for the population in the wild. For the striped bitterling, the captive breeding program at Lake Biwa Museum was successful in producing individuals for reintroduction and the reintroduced population showed evidence of breeding. Yet the obligatory mussel population declined possibly due to predatory alien species which also predated on the bitterlings. The program also suffered from lack of support due to changes in administration. For the Berg-Breede whitefish (*Barbus andrewi*), large numbers were released and initial monitoring showed that the reintroduced individuals had good survival rates. There was a lack of juveniles, indicating that either breeding was not taking place or the several species of predatory alien fish had an impact on larvae survival. As the program progressed, the fish research agencies were not able to maintain the level of monitoring needed due to staff and funding shortages.

The “major difficulties faced” for fish programs included water quality issues due to human impacts (cattle farming- sediment loading/elevated nutrient concentration;

contamination of waters by industrial and agricultural processes) which occurred in 30% of the programs, limited staff for funding for monitoring/management (39% of programs), presence of predatory or competing alien species (35%), conflicts of interests (anglers vs conservationists) in 26% of programs, poaching (17%), dams that limited migration or dispersal (17%), and lack of baseline data on biology/ecology (17%). For "lessons learned", there were two main themes that were noted in 39% of the programs – the need for scientific research on ecology/biology of the species as well as on program methodology to inform management decisions; the requirement for a partnership of cooperative stakeholders including the local community, scientists, government authorities and NGOs to plan, implement, manage and assess the programs. Other requirements noted were the need for a long-term program of management and monitoring (17%) and need for genetic management in the captive breeding program (17%).

Amphibians

Conservation situation/feasibility/risk assessment

For the 15 species of amphibians in 13 programs, 93.3% had been assessed and assigned an IUCN Red List status with 73.3% listed in the IUCN threatened categories (Table 2.2). Three species, listed as Endangered (Houston toad, *Anaxyrus housonensis*), Vulnerable (Chiricahua leopard frog, *Lithobates chicahuensis*), and Extinct in the Wild (Kihansi spray toad, *Nectophrynoides asperginis*), each had a PHVA done after assessment showed declining population sizes or the complete loss of habitat leading to extinction in the wild. Feasibility assessments included assessment of threats (chytrid fungus, *Batrachochytrium dendrobatidis;* mammalian predators; loss of habitat), research on genetics (Maud Island frog, *Leiopelma pakeka*; Hamilton's frog, *Leiopelma hamiltoni*), and identifying suitable habitat to meet specific habitat requirements (black, acid water habitat for Cape platanna, *Xenopus gilli*).

Design

For the design phase, over 93% of the programs had published Recovery Plans with 10 of those 14 species covered by species specific National Recovery Plans (Spain, US, UK, Australia, New Zealand). The other species were listed in IUCN Amphibian Conservation Action Plans (US and Tanzania) or in a Regional Biodiversity Action Plan (Western Cape, South Africa). Data management protocols are not specified in many of the recovery plans although there is mention of plans to develop recording and monitoring schemes to address information needs in Natterjack Toad (*Bufo calamita*) Species Action Plan (English Nature 2009).

Implementation

There were 9 species in programs with wild individuals as the main source or part of the source population for reintroductions, conservation introduction or supplementation. Five of the programs (Southern Corroboree frog , *Pseudophryne corroboree;* Chiricahua leopard frog, *Lithobat*es *chicahuensis*; Houston toad, *Anaxyrus houstonensis*; Iberian frog, *Rana iberica*; common mid-wife toad, *Altyes obstetricans*) involved a head-starting paradigm by harvesting eggs from the wild, hatching and rearing them through the late tadpole stage and releasing them in their natal pools or to artificial pools for further development. Incubation and rearing protocols were developed for hatching and rearing the tadpoles to the late tadpole stage. Due to the risk of spread of disease, the rearing facilities implemented quarantine protocols in special bio-secure rooms for housing the animals and testing for chytrid fungus infestation was frequent to ensure that there was no spread of disease. Some institutions delayed release until metamorphosis occurred since mature frogs are less susceptible to chytrid than tadpoles (Marantelli *et al*. 2004).

There were 9 species in programs with captive-bred individuals as the source population (see Appendix VI). All the programs except for that for Romer's tree frog (*Liuixalus romeri*) involved reintroductions. Pre-release protocols would include strict quarantine measures, breeding management (genetic and demographic), incubation and rearing techniques as well as health assessments prior to release (e.g., for Houston toads, pre-release health screenings included clear fecal parasite history, normal histopathology results for screened individuals and a negative result for chytrid). Six species were captive-bred in cooperating zoological institutions and one of these six species was managed under an AZA SSP involving 21 zoos and aquariums from the US, Canada, UK and Puerto Rico (Puerto Rican crested toad, *Peltophryne lemur*). All of these zoological institutions are ISIS members, using ISIS software to maintain their animal records. For Romer's tree frog (*Liuixalus romeri*), three ISIS member institutions – Melbourne Zoo, Frankfurt Zoo, and Kadoorie Farm and Botanic Garden – collaborate with Hong Kong University (not an ISIS member) for the captive breeding program for this species native to Hong Kong. Two species were captive-bred at a breeding center (not an ISIS member) within the historical range of the species (common mid-wife toad and Iberian frog captive-bred at Natural Park of Peñalara Rearing Center in Spain).

Data management processes differ in detail with some participating institutions maintaining counts of animals in a group record (Taronga Zoo for the Booroolong frog, *Litoria booroolongensis*) and some maintaining more thorough records for individual frogs (London Zoo for Mallorcan midwife toad, *Alytes muletensis*). For the mountain yellow-legged frog reintroduction program, San Diego Zoo Global (SDZG) and Los Angeles Zoo (LAZ) who currently have breeding populations, maintain their records in different ways. Los Angeles keeps individual records for the breeding adults and keeps all others (those hatched) in two group records containing only date hatched. Sexes are not identified. The parentage information includes probabilities for possible parents showing that the animals are kept in a group so that positive identification of the parents is not possible. SDZG maintains individual records on each frog including sex and parentage (if captive-hatched) but due to a previous internal records-keeping system, there is no weight information included. On the SDZG website there is a species datasheet with information on taxonomy, physical characteristics, distribution and status, behavior and ecology, reproduction and development and species highlights. Notably, there is a web link to *ZIMS* for information on the ISIS captive population, although one has to be an ISIS member to login to *ZIMS* .

A hard release paradigm was used for 12 of the 15 programs. Six of these programs experimented with releases of different life stages (egg, larva, juvenile, subadult, adult) to determine the method that would produce the best survival rates.

Supportive measures included removal of invasive predatory species or providing predator exclusion fencing (for 6 species) and set-up of artificial cisterns or tubs to increase breeding and development areas (1 species). Two programs used a soft release method with a third program planning on soft release for the future. For Southern Corroboree frogs, tadpoles or eggs at the hatching stage were placed in artificial tubs that were within a natural bog system. Upon metamorphosis, the juvenile frogs were swabbed for chytrid testing. Shade cloth lined the tubs to provide footing on the tub walls that served as exit ramps once the tadpoles metamorphosed into frogs (at 6-8 months after hatching).

Monitoring

Monitoring methods for amphibians included visual and auditory surveys, physical marking (for cohorts, not individuals) for recapture studies, health assessments (disease screening), genetic tracking, individual identification and radio-tracking, and data loggers to track environmental measures. Four of the programs used visual and/or auditory surveys alone to take counts of individuals at different life stages. Auditory surveys were done during the breeding season to count the numbers of adult males. Eight out of the 15 species were tracked as individuals through identification methods such as identifying individual color patterns, toe-clipping, passive integrated transponders (PIT tags), elastomers, or genetic markers. The majority of the programs used a combination of monitoring methods to assess survival, growth, reproduction, genetic diversity and health status. For example, captive bred Booroolong frogs were toe-clipped for individual identification prior to release and went through an intensive pre-release pathology screening. Monitoring was done at biweekly or monthly intervals after release through visual surveys at night. Frogs were captured and each identified, weighed, measured and swabbed for chytrid fungus. The released frogs' condition was compared to marked wild frogs caught at the same site, who went through the same assessment process.

Outcome Assessment

For the 15 amphibian species, programs for 6% were indicated as "highly successful" with 27% as "successful" and 67% as "partially successful" (Figure 2.6). The program rated as "highly successful" was for the Mallorcan midwife toad which was a long-term program (30 years) where the reintroduced population was successfully established and doubled its geographical range, resulting in a down-grading its status from Critically Endangered to Vulnerable. Successful programs included those for Maud Island frog and Hamilton's frog, both K-selected (long-lived) species whose populations were augmented through long-term translocation programs to new sites on various islands within the same archipelago. The indicators for success of the Puerto Rican crested toad program included meeting demographic and genetic goals for the captive population, post-release survival of released tadpoles to maturity and subsequent breeding. Even though the captive breeding program met objectives and breeding of released individuals and recruitment of juveniles had been confirmed over two breeding seasons, the authors rated the program as "partially successful" since long-term population persistence had not been documented.

The "major difficulties" faced for amphibian programs were concentrated on four issues. For 47% of the programs, predatory alien species remained an issue that impacted successful survival of released individuals. Two other main issues that each affected 40% of the programs were loss of suitable habitat and availability of new sites and lack of biological data or formal scientific knowledge that could inform conservation action. Finally, 33% of the programs reported that existing threats including high chytrid infection rates and environmental drought were still present. For “lessons learned”, the main lesson stated in 73% of the case studies was that scientific research was critical to inform conservation management and should be an integral part of all levels of the programs. For example, research as part of the programs showed that the life stages most appropriate for release were different for different species. For 47% of the programs, there were three main common themes: 1) partnership of cooperative stakeholders was critical for program success; 2) there was a need for long term monitoring and management of the programs; and 3) large numbers of individual animals were needed with multiple release events. Finally, 40% of the programs stated the importance of health screenings for both wild and captive source populations and need for bio-secure captive facilities.

Reptiles

Conservation situation/feasibility/risk assessment

For the 28 species of reptiles in 23 programs, 85.7% had been assessed and assigned an IUCN Red List status with 64.3% listed in the IUCN threatened categories (Table 2.2). Three of the four species that were not evaluated were lizard species that had stable populations on the mainland but had been decimated on islands due to predation from alien species. The fourth species was a tortoise species that had suffered from the pet trade and confiscations were being returned to the wild in a protected area. Two species listed as Critically Endangered had PHVAs done for specific analysis of causes of decline, threats, and population status.

For the reintroduction programs for island species (tuatara, *Sphenodon punctatus;* McGregor's skink, *Cyclodina macgregori;* Mokohinau skink, *Cyclodina townsi;* Pacific gecko, *Hoplodactylus pacificus;* Turks and Caicos rock iguana, *Cyclura carinata;*), feasibility assessments were done to evaluate available habitat and extent of predatory alien species on islands where the species had gone extinct. Results showed the need for eradication programs for species such as the brown rat (*Rattus norvegicus*), Pacific rat (*R. exulans*), small Asian mongoose (*Herpestes javanicus*) as well as feral cats (*Felis catus*). For the Antiguan racer (*Alsophis antinguae*) reintroduction program, assessment of the population was done through research on population status and behavioral ecology using radio-telemetry, mark-recapture and direct observation methods. For the head-start/release programs for crocodilian species (Philippine crocodile, *Crocodylus mindorensis*; Orinoco crocodile, *C. intermedius*; Indian gharial, *Gavialis gangeticus*), research identified species status, distribution and threats and assessed habitat using a variety of monitoring techniques including radio-telemetry and observational surveys.

Design

For the design phase, 92.9% of the programs had published Recovery Plans with 15 of those 28 species covered by species specific National Recovery Plans (Puerto Rico, US, Venezuela, Seychelles, UK, New Zealand). The other species were listed in IUCN

Crocodile Specialist Group and Iguana Specialist Group National Recovery Plans (Philippines, China, US, India, Turks and Caicos Islands) or in a Regional Ecological District Action Plan and Island Restoration Plan (New Zealand). In general, the Recovery Plans include monitoring plans but do not mention data management. The UK has a separate report by English Nature (UK government environmental authority) that assesses the current surveillance and monitoring systems for herpetofauna and the need for data management processes to satisfy information needs for conservation programs of threatened species (Gleed-Owen *et al.* 2005). This report outlines monitoring protocols with sampling regimes and systems for data collection, collation, management and dissemination as well as a listing of local record centre data holdings.

Implementation

There were 13 species in programs with wild individuals as the source population for reintroductions (6 species), translocation (1sp.), head-start/release (4 sp.), supplementation (1sp.) and rescue/rehabilitation/release (1 sp.). The head-start programs for crocodilians utilized rearing facilities established within the range of the species. None of the rearing facilities were ISIS members although the Deori Gharial Rearing Centre in Madhya Pradesh, India was listed on the ISIS institution list (see Appendix VI). Six of the programs with wild source populations tracked genetic diversity of the translocated animals. For example, tail tissue samples were taken from all of the tagged translocated snakes for genetic analysis in the Antiguan racer reintroduction program.

There were 9 species in programs solely with captive born/hatched individuals as the source population and 4 species in programs that used a combination of captive and wild sourced stock (see Appendix VI). Six of the programs were facilitated by ISIS member institutions in New Zealand, the UK, Australia and the US where pedigrees were tracked in the breeding program. Other facilities included university and government breeding centers with half of those as non-ISIS member institutions that were on the ISIS institution list (see Appendix VI). There were established regional zoo association breeding programs for 3 species including ZAA ASMPs for western swamp tortoise (*Pseudemydura umbria*) and Cook Strait tuatara (*Sphenodon punctatus*) and an AZA SSP® for Virgin Islands boa (*Epicrates monensis*).

A hard release paradigm was used for 26 of the 28 species. Supportive measures were used for 5 of these species, including predator eradication for those species released on islands and construction of artificial burrows at the release site. A combination of a soft release and a hard release was used for the trial release of woma python (*Aspidites ramsey*) in order to test the release methods. The only species that was released solely using a soft release paradigm was the St. Croix ground lizard (*Ameiva polops*). This was a reintroduction to establish a new population using translocated individuals. Using the enclosures helped facilitate monitoring of the population for a period of time after release. The only species that received pre-release training was the Virgin Island boa, where individuals were tested to ensure that they could capture live prey.

Monitoring

Monitoring methods for reptiles included visual surveys, visual sign surveys (nest counts, fecals), individual identification (micro-chipping, toe-clipping, scute notching, color patterns), capture for health assessments and measurements, genetic tracking, and radio-tracking. Simple surveys as the sole method were done to monitor counts for 3 species including two giant tortoise species (Arnold's giant tortoise, *Dipsochelys dussumieri* and Seychelles giant tortoise, *Dipsochelys dussumieri*) and the Indian gharial (*Gavialis gangeticus*). All of the other species were monitored with a combination of techniques in order to collect data on population size, survival, growth, development, reproduction, health status and spatial indices of distribution. For example, juvenile American alligators (*Alligator mississippiensis*) were marked by removal of two tail scutes and tagged with web tags on toes of rear feet prior to release. They were monitored using a combination of visual signs (nests), visual observation and aerial surveys for counts of different age groups (evidence of reproduction and recruitment), recapture for growth and development information and sampled for genetic testing to assess genetic diversity.

Individuals of 22 of the 28 species were individually identified for tracking, recapture, measurements and health assessments. Seventeen programs included recapture paradigms for hands-on assessments and 12 species were monitored through radio-tracking for information on habitat use, dispersal, home range and territory sizes and availability of resources. The reintroduced populations for five species were monitored for genetic diversity using non-invasive genetic sampling techniques.

Outcome Assessment

For the 28 reptile species, programs for 18% were indicated as "highly successful" with 36% as "successful", 43% for "partially successful" and 3% for "too soon to tell" (Figure 2.7). Scientists rated the translocation program for St. Croix ground lizard as “highly successful” because it exceeded the expectations for both short-term and long term indicators of success. For short-term, the indicators included behavioral adaptation to the new habitat and evidence of breeding. For long-term, the indicators included juveniles present within one year of the translocation, confirmation of dispersal and expansion of the range for the population. The population expanded to new areas and increased in size with the presence of hatchlings, juveniles and adults. The Virgin Islands boa reintroduction program, rated as “highly successful”, spanned a 30 year period that included preliminary research and development of a captive breeding program (AZA SSP®) resulting in the establishment of two stable populations in Puerto Rico and in the U.S. Virgin Islands.

The western swamp tortoise program, a long-term program beginning in 1994, was rated as “successful” since monitoring showed that target population sizes were attained at two of the three release sites and the captive population continues to be intensively managed to produce individuals for release. The program will be rated “highly successful” when juvenile recruitment is demonstrated and the population at the third translocation site becomes sustainable. For the reintroduction of shore skinks (*Oligosoma smithi*), short and long-term goals for the captive population were met to establish a sustainable captive breeding population for production of young for release to the wild. Short-term goals for the survival, establishment and breeding in the reintroduced population were also met and the long-term goal for a growing wild population will be assessed in the coming years.

Five of the eight programs that were rated “partially successful” were for turtle or tortoise species. These programs had success in the captive breeding component but difficulties in assessing survival due to monitoring challenges and lack of support for continuing the programs (e.g., black mud turtle, *Pelusios subniger parietalis* and yellow-bellied mud turtle, *Pelusios castanoides intergularis*). A head-start program for hawksbill sea turtles was rated as “partially successful” due to issues relating to care in captivity (hatchlings sustained injuries and infections while in rearing tanks) and also to lack of effective monitoring techniques for released animals. Although the head-start program in general was rated “successful” for the rearing component, overall success could not be determined until data from tagged released hatchlings are returned.

The main “major difficulty” faced by 75% of the programs was that it was difficult to monitor the released individuals due to the dense vegetation or topography of the habitat. There were ineffective monitoring techniques that led to low detectability and recapture rates. The second main difficulty, for 32% of the programs, was the lack of support and coordination by stakeholders (local agencies and the local community). Two other main issues surfaced – for 18% of the programs there was a lack of health protocols for disease testing prior to release and a difficulty in acquiring funding for long-term monitoring and expensive rearing processes. Another difficulty noted in 17% of the programs was the impact of human disturbance of the habitat from recreational users and poaching. For 15% of the programs, there were questions on small population sizes and genetic issues (inbreeding).

The main "lesson learned" for 50% of the case studies was that long term monitoring was critical for these long-lived species in order to facilitate adaptive management and investment should be made in development of identification and monitoring methods. In 36% of the programs, coordination and collaboration with stakeholders including scientists, local agencies and the local communities was listed as a critical component for successful conservation action. Removal of predatory alien species such as ravens (*Corvus corax*), foxes (*Vulpes* sp., *Urocyon* sp.) and rats (*Rattus* sp.) was listed as important for 29% of the programs and thorough disease screening and health assessments were listed as essential for 21% of the programs.

Birds

Conservation situation/feasibility/risk assessment

For the 37 species of birds in 36 programs, 97.3% had been assessed and assigned an IUCN Red List status with 56.8% listed in the IUCN threatened categories (Table 2.2). The one species that hadn't been assessed (North Island robin, *Petroica longipes*) was not an endangered species and was used in a research study to develop methods for translocations to fragmented habitats. There were two species listed as Critically Endangered that had PHVAs done (mangrove finch, *Camarhynchus heliobates* and northern ibis, *Geronticus eremita*). Feasibility assessments include research on biology and ecology of the species, identification of current threats, evaluation of habitat for suitable resources, evidence of lack of predatory species, identification of genetically diverse source populations, and research on past methodologies.

Design

For the design phase, 86.5% of the programs had published Recovery Plans with 18 of those 32 species covered by species specific National Recovery Plans (Australia, Ecuador, Pakistan, US, UK, New Zealand) or International Recovery Plans (European Union, Asia). Three species in Ireland were covered in Action Plans divided into categories of bird types (e.g., Upland Birds, Marine and Sea Cliff Birds, Lowland Farmland Birds). Seven species (22%) were listed as in need of conservation action in Regional or National Biodiversity Action Plans or Strategies for the Balkans, the US, the UK and Australia but did not have a specific recovery plan for each species. Lastly, there was one species covered under an IUCN SSC Specialist Group (Cracid Specialist Group) and 3 species covered under general ecosystem recovery plans for wildlife (New Zealand). In general, the Recovery Plans include monitoring plans but do not mention data management.

Implementation

There were 17 species in programs with wild individuals as the source population for supplementation (1 species), conservation introduction (3 species), conservation translocation (4 species), or reintroduction (9 species). For the supplementation of the critically endangered Northern bald ibis in Syria, research showed that appropriate genetic stock of juveniles and adults were available in a semi-wild population in Turkey. Supplementation methods were based on previous experimental trials for hand-raised birds in Europe. For the conservation translocation of the endangered Seychelles white-eye (*Zosterops modestus*), Phase 1 of the program consisted of research on population size, biology and ecology, and causes of decline which led to the development of the Species Action Plan. Scientists facilitating the reintroduction program for the golden eagle (*Aquila chrysaetos*) in Ireland relied on previous work with similar species in Scotland to develop the methodologies for collection of chicks from the wild, maintaining them in captivity until fledging, and for release.

There were 20 species in programs with captive-hatched individuals as the source population (see Appendix VI). Eighteen of these programs were reintroductions and the remaining two were supplementations. Five of these programs were facilitated by ISIS member institutions in Australia, Europe, and the UK. Captive stock for the reintroduction programs for bearded vulture (*Gypaetus barbatus*) and Socorro dove (*Zenaida graysoni*) came from the managed population in EAZA EEPs; for helmeted honeyeater (*Lichenostomus melanops*), captive individuals came from the managed population in a ZAA ASMP. Other breeding facilities included research and breeding centers, local game farms, and private aviaries. Although these facilities were not ISIS members, 5 of the 12 were listed on the ISIS institution list. Four species required pre-release training for predator avoidance and social structure (cheer pheasant, *Catreus wallichi*), feeding and social structure (red-billed chough, *Pyrrhocorax pyrrhocorax*), habitat use and feeding (red-billed curassow, *Crax blumenbachii*), and feeding (Ural owl, *Strix uralensis*). Two naturally gregarious species that live in flocks, cheer pheasant and red-billed chough, had pre-release training in social structure with additional predator avoidance training occurring for cheer pheasant.

A hard release paradigm was used for 16 species in the 36 programs with half of the species from captive stock and half from the wild. Supportive measures were used in 8 of these programs and included predator exclusion, supplementation of food, provision of nest cavities or boxes, and ongoing habitat restoration. For the hard-release programs, adults were released for 11 species and a combination of juveniles, sub-adults and adults were released for 5 species. The individuals for 19 species were released using a soft-release paradigm. Ten species were from captive stock and 9 from wild stock. The only program that released solely adult birds was the reintroduction program for red-necked ostrich which employed supplementation of food and water in a semi-wild environment in a large fenced enclosure. Other programs released juveniles or combinations of juveniles, subadults and adults (providing natural social groupings) in release aviaries on site with either natural water and food sources (e.g., fruiting trees) or were provisioned with food and water while acclimating to the environment. Supportive measures also included predator control and provisioning of artificial nest boxes or logs.

Monitoring

Monitoring methods for birds included visual and audial surveys, visual sign surveys (nest counts, feathers), aerial surveys, individual identification (micro-chipping, leg banding, patagial tagging, color patterns), camera-trapping, capture for health assessments and measurements, genetic tracking, and radio-tracking. The level of monitoring ranged from two programs that conducted simple visual surveys (akepa, *Loxops coccineus*; Hawaii creeper, *Oreomystis mana*) to programs that used complex monitoring processes involving individual identification, radio-tracking, capture/recapture for health assessment, and non-invasive genetic techniques to research the genetic diversity of the population (e.g., bearded vulture; North Island robin). Thirty-two of the programs (89%) used individual identification methods to assist in tracking survival, reproduction, health and development of the released animals. Twenty-five programs (69%) utilized radio-tracking methods in combination with one or more monitoring methods to gain an understanding of population dynamics and spatial distribution of the released animals. Eight programs (22%) incorporated capture/recapture methods to facilitate health and growth assessments as well as contribute to spatial data. Camera traps were used in 4 programs to assist in monitoring processes and were especially useful for species in habitats that were difficult to access (e.g., mountain habitat - Egyptian vulture, *Neophron percnopterus*). Genetic testing using non-invasive genetic procedures (testing moulted feather or pellet samples) or by testing biological samples taken during capture events (blood, skin) characterized population genetic diversity for animals in 6 of the programs (e.g., Ural owl).

Outcome Assessment

For the 36 bird species, programs for 19% were indicated as “highly successful” with 24% as “successful”, 49% as “partially successful”, 5% as “failures” and 3% as “too soon to tell” (Figure 2.8). The reintroduction program for Malherbe’s parakeet (*Cyanoramphus malherbi*) was assessed as highly successful since monitoring data confirmed a high survival rate of 72% for the released birds and three years after the first reintroductions, unbanded birds were observed nesting showing that first generation offspring were reproducing. Other indicators of success were an increase in population size and geographic range for this critically endangered species. The collaborative *ex situ* breeding program for bearded vulture (through an EAZA EEP involving 35 institutions) formed the source population for the highly successful reintroduction back to the European Alps. Special hand-rearing conditions to avoid human contact and a hacking paradigm for the release helped to acclimate the birds to natural conditions. The nestling, fledging, and post-release stages for individually identified birds were extensively monitored and due to the international extent of the range, all monitoring data were collected in an online database with access by all participants.

The helmeted honeyeater (*Lichenostomus melanops cassidix*) had declined to one small population of about 15 breeding pairs in Victoria, Australia when a reintroduction program was started to establish a new population through the release of captive-bred birds. The captive birds were managed within a ZAA ASMP and both ZAA institutions involved were ISIS members – Healesville Sanctuary and Taronga Zoo. Scientists were also managing the small wild population to maintain genetic diversity through manipulation of pairings or transfers of eggs between populations. The program was assessed as partially successful since the re-introduced population has grown and breeding has occurred, yet the population is still too small to be self-sustaining. Through close monitoring using individually identification methods (banding and radio-tracking), the scientists have noted natural dispersal and anticipate the establishment of several colonies that will function as a meta-population in the future. Only two programs were rated as “failures” due to lack of knowledge of life history, experience with breeding management, and little or no post-release monitoring (white-headed duck, *Oxyura leucocephala* and cheer pheasant).

The most frequently cited “major difficulty faced” was the lack of knowledge of natural history and that management decisions were based on empirical rather than scientific evidence (30% of the programs). Monitoring was a major issue for 25% of the programs as rough terrain with limited access made tracking birds difficult. Additionally, 19% of the programs faced lack of effective equipment as well as the technical expertise to facilitate the monitoring processes. Lack of adequate funding also was a major issue that affected monitoring as well as the staffing needed to sustain the programs (22% of programs). For 25% of the programs, there was difficulty in developing partnerships with ranchers and landowners due to the inability to effectively establish awareness of the conservation benefits to the local communities. Other major difficulties included human-induced conflict (collisions with aerial cables, ski lifts, automobiles; illegal hunting; poisoning) for 25% of the programs, stochastic environmental events (wild fires, drought, excessive rain) for 19% of the programs and disease management challenges (lack of health screening protocols, ineffective disease prevention) for 14% of the programs.

The main “lesson learned” stated in 44% of the case studies was that research was critical to identify the best release protocols (best time of year, age at release, number of individuals to release, hard or soft release paradigm). Equally important (44% of the programs) was the lesson that communication and cooperation were critical between all the stakeholders (government authorities, scientists, local landowners, local community, NGOs). For 39% of the programs, development of effective captive rearing techniques (simulating natural social grouping, encouraging parent rearing or hand-rearing with limited human exposure, environmental conditions for incubation) was important to produce individuals that would have a higher chance of survival upon release. An additional 11% specified the importance of genetics in managing the captive population and also identifying the genetic diversity in both the captive and wild populations. Finally, 14% of the programs mentioned that supportive measures such as providing food and artificial nesting sites at the release location supported site fidelity, enabled monitoring of the release population, and also attracted wild conspecifics facilitating the integration into the wild population.

Mammals

Conservation situation/feasibility/risk assessment

For the 41 species of mammals in 42 programs, 100% had been assessed and assigned an IUCN Red List status with 78% listed in the IUCN threatened categories (Table 2.2). There were 19 mammal species (46.3%) covered under a PHVA, the greatest percentage of all the animal groups. For 11 of the 24 species utilizing wild born individuals, there was a PHVA or conservation management workshop held and thus assessments were done using available data for status, distribution, and threats causing population declines. Some other programs conducted preliminary trials through releases of small numbers within the historical range of the species, and conducted intensive monitoring to assess feasibility for a full blown program (e.g. Amur goral, *Naemorhedus caudatus*). For other species, governments listed the species for protection through national legislation and conducted feasibility assessments prior to the beginning of the recovery program. For the grey wolf (*Canis lupus*) reintroduction in western U.S., the USFWS mandated planning for the return of this endangered species to central Idaho and Yellowstone National Park in Wyoming and developed management agreements with other natural resource agencies such as U.S. Department of Agriculture Wildlife Services and the National Park Service to prepare an environmental impact statement on the restoration of wolves prior to the start of the recovery program.

Design

For the design phase, programs for 73.2% of the species had published Recovery Plans with 15 of those 41 species covered by species specific National Recovery Plans (Australia, Brazil, Indonesia, Kenya, Mongolia, New Zealand, Saudi Arabia, South Africa, South Korea, U.S.) or International Recovery Plans (U.K., Western Equatorial Africa). Six species were covered by national action plans by taxon (Australia, Saudi Arabia, Tunisia). There were 6 species covered under IUCN SSC Specialist Group Action Plans (Caprinae, African Elephant, Canid, Pigs, Peccaries and Hippos, Primate and Conservation Breeding Specialist Groups) and 4 species covered under general ecosystem recovery plans for wildlife (Saudi Arabia, Sweden, Tanzania). It was evident that biological and ecological data were lacking for these Action Plans especially in those written prior to 2005 and objectives included data collection for species abundance and distribution as well as research on population genetics and demography (Shackleton 1997). For the Conservation Assessment and Management Plan for the Arabian Ungulates and Leopard (CBSG 2001), one of the main issues was the lack of knowledge and no central database to share information between the different areas in the region. A main objective was to establish a regional registry for the captive population of Arabian oryx along with a genetic database to facilitate breeding management and monitor the genetic diversity of both the captive and reintroduced populations.

Implementation

There were 24 species in programs with wild individuals as the source population for reintroductions (9 species), translocations (2 sp.), supplementation (1sp.) and rescue/rehabilitation/releases (13 sp.). There were 20 species in programs solely with captive born individuals as the source population and 6 species in programs that used a combination of captive and wild sourced stock. Fifteen of the programs were facilitated by ISIS member institutions in Australia, Europe, Saudi Arabia, South Africa, United Arab Emirates (UAE), UK, and North America. Other facilities included private royal collections, government breeding centers and research centers with five out of eight as non-ISIS member institutions that were on the ISIS institution list (see Appendix VI). There were established regional zoo association breeding programs for 9 species including two ZAA ASMPs, two AZA SSP®s, two EAZA EEPs, and three Global Species Management Programs combining AZA SSP® and EAZA EEP populations. One species breeding management program was maintained within one ISIS member institution in the UK. Twelve species required pre-release training for socializing in natural social groups (e.g. African wild dog; western lowland gorilla, *Gorilla gorilla gorilla*), feeding behavior (e.g., black-footed ferret), predator avoidance (e.g., golden lion tamarin), habitat use (e.g., black and white ruffed lemur, *Varecia variegata*) and physical conditioning (e.g., yellow-footed wallaby, *Petrogale xanthopus*).

A hard release paradigm was used for 19 species in the 42 programs with 12 species from wild stock, 5 species from captive stock and 2 species with a combination of wild and captive stock. Supportive measures were used in 9 of these programs and included predator exclusion and supplementation of food. For the hard-release programs, adults were released for 11 species, a combination of juveniles, sub-adults and adults were released for 2 species, juveniles were released with sub-adults for 2 species, and sub-adults were released with adults for 2 species. There were four rescue/rehabilitation/release programs that used a hard release paradigm, all for primates (chimpanzee, *Pan troglodytes*; Sumatran orangutan; Bornean orangutan, *Pongo pygmaeus;* mona monkey, *Cercopithecus mona*), where individuals had been confiscated or turned in by people who had them as pets but could no longer handle them. Although the actual release involved the hard release paradigm, all of these species were maintained for a certain amount of time in captivity. These wild born animals had been in captivity for varying amounts of time and required intensive care for very young animals, with ongoing health assessments and training in habitat use, foraging skills and physical conditioning prior to release. All the primate species were released as juveniles or sub-adults after socialization and pre-release training occurred. The only program that involved an ISIS member institution was for the chimpanzee introduction to Rubondo Island National Park in Tanzania. The chimpanzees were wild born but spent between 3.5 months and 9 years in European zoos. Although the program took place prior to the development of the ISIS database, the Frankfurt Zoo had entered historical data that documented the chimpanzees' acquisition and disposition dates in their animal records.

Whereas three fourths of the species bred in captivity were in programs utilizing soft release paradigms, life history attributes of a few species dictated the use of a hard release paradigm. The species were all herbivores reared in semi-natural conditions and included four ungulates (Apennine chamois, *Rupicapra pyrenaica*; Arabian oryx; mountain gazelle, *Gazella gazella;* roe deer, *Capreolus capreolus*) and two marsupials (yellow-footed wallaby and tammar wallaby, *Macropus eugenii eugenii*). There were scientific breeding management programs (ZAA ASMPs) for both wallaby species involving numerous zoological institutions (all ISIS members) in the Oceania region. The yellow-footed wallaby was the only species that required pre-release training in foraging skills, physical conditioning and social structure. For all of the hard release programs, animals were released in protected areas with appropriate habitat in natural social groups (herd for ungulates, groups for wallabies). For the wallabies, alien and feral predators had been removed and predator control continued as supportive measures.

The individuals for 23 species were released using a soft-release paradigm. Fourteen species were from captive stock, 5 from wild stock and 4 from a combination of captive and wild stock. Supportive measures were used in all but one of these programs and included acclimatization enclosures with pre- and post-release food and water supplementation, predator control, and artificial nest boxes or logs. Adults were released for 10 species, juveniles for 2 species, adults with sub-adults for 3 species, juveniles with sub-adults for 1 species and a combination of juveniles, sub-adults, and adults for 6 species. Using a soft release paradigm for wild-born animals helped to establish site fidelity to facilitate monitoring (e.g. lesser short-tailed bat, *Mystacina tuberculata*), acclimatization to habitat resources (e.g. Arabian oryx), establishment of natural social groups and acquisition of survival skills prior to release (e.g. chimpanzee), and provisioning of nutritional foods and assessments of health status (e.g. black rhinoceros, *Diceros bicornis minor*).

Monitoring

Monitoring methods for mammals included visual and audial surveys, visual sign surveys (nest counts, feces, footprints, hair), aerial surveys, spot-light surveys, individual identification (micro-chipping, ear tagging, ear notching, collaring, hair-clipping or dyeing, color patterns), camera-trapping, capture for health assessments and measurements, genetic tracking, and radio-tracking. The level of monitoring ranged from four programs that conducted simple visual surveys (e.g., African elephant, *Loxodonta africana*) to programs that used complex monitoring processes involving individual identification, radio-tracking, capture/recapture for health assessment, and non-invasive genetic techniques to research the genetic diversity of the population (e.g., yellow-footed wallaby). Monitoring for 34 programs (68%) involved visual observation surveys and 37 programs (74%) used individual identification methods to assist in tracking survival, reproduction, health and development of the released animals. Thirty-one programs (62%) utilized radio-tracking methods in combination with one or more monitoring methods to gain an understanding of population dynamics and spatial distribution of the released animals. Fifteen programs (30%) incorporated capture/recapture methods to facilitate health and growth assessments as well as contribute to spatial data. Visual signs were used in seven programs (14%) to determine presence and location (e.g. footprints of newborn pygmy hogs, *Porcula salvania,* indicated successful reproduction in the wild by a released female). Camera traps were used in four programs to determine spatial distribution, presence/absence and social interactions and were especially useful for species in habitats that were difficult to access (e.g., rocky cliffs – Amur goral) or were nocturnal (lesser short-tailed bat). Genetic testing using non-invasive genetic procedures (testing feces or hair samples) or by testing biological samples taken during capture events (blood, skin) characterized population genetic diversity for animals in 4 of the programs (e.g., golden lion tamarin).

Outcome Assessment

For the 42 mammal programs, 18% were indicated as "highly successful" with 54% as "successful", 24% as "partially successful", 2% as "failures" and 2% as "too soon to tell" (Figure 2.9). The reintroduction of the yellow-footed wallaby was rated as "highly successful" since there was success at all levels of the program. Husbandry methodology had been perfected within a genetically managed captive breeding program (ZAA ASMP) and individuals for release were chosen based on genetics, age, body condition, reproductive fertility, dental and general health. Intensive monitoring after the release of the initial individual animals showed that multiple generations had been born and the population size had increased.

The reintroduction program for woylie (*Bettongia penicillata*) was rated as "partially successful" due to success of one of the two reintroduced populations. The population in one site had shown survival, reproduction and growth, yet the other population in the other site had radically declined due to competition from another congeneric species that had also been reintroduced to the area. Three of the five reintroduction success indicators specified at the beginning of the program had been met suggesting that the overall program would be a success in the future.

The only mammal program that ended in failure was the reintroduction of rock hyrax (*Procavia capensis*) to an area in the KwaZulu-Natal province of South Africa where they were locally extinct. Two groups were collected from the wild with one released after three months of health monitoring and the other group released after remaining in captivity as part of a research program. High predation from caracal (*Caracal caracal*) and crowned eagle (*Stephanoeaetus coronatus*) were the main causes of mortality with one group lost after 18 days and the other after 89 days after release. The importance of individual identification and intensive monitoring was noted as well as providing a captive environment that included natural habitat features (rocky area with crevices) such that animals would learn to escape from predators.

The two most prevalent “major difficulties faced”, each noted for 30% of the species in the programs, included 1) the lack of information needed to inform adaptive management - knowledge on biology/ecology of the species and proper management methodologies, lack of records from previous programs; 2) difficulties with monitoring - inadequate post-release monitoring, poor access due to rough habitat, technical difficulties with radio-tracking equipment, lack of personnel or funding. Lack of suitable habitat was noted for 24% of the programs and obtaining cooperation from local communities, government and NGOs for 22% of the programs. Health issues such as lack of knowledge of disease or potential disease risk and inadequate pre-release health assessments were noted for 22% of the programs.

For “lessons learned”, the main lesson stated in 38.1% of the case studies was that long term monitoring was required for adaptive management in order for the programs to evolve and meet program objectives. Second at 31% was the need for careful population or meta-population management both *ex situ* and *in situ* to insure the best possible genetic diversity for all populations. Social structure was an important parameter to take into account for 23.8% of the programs. Also, 23.8% of the programs noted the importance of multi-disciplinary teams and partnerships representing multiple stakeholders for planning, implementation and assessment of the programs. For 21.4% of the programs, systematic data collection and data management were considered critical to provide an evidence-based approach for evaluation. Scientists noted that the latest scientific data should be used for assessment and adaptive management of the programs. For 21.4% of the programs, environmental education and outreach was essential to foster a good relationship with the local communities and facilitate awareness of the issues.

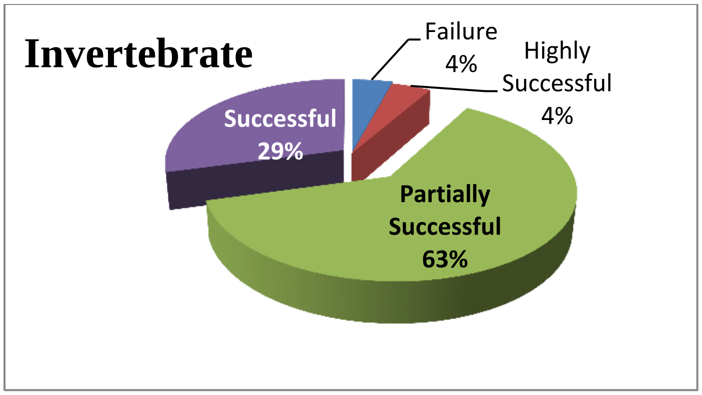


Figure 2.4. Success/failure of invertebrate conservation translocation programs. N = 24 species

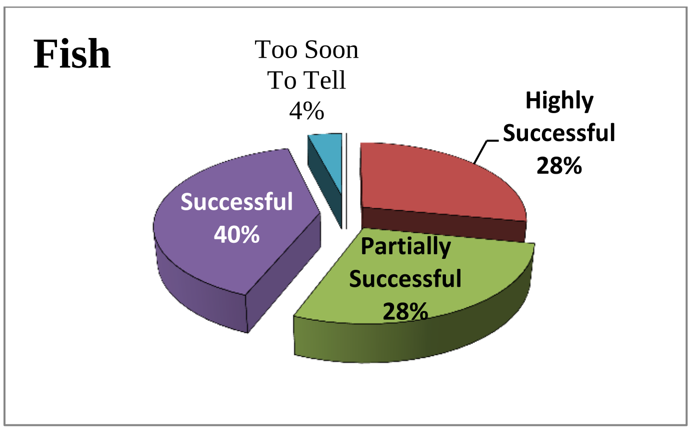


Figure 2.5. Success/failure of fish conservation translocation programs. N = 23 species

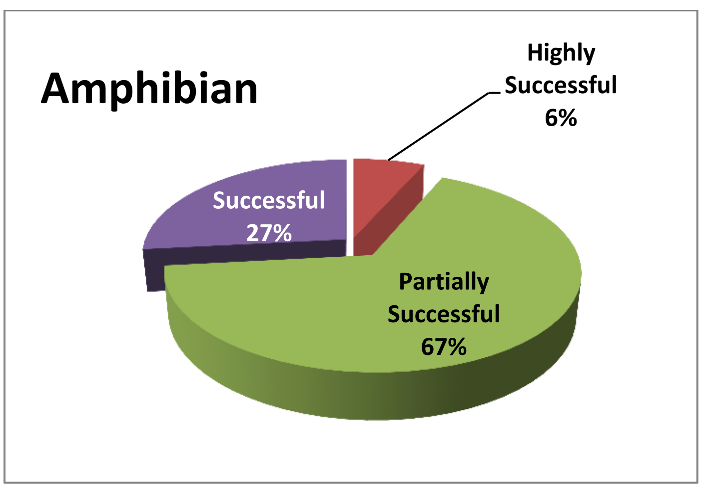


Figure 2.6. Success/failure of amphibian conservation translocation programs. N = 15 species.

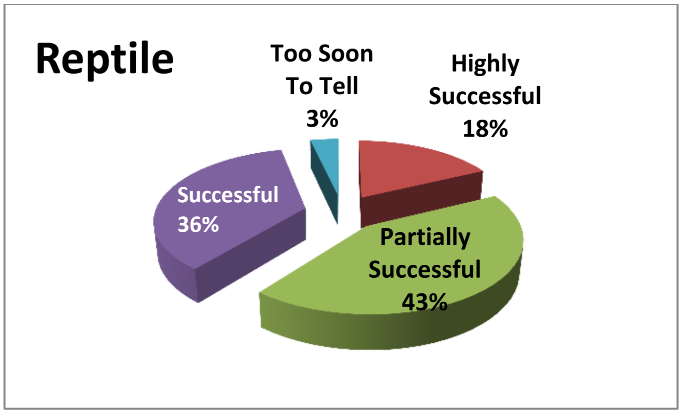


Figure 2.7. Success/failure of reptile conservation translocation programs. N = 28 species

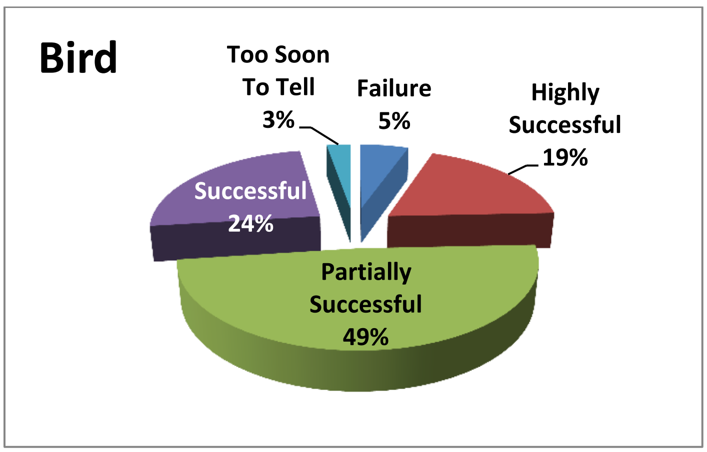


Figure 2.8. Success/failure of bird conservation translocation programs. N = 37 species

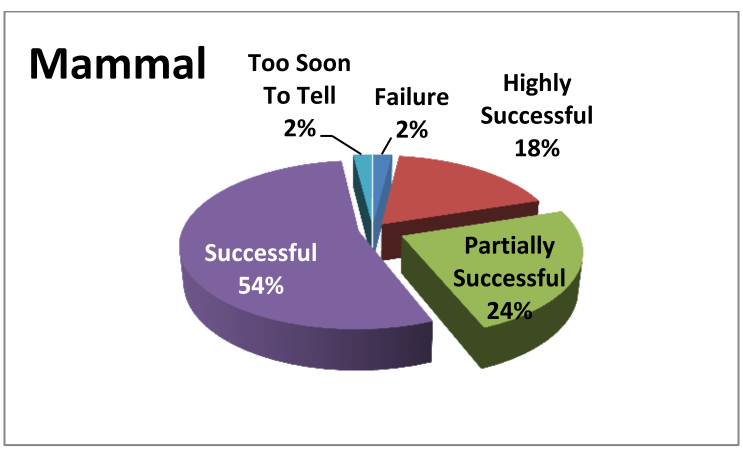


Figure 2.9. Success/failure of mammal conservation translocation programs. N = 50 species

PHVA evaluation

There were 10 PHVAs or conservation workshops for the species in the RSG Global Re-introduction Perspectives dataset (see Appendix IV – PHVA and Workshop reports references are listed under each species). Six were for mammal species (African wild dog; Asiatic black bear,*Ursus thibetanus*; Arabian ungulates, *Oryx* and *Gazella* sp.; gibbons, *Hylobates and Symphalangus* sp.; orangutan, *Pongo* sp.; and scimitar-horned oryx, *Oryx dammah*), with two for reptiles (gharial and Orinoco crocodile), one for birds (mangrove finch, *Camarhynchus heliobates*), and one for amphibians (Houston toad). For the mammals, technical workshops for conservation action planning were done for the G*azella* species, gibbons and scimitar-horned oryx and the other species programs were full PHVAs. The dates for the PHVAs and workshops ranged from the earliest in 1994 for Houston toad to the most recent in 2012 for scimitar-horned oryx.

Nine of the ten PHVAs or workshops noted the need for improved scientific information and central coordination of data as top priorities. The tenth one, in a technical workshop on reintroduction for scimitar-horned oryx, had the development of a management plan as a top priority and mentioned the need for scientific-based pre-release management as well as monitoring for the released animals. Five noted the need for collating all data on the species, both *in situ* and *ex situ*, or for the development of registries or studbooks for genetic management of the *ex situ* population so that captive-bred individuals could be used for reintroductions or supplementations. Eight of the PHVAs or workshops noted that data for some demographic parameters were lacking, estimates were used based on best guesses, or data were from captive animals or work on similar species. Only one PHVA (for orangutan) had sufficient biological data based on 30+ years of field research. For genetic parameters, seven of the PHVAs noted that genetic management was not currently taking place, the amount of inbreeding was unknown, or that genetic analysis was needed to determine genetic diversity of both *in situ* and *ex situ* populations.

All of the PHVAs and workshops had participation from zoological institutions, either directly as subject matter experts (SME) participating in the meeting or through funding support. Two of the programs involved SMEs from within the endemic country of the species whereas the remainder involved international collaboration with zoological experts from a number different countries participating in the planning processes. In some cases, the reintroduction programs involved populations in captive management programs in a region other than their native range countries (e.g., AZA SSP® and EAZA EEP involved with scimitar-horned oryx reintroduction in Tunisia) or the zoological participants were involved due to special expertise in that particular species (e.g., specialists from the USA and the UK involved in mangrove finch program in Ecuador).

Discussion

Overview

Analysis of the methodologies for planning, implementation, monitoring and assessment of 153 conservation translocation programs that spanned over the last 50 years (with one reintroduction program for Eurasian beaver, *Castor fiber* occurring from 1922-1939) illustrated the parameters used at each level of the conservation translocation cycle for management and assessment of conservation action. The dataset of case studies of conservation translocation programs published in three volumes of IUCN Global Re-introduction Perspectives (Soorae 2008, 2010 and 2011) were characterized to show the representation of programs for different animal groups, in the eight IUCN Statutory World Regions, by IUCN status and success of the programs by animal group. The IUCN SSC Reintroduction Specialist Group initiated an open request for conservation practitioners to submit their case studies and thus those studies included in the "Global Re-introduction Perspectives" are considered an opportunistic dataset rather than a random sample representing the whole dataset of conservation translocation programs. Therefore, the analyses were limited to show trends for this dataset and more rigorous statistical analyses for comparisons between different taxa were not appropriate for this study.

Results for type of conservation translocation showed that reintroductions or a combination of a reintroduction with another paradigm such as supplementation or head-start/release were implemented in the majority of the case studies. All eight IUCN world regions were represented with the greatest percentage of programs occurring in West Europe (19.6%) and Oceania (19%), and similar numbers of programs occurring in Africa (13.7%), North America and the Caribbean (15.7%), South and East Asia (13.1%) and West Asia (11%). The fewest programs occurred in Meso- and South America (3.9%) and East Europe (3.9%).

If a species conservation status is categorized on the IUCN Red List, this is an indication that an assessment has been done using available data, although parameters such as population size or extent of occurrence may be estimated, inferred, or projected through PVA analysis. Over 93% of the amphibian and bird species in the study had a Red List status and 100% of the mammalian species were listed. For invertebrates, 70.8% were listed and both fish and reptiles were above 82%. There were 38 species rated as Least Concern and 16 species whose conservation status had not been evaluated. Although a species may be classified as Least Concern, this applies to its global status and it may be threatened within a particular region within its natural range thus warranting conservation measures. For those species that had not been evaluated, regional or local assessments may have determined a conservation need even though an official Red List assessment hadn't been done. A conservation translocation program should be developed within the infrastructure of the national and regional conservation communities, recognizing the framework of government agency legal policies, national biodiversity action plans or existing species recovery plans (IUCN/SSC 2013).

A documented recovery plan, an important component for the design phase in the conservation translocation cycle, forms the roadmap for action as well as providing the yardstick for assessment. Overall, 81% of the species in the study programs were covered by some type of published recovery plan, whether it was a species-specific national action plan, a regional or international plan, a national or regional action plan for a group of taxa; an IUCN/SSC Specialist Group Action Plan; a national biodiversity plan; or an action plan for an ecosystem. The action plans vary in specificity from a single species plan targeting objectives and goals for a single taxon to a regional biodiversity plan that has the species on a list for conservation action for their region. Necessary for the ultimate success is the collaboration of different stakeholders including species specialists, researchers, government authorities, zoologists, social scientists, academics and local communities that have to come together to develop and implement the conservation planning and action.

A PHVA can be held for initial assessment of a species' status or at any time during a conservation program for use in collection of data, analysis of extinction risk and developing further goals for conservation. In many cases, the PHVA is not a replacement for a recovery plan but rather brings together stakeholders to gather information for analysis in order to better inform for the development or adaptation of a recovery plan. Only a small percentage of invertebrate, reptile and bird programs in the case study dataset (8.3%, 7.1%, 5.4% respectively) have had a PHVA done. For amphibian programs, 20% included a PHVA and mammals topped the list with 46.3%. This may be due to the fact that 78.1% of the mammal species and 73.3% of the amphibian species in the dataset had a greater conservation need and were listed in a threatened category on the Red List whereas the percentages of reptile, bird and invertebrate species listed as threatened were below 61%. Fish species, however, matched the 73.3% in threatened IUCN categories for amphibians and haven't had any PHVAs done. For any PHVA, specific biological and demographic data are needed for the species as well as an understanding of the threats facing the population in order to model extinction risk and propose further conservation action. In many cases, biological data may be limited and information may come from the *ex situ* community who had done research or compiled data for that species or from field studies of similar species.

Success of a program is measured by assessing whether indicator parameters have satisfied specific program goals and objectives. In assessing success, programs for mammals had the best success rate (72%) with fish close behind (68%). Over half of reptile programs (56%) and less than half of bird programs (42%) were rated as successful. Only a third of invertebrate and amphibian programs were rated as successful. There are inherent issues in analyzing program success at three levels: 1) at the taxonomic level, for reintroduction projects worldwide, mammal and bird programs are over-represented in relation to the number of described species whereas fish species are under-represented (Seddon *et al*. 2005); 2) early programs (prior to 1988) generally reported descriptive accounts and monitoring to answer *a priori* questions was limited, thus assessment of success was difficult (Armstrong and Seddon 2008); 3) published case studies may consist of those programs that are successful or partially successful with few reports of the programs that have failed (Seddon 1999). It is difficult to assess success by taxa through analysis of this dataset of case studies. Since authors submitted their case studies opportunistically, there the submissions may not be representative samples of all of the programs for each taxon. Also, it was apparent that the conservation translocation programs were evaluated for success using different criteria. Thus, a program rated as "successful" might mean that there was a successful translocation of individuals, survival of the released population and evidence of breeding whereas another program with an established captive breeding program, survival and breeding of released individuals is rated as "partially successful" since long-term population sustainability was not yet documented.

Parameter assessment by taxa

Each animal group (invertebrate, fish, amphibian, reptile, bird, or mammal) has specific life history traits that will dictate the requirements for conserving sustainable populations in the wild (see Life History Traits, Appendix V). Taking life histories into account, the author investigated the methodologies, management strategies, and assessments along the conservation translocation cycle (Figure 2.1) for each animal group. Parameters for each level were similar among animal groups with some attributes unique to each group.

Invertebrates

Invertebrates have life cycles with several different life stages within a short period of time that each rely on different features of the environment (Joint Nature Conservation Committee [JNCC] 2008). Thus, they depend on complex interactions with the environment and oftentimes have specialized habitat requirements. Many species require a number of micro-habitats to obtain resources at different stages of their life cycle. The complex requirements for natural resources makes management challenging and requires expertise in invertebrate captive propagation as well as specialized monitoring techniques to assess not only the release population but the availability of the required habitat for each life stage. For programs with wild source of individuals, preliminary research was done to determine parameters such as existing habitat requirements, source population size and structure, and reproductive behavior. Habitat research resulted in habitat restoration if found not suitable at the release site.

Conservation status was assessed for 70% of the invertebrate species in the study through IUCN Red Listing with over 41% listed in the IUCN threatened categories whereas only 2 of the 15 invertebrate programs had a PHVA done. Although invertebrates constitute 95% of all animal species on Earth and serve widespread ecosystem service functions, there is a disparity in assessment and listing in the Red List. Invertebrates make up 33% of the threatened species on the list yet they represent over 90% of global animal diversity (Black *et al*. 2001). Over 79% of the programs had a published recovery plan which shows that the population extinction risk had been evaluated and management actions pulled together for conservation for those species.

Five of the e*x situ* populations were carefully managed in breeding programs to maintain genetic diversity with four programs facilitated by ISIS member institutions who maintained the records in the ISIS database. Husbandry knowledge is critical for a successful program including enclosure requirements (adequate size, appropriate substrates for egg deposition if required, nesting/denning sites etc.), environmental requirements (temperature, humidity, water quality for aquatic species), reproductive protocols (introducing breeding individuals, incubation protocols, separation protocols), feeding protocols, and health care. The natural life history of the species is critical to understand for effective management. For all of the captive breeding programs, pre-release protocols include health assessments which include inspection for parasites, monitoring weights, and taking samples for analysis for disease.

All of the invertebrate species were released using a hard-release paradigm except for the giant clams, and evaluations of life history traits and habitat requirements were done to determine the appropriate life stage for release. The addition of supportive measures including supplemental feeding and nest or denning structures ensured a greater probability of survival and subsequent reproduction. Thus, data to determine natural life cycles as well as the social and reproductive traits are critical for implementation of a successful conservation translocation program for invertebrates.

Due to the specialized micro-habitat requirements, monitoring invertebrates must include assessment of the presence of the different life stages and the habitat resources relevant for all of the life stages (JNCC 2008). Thus the parameters measured included absence/presence, survival, growth and health status, reproductive success, land use and dispersal, habitat quality, and genetic diversity of both the source and release populations. Required data would include counts at various life stages within micro-habitats and quality of micro-habitat attributes. Depending on the biology of the species, monitoring would take place at certain times of the year in order to detect the different life stages. National butterfly monitoring programs in Europe make use of scientists and trained volunteers to conduct surveys of butterfly populations at different times of the year (van Swaay *et al.* 2008). Butterfly Conservation Europe acts as a coordinating organization overseeing recording and monitoring programs and maintains species data from an online data entry system (Butterfly Conservation Europe 2014).

In assessing the programs, the greatest percentage were indicated as “partially successful” (63%) with a third (33%) indicated as “successful”. For the programs that involved a captive breeding population as the source population, the establishment of a sustainable *ex situ* population that was genetically diverse and demographically stable was critical to success yet was only one component required for overall success of the program. Once released to the wild, survival, reproduction, and recruitment for a certain number of generations would indicate success. Partial success would be attributed to a program that had established husbandry protocols for successful reproduction while under human care, but did not have high levels of survival or recruitment for released juveniles. Other detrimental factors that could contribute to partial success included high predation of released individuals, continuing habitat loss or lack of natural resources for subsequent generations in the wild.

A major difficulty faced in invertebrate programs was the lack of basic evidence-based information on ecology and biology of the species or on effective invertebrate translocation methodologies. These issues point to the need for conservation translocation programs to establish *a priori* questions in the design phase that would guide data collection for assessment and result in adaptive management (Seddon *et al*. 2007). Invertebrate programs were especially sensitive to habitat issues such as loss of ecological processes and difficulty in managing habitat or predators and stochastic environmental events such as drought, hot or freezing weather. Understanding the requirements for ecological complexity and the potential for environmental stochasticity issues throughout the program will help implement adaptive management strategies to ensure successful conservation measures. The importance of long-term collaboration between a multi-disciplinary group of stakeholders emphasizes the need for consilience in integrating the social and biological sciences to include government authorities, scientists, academics, and local communities is required for effective conservation action (Miller and Lacy 2003).

Fish

Fish pose unique challenges for conservation translocation programs due to their aquatic habitat requirements. Fish are sensitive to water pollution which may affect health and reproduction, and thus proximity to human industrial settlements may be detrimental for population sustainability (State of Alaska 2014). The range for a particular fish species might be within a lake or a pond, within a system of rivers, in the great expanse of the ocean or a combination of rivers and the ocean (for anadromous species). Thus, monitoring techniques for species that live in an aquatic environment are specialized in dealing with habitat challenges encountered in conservation program management.

For fish species in the study, 87 % were listed on the IUCN Red List with over 73% listed in the IUCN threatened categories. There were no PHVAs done for the fish species in the study which may be partially due to the fact that seven species had specific national recovery plans that included life history, conservation status, range, threats, and conservation action needed. Another seven species were listed in Regional and National Biodiversity Action Plans but these did not go into depth about the specifics for each species, nor about the conservation action needed.

The majority of the programs (87.5%) used fish bred or raised in an *ex situ* institution or organization. Husbandry and reproduction methodologies were well developed due to the long history of government-run fish hatcheries for supplementation and stocking of game fish (Weber 2002). All programs used a hard release paradigm with no supportive measures after release. Fish hatcheries incorporate water quality management such that the physical and chemical qualities of the water are maintained as close to the natural state of the species so that development of eggs and growth of fry are under conditions similar to the wild (Piper *et al.* 1986). Thus acclimation to the wild is not an issue.

Only one institution, the Tennessee Aquarium, participating in lake sturgeon reintroduction, was an ISIS member although it is unclear if all the lake sturgeon records were kept in the ISIS database. The use of ISIS software had been limited for fish records due to the lack of functionality in *ARKS* software to cover groups and aquatic systems. *ZIMS* ' functionality has now been expanded to be useful for aquarium data management.

Monitoring required methods specific for aquatic species such that surveys and recaptures were the ones most frequently used. Although over half of the programs (13) marked individuals for identification after recapture, all but three programs marked cohorts rather than individuals to distinguish released fish from wild recruits. Body size and longevity may determine the ease in marking individuals as the larger long-lived species (lake sturgeon and Adriatic sturgeon) were implanted with PIT tags and the lake sturgeon were tracked using radio-telemetry. The importance of genetic diversity was noted in three programs that monitored the reintroduced population through genetic sampling and analysis. Recent advances in genetic research have provided new non-invasive genetic techniques to evaluate DNA from cellular material shed by fish in water which will aid in the analysis of genetic diversity in translocated populations (Turner *et al.* 2012).

Overall, the majority of fish programs were successful ("highly successful" – 28% and "successful" – 40%). Fish had the highest percentage of highly successful programs of all the animal groups (invertebrates – 4%; amphibians – 4%; reptiles – 18%; birds – 19%; mammals – 18%). This may be due to a number of factors. Fish hatcheries have a long history in developing husbandry and reproductive techniques for re-stocking wild populations all over the world due to the demand for fish as a food commodity and concern about the impacts of depleted stocks (Weber 2002). Thus, the aquaculture industry was well in place to assist in conservation programs. Secondly, fish produce an enormous number of eggs per reproductive event since there is very high predation on eggs and fingerlings in the wild (Yarqon bleak, *Acanthobrama telavivensis* - Elron *et al*. 2006; burbot - Vught 2007).

In spite of a long history of successful aquaculture management, the issues faced had to do with assessing and managing the populations once released to the wild. The main issues dealt with human impacts on water quality, presence of predatory or competing alien species, and lack of funding for management staff. Scientific research on ecology and biology was needed to understand each species life history and how it fit into ecological systems. Fish are part of dynamic food chains and thus reintroduction programs need to take into consideration the specific ecosystem services and natural resources available in the release aquatic systems (Holmlund and Hammer 1999).

Amphibians

Amphibians, of all the animal groups, are the most threatened with more than a third of known species at risk of extinction (Wake and Vredenburg 2008). Amphibians are ectothermic (body heat is regulated by external environment) and have permeable skin that is a sensitive integument allowing absorption of water and oxygen (Duellman and Trueb 1986). Their unique adaptations for required moist environments make them very susceptible to environmental stresses such as chemical contamination of water sources (pollution), climate change, habitat degradation and loss, and the spread of infectious diseases. In the past decade, an emerging infectious disease caused by the chytrid fungus *Batrachochytrium dendrobatidis* has been found to cause massive die-offs of amphibian species, causing an accelerated rate of extinction and a rapid decline in frog populations in many parts of the world (Wake and Vredenburg 2008). Methodologies for managing *ex situ* insurance populations and for reintroductions thus have to take into consideration the requirements for preventing contraction and spread of disease. All of the species of amphibians in the study were anurans (frogs and toads) and thus results were limited to this Order of amphibians.

The amphibian case studies reflected the urgency for amphibian conservation as over 93% of the amphibian species had an IUCN Red List assessment of which over 73% were listed in the IUCN threatened categories and all of the species were covered under a recovery plan. Further assessments were done through PHVAs for three species that required immediate action and listed as Endangered (Houston toad), Vulnerable (Chiricahua leopard frog), and Extinct in the Wild (Kihansi spray toad).

Due to the threat of chytrid infection, all amphibian programs maintained strict quarantine protocols requiring close health monitoring at all stages of the program. The Amphibian Ark has developed biosecurity and husbandry standards for *ex situ* programs to assist in establishing insurance populations for frog species under threat of extinction from spread of the chytrid fungus (Zippel *et al*. 2006). Amphibian data entry guidelines, created for AZA registrars and studbook keepers, are also available from the Amphibian Ark to promote consistent recording of data for *ex situ* populations to support effective husbandry and population management practices (Amphibian Ark 2010). The use of an ISIS application is not mentioned in the guidelines yet *ZIMS* offers the functionality for all of the data entry protocols.

A hard release paradigm was the release method of choice for 80% of the amphibian programs. The majority of the programs released larvae (tadpoles) or a combination of larvae with other life stages (egg masses, juveniles and adults). The egg and larval stages are the easiest to move and there's evidence that larvae metamorphosing at a release site will retain site fidelity and will be less likely to disperse (Dodd 2010; Vandewege *et al.* 2013). To improve survival of young life stage individuals, management of the release sites included removal of invasive fish and bullfrog species (e.g., common mid-wife toad and Iberian frog) or erecting predator-proof fencing around the habitat in order to exclude predatory lizards (e.g., Hamilton's frog and Maud Island frog). Two programs utilized a soft-release method, incorporating artificial tubs that used stream water and natural pond silt to acclimate the tadpoles to natural conditions. This paradigm allowed for acclimation and growth to the metamorph stage as well as health monitoring for presence of chytrid prior to release. Paramount to this release method was the assessment of water quality of the water source from the stream and testing for chytrid fungus in the natural environment.

Monitoring small bodied frogs and toads is an imprecise science since it is nearly impossible to be able to observe or detect the presence of all of the individuals within a population (Schmidt and Pellet 2012). In order to assess general population parameters (size, presence of different life stages, abundance and distribution), sampling (through visual or auditory observation and capture-recapture methods) will involve incorporation of a parameter of the probability of detection. Pellet *et al*. (2007) found that when investigating the relationship between counts of singing male European treefrogs (*Hyla arborea*), the number of captures, and mark-recapture estimates of abundance, the number of calling males represented only a fraction of the total male population at the breeding ponds. Thus auditory counts under-estimated true abundance. Funk *et al*. (2003) compared different monitoring methods for monitoring population trends of forest-dwelling *Eleutherodactylus* frogs and found that mark-recapture methods were better than visual encounter surveys and distance sampling at estimating the abundance in these populations. Monitoring amphibians released to the wild poses additional challenges since additional information besides abundance is needed such as individual survival, growth, evidence of reproduction and recruitment in order to assess population sustainability. Thus a combination of monitoring methods will offer the best strategy for gaining the required information. Over half of the programs tracked released animals using individual identification methods combined with other monitoring methods as well as genetic analysis to track genetic diversity of both captive and reintroduced populations. For Mallorcan midwife toads (*Alytes muletensis*), microsatellite DNA analysis showed that wild populations retained high levels of genetic diversity even in fragmented landscapes and reintroduced or captive toads had not lost fitness or genetic variability for up to eight generations in captivity.

The majority of the amphibian programs were rated as “partially successful” (67%) with one third rated as “successful” or “highly successful”. Four out of the six programs that had a captive breeding program were rated as “partially successful” which may be due to the fact that although the captive breeding component and releases were successful, the populations had not yet demonstrated long term persistence.

Difficulties with predation by invasive species was the overriding issue that almost half of the programs faced (47%) and many programs incorporated predator eradication and control as supportive measures. It was also important to have continued monitoring of the invasive species populations as well as the translocated species populations. The overriding lesson learned was that that the lack of biological data or formal scientific knowledge was a major impediment to progress and scientific research was critical at each step of the programs to inform conservation management. The success of programs depended on collaboration from a multi-disciplinary team of cooperative stakeholders that would commit to long-term management for the programs.

Reptiles

Reptiles are usually cryptic, ectothermic vertebrates that lack true social behavior and exhibit little or no parental care (with exception to crocodilians) (JNCC 2004). Terrestrial species, most of which are diurnal, require a heterogeneous habitat that includes open areas for basking that are close to areas of vegetation for refuge. Some species in colder climates require hibernation areas. For egg-laying species there are specific breeding habitats required (e.g., sandy beach for Hawksbill turtle, *Eretmochelys imbricata*) or specialized environmental conditions for effective propagation (e.g. temperature-dependent sex determination in giant tortoises). Many of the reptile species are long-lived (ranging from 10-12 years for the smaller lizards to over 100 years for tuataras and giant tortoises) and thus the conservation programs may take a long time to reach conservation goals, emphasizing the need for long-term commitment to these programs.

A high percentage (85.7%) of reptile species were listed on the IUCN Red List with 75% of the listed species in the threatened categories. Further assessments were done through PHVAs for two species listed as Critically Endangered (Orinoco crocodile and Indian gharial) that required immediate action. Almost 90% of the species were covered by recovery plans and the IUCN Crocodile Specialist and Iguana Specialist Groups were very involved in the action plans for all the crocodilian and iguana species. Data management guidelines were lacking in the recovery plans but the UK provided data specifications in the “Common Standards Monitoring Guidance for Reptiles and Amphibians” generated by the Joint Nature Conservation Committee (JNCC 2004).

The life history attributes of reptiles facilitate the use of captive-born or reared animals for translocation programs (Germano and Bishop 2008). Unlike short-lived amphibians that go through a larval stage after hatching, long-lived reptiles hatch (for egg-laying species) or are born (for live-bearing species) as mini-adults and require a number of years to grow to sexual maturity. Whereas amphibian larvae require different habitat and food resources than adults (e.g., Mallorcan midwife toad tadpoles are herbivorous and adults are carnivorous), reptiles remain at the same trophic level throughout their lives. Reptiles are non-social animals that generally do not exhibit parental care as 97% of all reptile species leave their eggs soon after laying (Somma 2003). The exception is the crocodilians who display parental care such as guarding the nest after egg laying, opening the nest when detecting that the young have hatched, carrying the young to water and guarding the young for a certain amount of time until they grow to a size where they are not as susceptible to predation (Thorbjarnarson and Hernández 1993). For most reptile species, the young are immediately independent and thus there are no constraints for releasing them to the wild except for the risk of predation. A head-start paradigm is useful for rearing reptile hatchlings to a size where their risk of predation is diminished (Heppell 1996). This works well for crocodilian species since it replaces the parental care functions to ensure survival of the young. Thus, all but one program used a hard release paradigm. Head-start programs and captive breeding programs would involve release of juveniles and adults whereas adults were released for translocation or rescue-rehabilitation-release programs. Genetic diversity was carefully tracked in six of the nine programs that used captive-born/hatched animals as the source population and held breeding programs in ISIS member institutions, including the three breeding programs managed by regional zoo associations. Genetic sampling and analysis was also used in monitoring 6 of the 13 wild-sourced species programs.

Reptiles as ectotherms are very sensitive to variation in environmental conditions and thus may be inactive and not visible for long periods of time during unfavorable conditions (Pough 1983). An understanding of their normal activity patterns is essential for monitoring them in the wild. Simple observational surveys were utilized for monitoring large-bodied reptiles such as giant tortoise species and Indian gharial. The majority of the programs (79%) utilized individual identification methods and a combination of monitoring techniques to track population survival, reproduction and growth.

Overall, there were difficulties in monitoring and also lack of support by local agencies and the local community. Thus the main lesson was the need for long-term monitoring and development of effective monitoring methods in order for adaptive management to occur to achieve the conservation goals. Also, programs required eradication and continued surveillance of alien predatory species as well as pre- and post-release health assessments to ensure survival of released animals. Lack of support for reptile species conservation programs may be affected by negative public attitudes as a result of cultural-based fears or general phobias (Knight 2008). Thus, over a third of the programs noted that collaboration must include not only scientists and local agencies but also the local communities for all stages of the programs.

Birds

Conservation translocation programs for birds are numerous with over 200 species involved in releases in over 400 sites around the world (Lincoln Park Zoo Avian Reintroduction and Translocation Database 2014). Most species of birds exhibit a monogamous mating system (92%) with the rest showing polygyny, polyandry and promiscuity (approximately 2%, 1% and 6% respectively) (Ligon 1999). All birds show parental care for their young and both parents (for monogamous species) incubate eggs, feed and protect hatchlings, shielding them from sun or rain. For some species, parents may train the youngsters to forage for food or avoid predators (Wesołowski 2004). Birds are also able to disperse to other areas with some species making seasonal migrations that may cover great distances. These biological attributes are taken into consideration when using methodologies for conservation translocation programs.

Birds have had the most complete IUCN Red List assessments done of any taxon. BirdLife International, the official IUCN Red List Authority, completed the latest full assessment in 2013 (BirdLife International 2013) and found that 13% of all species are globally threatened with an additional 8% listed as Near Threatened. Except for one species used in a research study, all of the bird species were listed in the Red List with over half listed in the threatened categories. Two Critically Endangered species had PHVAs done. The majority of the species were covered by national action plans and due to the migratory nature of some bird species, there were four international recovery plans requiring cooperative efforts between countries.

Half of the programs using wild individuals as the main source population employed a hard release paradigm where birds were captured, given health assessments, banded for individual identification, and transported to the release site for release. For the hard-releases, all but one species were Passeriformes – small bodied perching birds- that tended to be difficult to capture and also difficult to monitor once released back to the wild. All these species are monogamous and have altricial young requiring extensive parental care from both dam and sire. Thus, all the birds captured and translocated were adults since no extended care was needed. All the species were endemic to restricted ranges such as islands or mountain ranges and moved to other habitat similar to the habitat of origin so there was no need for an acclimation period. For the programs using wild-sourced populations and employing a soft-release paradigm, half of the species were raptors (from the Orders Accipitriformes and Falconiformes) with others representing Ciconiiformes, Apterygiformes, Psittaciformes and Passeriformes. All but four of the species (Passeriformes - Seychelles white eye, *Zosterops modestus*; noisy scrub bird, *Atrichornis clamosus*; helmeted honeyeater. *Lichenostomus melanops*; and Psittaciformes – red-fronted parakeet, *Cyanoramphus novaezelandiae*) were large-bodied, long-lived birds that exhibited a monogamous mating system. In general, for raptors, natural conditions were replicated with provision of carrion using a hatch and sleeve to avoid human contact. In the wild, new fledglings are provided carrion by their parents so this supplementation was also done for released birds for several months after release. Since wild birds of prey remain close to their natal nest sites for breeding, the use of release aviaries for immature birds facilitates site fidelity and contributes to success in monitoring the released birds. Captive bred birds were bred in a government or local breeding center, with none of the facilities as ISIS members and only one listed on the ISIS institution list. Adult birds were released as pairs for monogamous species or as part of flocks including different age groups to simulate the natural social groupings in the wild. Two naturally gregarious species that live in flocks had pre-release social structure training and predator avoidance training.

More than half of the programs with captive-bred birds as the source population used a soft release paradigm for reintroductions. The soft release methods help birds transition from captivity to the wild by allowing them to acclimate to the environment, learn the necessary foraging and predator avoidance skills in a protected area and facilitate close monitoring for health status (Seddon and Cade 1999). Natural social groupings and simulation of natural circumstances that will be encountered in the wild also help increase survival once the full release occurs. Soft release methods also provide opportunities for testing hypothesis on the efficacy of different methodologies, requiring documentation at each step.

The mobility of birds may cause some issues when released animals are being monitored for conservation translocation programs. Home range sizes may be very large and/or include inaccessible areas (e.g., rocky cliffs for griffon vulture, *Gyps fulvus*) or a species may be migratory for breeding and overwintering seasons (e.g., red kite, *Milvus milvus*). The ability to easily disperse from a release site will affect the results from mark/recapture studies, giving an underestimate of abundance or survival success (Royle and Nichols 2003). Thus release methodologies to encourage site fidelity for the release site, such as soft-release methods and supplementation with feeding stations, can help to facilitate monitoring or capture-recapture methods for assessing survival and health status.

Visual surveys were employed for monitoring small-bodied passerines whose size precluded the use of radio-transmitters (e.g. akepa and Hawaii creeper). Home range sizes for the Hawaiian passerines are fairly small since these species are naturally highly selective foragers (Ralph and Fancy 1994) and individuals tended to return to the supplemental food resources placed on platforms in several locations close to the release site, making visual observations possible. Capture methods of unidentified individuals yielded information on health status and reproduction, and offered the opportunity to take samples for genetic analysis and tag the individuals for future identification.

Less than half of the bird programs were successful or highly successful, based on captive propagation success, survival rates of released birds, evidence of reproduction, increases in population sizes and expansion of geographic ranges. Those programs rated as partially successful may have had success for short-term indicators such as survivorship of released birds but may be too soon to tell for long-term indicators such as reproduction or establishment and growth of the populations.

For bird programs, the lack of knowledge of natural history of the species and lack of scientific evidence to inform management decisions were the top difficulties mentioned in the programs. Thus, the overall main lesson was the need for research on life history and methodologies to implement the programs. Communication and cooperation between a multi-disciplinary team as well as with the local communities were critical for successful programs. Programs with a captive source population needed the anchor of a successful captive-breeding program that would produce a genetically diverse population that could adapt to life in the wild, with species-appropriate behavioral skills for survival in the wild. Thus the methodologies for reproduction, incubation of eggs, rearing, pre-release training, release, providing supportive measures and monitoring were important to develop and document for these programs.

Mammals

Studies have shown that there is a concentration on mammal conservation translocations when compared to other taxa (Fischer and Lindenmayer 2000; Seddon *et al*. 2005; Czech *et al.* 1998). This trend continued in the number of case studies involving mammals versus other taxa in the three issues of the RSG Global Re-introduction Perspectives (Soorae 208, 2010, 2011). Mammals exhibit the whole array of mating and social systems, although only 3-5% are monogamous (Nair and Young 2006). All mammals exhibit maternal care with less than 10% also showing paternal care (Woodroffe and Vincent 1994). They live in diverse habitats and exhibit a wide array of physiological characteristics so the architecture of each conservation program is specific for each species depending on life history parameters.

All of the mammal species were listed on the Red List and had the greatest percentage of threatened species (78.1%) of all the taxa. Almost half of the programs were guided by a PHVA (46%), again with the greatest percentage compared to other taxa (amphibians came in second with 20%). The IUCN SSC Specialist Groups produced plans for 6 species, which was the most for any taxa (reptile specialist groups were second with 5 species plans). This shows that the Specialist Groups for mammals are the most active, at least within the constraints of this dataset of case studies. Data management plans were lacking within the recovery plans for the most part except for a few that mentioned the need for a centralized database to share information between stakeholders. This illustrates the need for standardized data management plans to facilitate the programs.

Many mammal species have complex social dynamics as well as high parental care investment that are taken into consideration when implementing methodologies for conservation translocation programs. Thus captive bred mammals or those that are maintained in captivity during developmental years or for an extended length of time require simulation of natural conditions for social groupings, foraging, predator avoidance or capturing prey, and habitat use in order to survive once released to the wild. Mammal programs incorporated pre-release training methodologies for the greatest percentage of case studies of all the taxa with almost twice as many mammal species requiring pre-release training than bird species. Only a few reptile and amphibian programs and no fish or invertebrate species incorporated pre-release training methodologies.

By individually identifying animals, fine-tuned monitoring data could be collected to determine individual health status, growth and development, parentage for young, social dynamics, spatial organization with home range and territory sizes, and habitat use. Almost two thirds of the programs used individual identification methods such that survival, reproduction, and health could be tracked for individual animals. Combining data for all the individuals within a population would provide information to assess the population as a whole, giving a valuable overview to evaluate the program. For some species, the genetic diversity was carefully monitored in both the captive source population and the release population to enable genetic management of both populations.

A large majority of the species that were captive bred (78%) were maintained in ISIS member institutions with two of the five other breeding facilities included in the ISIS institution list. Nine species were managed under regional zoo association or global species breeding management programs (the only taxon with GSMPs) and thus for these species, a good base of records exists for the captive component of these programs. At least one SSP®, for the golden lion tamarin, includes wild individuals in the studbook in order to track genetic diversity in the wild population as well as the captive population.

Mammals had the greatest percentage (72%) of programs rated as "highly successful" and "successful" of any taxa in this dataset of case studies with fish coming in second with 68%. This may be a reflection of the bias seen in support for mammal programs (Seddon *et al*. 2005) or merely a characteristic of this particular dataset of case studies. Programs that were rated as "successful" tended to have a genetically diverse founder population through a managed captive-breeding program (for captive-bred sources), implemented the release in accordance with relevant methodologies to accommodate life history attributes, and documented each component of the program in order to apply adaptive management.

The major issues noted for mammals programs were lack of knowledge on biology/ecology of the species and lack of records to learn from previous programs. These issues along with difficulties with long-term monitoring affected the successful implementation and adaptive management of a number of programs. Thus there was a need for effective documentation to provide an evidence-based approach for evaluation and adaptive management. Genetic management of both *ex situ* and *in situ* populations was critical to insure that populations would be sustainable in the future, calling for studbooks to be utilized to form the genetic basis for analysis. Formation of natural social groupings and use of pre-release methodologies to simulate natural conditions was important for mammal species to decrease mortality risk after release. In order for programs to be effective, a multi-disciplinary team and partnerships needed to be involved for planning, implementation and assessment of programs.

Data gaps in PHVA processes

In the review of PHVAs, all of the programs except one had insufficient data to adequately populate the fields necessary for modeling to project extinction risk. The PHVAs and the workshops all noted the need for use of scientific-based evidence to manage and assess the programs as well as the need for genetic management of the captive populations. What should be noted is that four of the PHVAs were done between the years 1994-1998, prior to the publication of the RSG Guidelines for Re-introductions (IUCN 1998). Three others were held between 2001 and 2004. Data gaps increase the uncertainty in the projections with possible consequences for underestimating extinction risk and impacting management decisions for conservation action (Gillespie *et al*. 2011). Involvement of the *ex situ* conservation community is an important component of the conservation programs in contributing expertise in population management and species knowledge as well as providing a source for reintroductions or supplementations for threatened species.

Conclusions

Ongoing assessment and management of conservation translocation programs are essential in order to apply adaptive management strategies to reach program goals. Although ultimate success is defined at the population, meta-population and ecosystem levels, these are the long term goals and smaller measures of success are assessed all along the continuum of the conservation translocation cycle. Changes due to stochastic events or an increase in threats may occur at any point in the cycle requiring adjustment of methodologies. Recognizing parameters that are important to consider for each component of the program will aid in identifying the data needed to provide the evidence for scientific-based decision-making.

For the case studies published in the RSG Global Re-introduction Perspectives, the overriding theme for all animal groups was the lack of evidence-based information on life history, biology and ecology of the species and that scientific research was critical for each step of the conservation translocation programs. Species-specific information is needed to apply appropriate methodologies for *ex situ* care and breeding management, for capture and transfer of wild individuals, for the actual release, and post-release supplementation and monitoring. For all animal groups, there were both wild and captive source populations for the programs, hard and soft release methodologies utilized, and use of various monitoring techniques to assess survival, reproduction and population sustainability.

For all the programs, there were basic components important to consider:

1) Life history attributes will dictate methodologies used at each stage of the conservation translocation program. Life span, trophic level, social system, mating system, reproductive physiology, extent of parental care, habitat requirements, home range size, and activity type (diurnal, nocturnal, etc.) are among the attributes important to understand in order to plan and implement conservation action. Data on these life history parameters are lacking for many species and thus *a priori* questions formulated to answer these questions will guide the research for each program.

2) Genetic diversity was important for both the source and released populations to mitigate damaging effects of small populations. Thus, population size is an important parameter to monitor for these programs. For *ex situ* populations, an organized breeding management program where the pedigree of each animal is known will insure that genetic diversity is maximized and inbreeding minimized. This requires individual identification and the use of a studbook or registry to track parentage, reproduction and the basic age distribution of the population to give an overview of population sustainability. After release to the wild, genetic diversity can be tracked either by identifying parentage through monitoring or genetic testing. Ideally, the population in the wild is incorporated into the studbook such that there can be a holistic view of relatedness within the entire population, both *in situ* and *ex situ*. This would facilitate

meta-population management to insure that both *in situ* and *ex situ* populations would retain genetic diversity. For species that cannot be tracked by individual (species that live in groups, small body size with no outward identifying marks, difficult to individually mark), *ex situ* group management can be accomplished by keeping group sizes small starting with known founders, tracking movement of offspring to newly formed groups, keeping as many groups as facilities can accommodate, or transferring all individuals of one sex out to prevent inbreeding (Princée 1995).

3) Habitat has to be appropriate with needed resources for all life stages. This requires an understanding of the life stages for each taxon as well as the habitat resources necessary to sustain each life stage. Developmental stages should be documented either through monitoring animals in the wild or through observation *ex situ*, although time frames for development *ex situ* may be different than in a natural environment. Habitat should be assessed prior to release and then monitored afterwards to ensure that the necessary resources continue to be available.

4) Health assessments are critical for all stages of the programs to mitigate the spread of disease or assess the causes of poor health. For animals in zoological institutions, health records are kept on individuals throughout their lives. Health exams prior to release are critical to prevent an animal that is diseased from spreading the illness to the wild population if released. Health assessments on animals in the wild after release can be attained during capture events or through visual assessment of body condition and health. For a captive-born/hatched animal released to the wild, having one health record will assist in linking health history while in captivity to health status in the wild.

5) Transitioning captive born/hatched or captive reared animals to life in the wild may require pre-release methodologies including training in predator/human avoidance, foraging or killing prey, land use (locomotion skills), physical conditioning, or acquiring social skills. Release methods may include a soft-release paradigm for acclimatization to the natural habitat with supplementation after release.

6) Long-term monitoring with documentation is an important component of any program in order to obtain the evidence necessary to assess the program and apply adaptive management. Monitoring methodologies will depend on the taxon in accordance with life history parameters and also on the *a priori* questions that guide the programs.

7) A multi-disciplinary team is required for planning, implementation, monitoring and assessment of the programs. Collaboration must include *in situ* and *ex situ* conservation communities as well as local communities with effective communication occurring between all stakeholders.

Each conservation translocation program should be a research study that addresses specific *a priori* questions at each stage of the conservation translocation cycle. Documentation of each component of the program will allow analyses for understanding of the mechanisms involved in success or failure and give a scientific basis to inform for adaptive management strategies. Results should be shared through publication so that other programs can benefit from the findings. Starting with basic life history traits, there are important parameters and methodologies at each stage of the programs that require documentation for assessment at the population, meta-population, and eco-system levels (Table 2.3).

Table 2.3 Important parameters and methodologies along the conservation translocation cycle for basic life history, data management processes and at the population, meta-population and ecosystem levels.

	Conservation situation/ feasibility/risk assessment	Design	Implementation		*Ex situ* /*in situ* integration	Monitoring
	IUCN Red List parameters	Species traits	*Ex situ*	*In situ*	Release strategies	Individuals or Groups
Life History	Population size (adult individuals) and number of populations	Required habitat and resources	Wild/captive born source	Research: Life history attributes	Pre-release health assessment	Individual ID methods Group ID methods
	Geographic range	Social grouping	Husbandry methods	Habitat/resource use	Soft/hard release methods	Monitoring methods
	Habitat resource requirements	Mating system	Breeding methods	Population size	Supportive measures	Reproduction parameters
	Threats and population declines	Reproductive traits	Environmental measure	Genetic diversity		Health assessment
		Physiological traits	Health and disease	Disease/pathogens		Habitat/resource assessment
			Pre-release methods	Threats		
Data Management	IUCN Species Information System	Data management plan	Records (ISIS ZIMS or other)	Records databases	ISIS ZIMS, studbooks Records databases	Records databases
Population	Population and Habitat Viability Assessment	Conservation action	Population management	Population management	Population management	Population sustainability
	Habitat - carrying capacity and habitat loss/gain	Specific objectives and goals	Head-starting or breeding management:	Monitor reproduction, collect eggs/hatchlings for *ex situ* rearing	One plan approach for analysis to include *ex situ* & *in situ* populations	Monitoring methods: Individual ID or group ID
	Reproduction - breeding system, age at first reproduction, maximum breeding age, sex ratios, litter/clutch size, proportion of breeding adults	*Ex situ* breeding Headstarting Conservation translocation	Genetic diversity Age distribution Reproduction parameters Fecundity Generation time Age-specific survival	Translocation methods - appropriate life stages with known genetic background	Communication and information exchange between *ex situ* and *in situ* partners	Age-specific survival Mortality - occurrence/cause Reproduction Health Population structure by age class
	Age-specific survival for males/females	Life history research	Cooperative breeding program : e.g. SSP, EEP. ASMP			Location (home range, dispersal)
	Genetics-inbreeding depression, number of lethal equivalents	Habitat restoration				Status of habitat resources
	Catastrophes, harvesting, supplementation		Regional Studbook			Carrying capacity
Meta-population	Number of populations	Genetic management	Global Species Management Program	Number of populations	Include all *ex situ* & *in situ* populations	Standardized protocols over all populations
	Connectivity	Corridor construction Assisted translocation	International Studbook	Connectivity	Population genetic differentiation	Genetic diversity
Ecosystem	Biodiversity	Habitat resources		Research:		Invasive species
	Presence of disease	Population monitoring		Species interactions		Symbiotic species
	Habitat resources	Disease monitoring		Ecosystem function		Species interactions
		Biodiversity monitoring				Ecosystem composition
						Ecosystem function - productivity

References

Akçakaya, H.R. and P. Sjögren-Gulve. 2000. Population viability analyses in conservation planning: an overview. Ecological Bulletins 48: 9-21

Amphibian Ark. 2010. Amphibian Data Entry Guidelines. http://www.amphibianark.org/pdf/Husbandry/Amphibian%20Data%20Entry%20Guidelines%202010.pdf. Accessed 9.August.2014

Armstrong, D.P. and M. Reynolds. 2012. Modelling reintroduced populations: the state of the art and future directions. pp. 165-222. In: Ewen, J.G., D.P. Armstrong, K.A.Parker, P.J. Seddon (eds.). Reintroduction Biology, Wiley-Blackwell Publishing, Chichester, West Sussex, UK

Armstrong, D.P. and P.J. Seddon. 2008. Directions in reintroduction biology. Trends in Ecology and Evolution 23(1): 20-25

Asa, C., P. Miller, M. Agnew, J.A.R. Rebolledo, S.L. Lindsey, M. Callahan and K. Bauman. 2007. Relationship of inbreeding with sperm quality and reproductive success in Mexican gray wolves. Animal Conservation 10(3): 326-331

AZA. https://www.aza.org/species-survival-plan-program/. Accessed 10.Nov.2013

Bartel, R.A. and D.R. Rabon. 2013. Re-introduction and recovery of the red wolf in the southeastern USA. pp. 107-115. In: Soorae, P.S. (ed.). Global Re-introduction Perspectives: 2013. Further case studies from around the globe. Gland, Switzerland IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Bartel, R.A. and J.O. Sexton. 2009. Monitoring habitat dynamics for rare and endangered species using satellite images and niche-based models. Ecography 32(5): 888-896

Beck, B.B., M.L. Castro, T.S. Stoinski, J. Ballou. 2002. The effects of pre-release environments on survivorship in reintroduced golden lion tamarins. pp. 283-300. In: Kleiman D.G and A. Rylands (eds.). The Lion Tamarins of Brazil: Twenty-five Years of Research and Conservation. Smithsonian Institution Press, Washington, D.C.

Beck, B.B., L.G. Rapaport, M.R. Stanley Price, and A.C. Wilson. 1994. Reintroduction of captive-born animals. pp. 265-286. In: Olney, P.J.S, G.M. Mac and A.T.C. Feistner (eds.). Creative Conservation: Interactive Management of Wild and Captive Animals. Chapman and Hall, London

Biggins, D.E., A. Vargas, J.L. Godbey, S.H. Anderson. 1999. Influence of prerelease experience on reintroduced black-footed ferrets (*Mustela nigripes*). Biological Conservation 89(2): 121-129

BirdLife International.2013 One in eight of all bird species is threatened with global extinction. Presented as part of the BirdLife State of the world's birds website. Available from: http://www.birdlife.org/datazone/sowb/casestudy/106. Accessed 9.May.2014

Black, S.H., M. Shepard, M.M. Allen. 2001. Endangered invertebrates: the case for greater attention to invertebrate conservation. Endangered Species Update 18(2): 42-50

Boyce, W.M., M.E. Weisenberger, M. C. T. Penedo, C.K. Johnson. 2011. Wildlife translocation: the conservation implications of pathogen exposure and genetic heterozygosity. BioMed Central Ecology 11: 5

Bremner-Harrison, S., P.A. Prodohl and R.W. Elwood. 2004. Behavioural trait assessment as a release criterion: boldness predicts early death in a reintroduction programme of captive-bred swift fox (*Vulpes velox*). Animal Conservation 7(3): 313-320

Butterfly Conservation Europe. http://www.bc-europe.eu/ Accessed 5.May.2014

Bubb, P. A. Chenery, P. Herkenrath, V. Kapos, A. Mapendembe, D. Stanwell-Smith, M. Walpole. 2011. National indicators, monitoring and reporting for the Strategic Plan for Biodiversity 2011-2020. UNEP-WCMC, Cambridge

Carpenter, J.W., R.R. Gabel and J.G. Goodwin, Jr. 1991. Captive breeding and reintroduction of the endangered masked bobwhite. Zoo Biology 10(6): 439-449

Castro, T.S., B.B. Beck, D.G. Kleiman, C. Ruiz-Miranda, and A.L. Rosenberger. 1998. Environmental enrichment in a reintroduction program for golden lion tamarins (*Leontopithecus rosalia*). pp. 97-128.In: D.J. Sheperdson, J.D. Mellen and M. Hutchins (eds.). Second Nature: Environmental enrichment for captive animals. Smithsonian Institute Press, Washington, D.C.

Cheyne, S.M. 2006. Wildlife reintroduction: considerations of habitat quality at the release site. BioMed Central Ecology 6: 5

Connolly, J.D. and A. Cree. 2008. Risks of a late start to captive management for conservation: phenotypic differences between wild and captive individuals of a viviparous endangered skink (*Oligosoma otagense*). Biological Conservation 141(5): 1283-1292

Conservation Breeding Specialist Group (CBSG). http://www.cbsg.org/document-repository. Accessed March 2014

Conservation Breeding Specialist Group (SSC/IUCN). 2001. Conservation Assessment and Management Plan for the Arabian Leopard and Arabian Ungulates with Population and Habitat Viability Assessments for the Arabian Leopard, Arabian Oryx, and Tahr Reports. CBSG, Apple Valley, MN. USA

Conservation Breeding Specialist Group (CBSG). 2010. Population and Habitat Viability Assessment (PHVA) Workshop Process Reference Packet. http://www.cbsg.org/sites/cbsg.org/files/PHVA_Reference_Packet_2010.pdf Accessed 21.Feb.2014

Convention on Biological Diversity. http://www.biologicaldiversity.org/species/invertebrates/. Accessed 3.May.2014

Convention on Biological Diversity (CBD) 2010. Decision X/2. The Strategic Plan for Biodiversity 2011-2020, including Aichi Biodiversity Targets. Nagoya, Japan 18-29.October.2010 https://www.cbd.int/sp/default.shtml Accessed 12.Feb.2014

Conroy, M.J., Y. Cohen, F.C. James, Y.G. Matsinos, B.A. Maurer. 1995. Parameter estimation, reliability, and model improvement for spatially explicit models of animal populations. Ecological Applications 5(1): 17-19

Cook, C.N., D.G. Morgan, and D.J. Marshall. 2010. Reevaluating suitable habitat for reintroductions: lessons learnt from the eastern barred bandicoot recovery program. Animal Conservation 13(2): 184-195

Czech, B., P.R. Krausman, and R. Borkhataria. 1998. Social construction, political power, and the allocation of benefits to endangered species. Conservation Biology 12(5): 1103-1112

Dodd, C.K. Jr.2010. Conservation and management. pp. 508-527. In: Dodd, C.K. Jr. Amphibian Ecology and Conservation. Oxford University Press, New York

Duellman, W. and L. Trueb. 1986. The Biology of Amphibians. McGraw-Hill Book Company, New York, New York, pp. 670

Earnhardt, J.M. 1999. Reintroduction programmes: genetic trade-offs for populations. Animal Conservation 2(2): 279-286

Elron, E. A. Gasith, M. Goren. 2006. Reproductive strategy of a small endemic cyprinid, the Yarqon bleak (*Acanthobrama telavivensis*), in a Mediterranean-type stream. Environmental Biology of Fishes 77(2): 141-155

English Nature. 1992. Natterjack Toad Species Action Plan. UK

Ewen, J.G., K. Acevedo-Whitehouse, M.R. Alley, C. Carraro, A.W. Sainsbury, K. Swinnerton and R. Woodroffe. 2012. Empirical consideration of parasites and health in reintroduction. pp. 290-335. In: Ewen, J.G., D.P. Armstrong, and K.A. Parker (eds.). Reintroduction Biology: Integrating Science and Management. Blackwell Publishing Ltd., Chichester, West Sussex, UK

Favé, M.J., P. Duchesne, and J. Turgeon. 2008. Inbreeding dynamics in reintroduced, age-structured populations of highly fecund species. Conservation Genetics 9(1): 39-48

Fischer, J. and D.B. Lindenmayer. 2000. An assessment of the published results of animal relocations. Biological Conservation 96(1): 1-11

Florida Fish and Wildlife Conservation Commission. 2003. Miami Blue Butterfly Management Plan *Cyclargus thomasi bethunebakeri*. Tallahassee, FL

Funk, W.C., D. Almeida-Reinoso, F. Nogales-Sornosa, and M.R. Bustamante. 2003. Monitoring population trends of *Eleutherodactylus* frogs. Journal of Herpetology 37(2): 245-246

Frankham, R., J.D. Ballou, and D.A. Briscoe. 2005a. Genetic management for reintroduction. pp. 448-470. In: Introduction to Conservation Genetics, Cambridge, United Kingdom

Frankham, R., J.D. Ballou, and D.A. Briscoe. 2005b. Genetic management of captive populations. pp. 420-447. In: Introduction to Conservation Genetics, Cambridge, United Kingdom

Gascon, C., Collins, J. P., Moore, R. D., Church, D. R., McKay, J. E. and Mendelson, J. R. III (eds). 2007. Amphibian Conservation Action Plan. IUCN/SSC Amphibian Specialist Group. Gland, Switzerland and Cambridge, UK. pp. 64

Germano, J.M. and P.J. Bishop. 2008. Suitability of Amphibians and Reptiles for Translocation. Conservation Biology 23(1): 7-15

Gillespie, G.R., M.P. Scroggie, J.D. Roberts, H.G. Cogger, M.J. Mahony, and K.R. McDonald. 2011. The influence of uncertainty on conservation assessments: Australian frogs as a case study. Biological Conservation 144(5): 1516-1525

Gleed-Owen, C., J. Buckley, J. Coneybeer, T. Gent, M. McCracken, N. Moulton, and D. Wright. 2005. Costed plans and options for herpetofauna surveillance and monitoring. English Nature Research Reports 663

Grenier, M.B., S.W. Buskirk, and R. Anderson-Sprecher. 2009. Population indices versus correlated density estimates of black-footed ferret abundance. Journal of Wildlife Management 73(5): 669-676

Griffith, B, J.M. Scott, J.W. Carpenter and C. Reed. 1989. Translocation as a Species Conservation Tool: Status and Strategy. Science 245(4917): 477-480

Griffiths, R.A. and L. Pavajeau. 2008. Captive breeding, reintroduction, and the conservation of amphibians. Conservation Biology 22(4): 852-861

Group on Earth Observations Biodiversity Observation Network (GEO BON). https://www.earthobservations.org/geobon_ebv.shtml Accessed 12.Feb.2014

Gusset, M.2009. A framework for evaluating reintroduction success in carnivores: lessons from African wild dogs. pp. 307-320. In: Hayward, M.W. and M.J. Somers (eds.).Reintroduction of Top-order Predators. Ltd.Blackwell Publishing, Oxford, UK

Gusset, M., S.J. Ryan, M. Hofmeyr, G. van Dyk, H.T. Davies-Mostert, J.A. Graf, C. Owen, M. Szykman, D.W. Macdonald, S.L. Monfort, D.E. Wildt, A.H. Maddock, M.G.L. Mills, R. Slotow, and M.J. Somers. 2008. Efforts going to the dogs? Evaluating attempts to re-introduce endangered wild dogs in South Africa. Journal of Applied Ecology 45(1): 100-108

Gusset, M., R. Slotow and M.J. Somers. 2006. Divided we fail: the importance of social integration for the re-introduction of endangered African wild dogs (*Lycaon pictus*). Journal of Zoology 270(3): 502-511

Gusset, M., G.B. Stewart, D.E. Bowler, and A.S. Pullin. 2010. Wild dog reintroductions in South Africa: a systematic review and cross-validation of an endangered species recovery programme. Journal for Nature Conservation 18(3): 230-234

Hardman, B. and D. Moro. 2006. Optimising reintroduction success by delayed dispersal: is the release protocol important for hare-wallabies? Biological Conservation 128 (3): 403-411

Hedrick, P.W. and T.J. Kim. 2000. Genetics of complex polymorphisms: parasites and maintenance of MHC variation. pp. 204-234. In: R.S. Singh and C.B. Krimbas (eds.). Evolution Genetics: from Molecules to Morphology. Cambridge University Press, Cambridge, UK

Heppell, S.S., L. B. Crowder, and D. T. Crouse 1996. Models to evaluate headstarting as a management tool for long-lived turtles. Ecological Applications 6 (2):556–565

Holmlund, C.M. and M. Hammer. 1999. Ecosystem services generated by fish populations. Ecological Economics 29(2): 253-268

Ingendahl, D. H. Klinger, F. Molls, and A. Nemitz. 2010. Re-introduction of Atlantic salmon to the River Rhine System: case study of the River Sieg, Germany. pp. 53-57. In: Soorae, P.S. (ed.). Global Re-introduction Perspectives: 2010. Additional case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

International Species Information System (ISIS). *ZIMS* . www.isis.org

IUCN/SSC .2013. Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0 . IUCN Species Survival Commission, Gland, Switzerland. p.34

IUCN. 2012. IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. pp. 32

IUCN.1998. Guidelines for Re-introductions. IUCN/SSC Re-introduction Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. pp. 10

IUCN Habitat Classification Scheme: http://www.iucnredlist.org/technical-documents/classification-schemes/habitats-classification-scheme-ver3. Accessed 11.March.2014

Janzen, F.J. and G.L. Paukstis. 1991. Environmental sex determination in reptiles: ecology, evolution and experimental design. Quarterly Review of Biology 66(2): 149-179

Joint Nature Conservation Committee.2004. Common Standards Monitoring Guidance for Reptiles and Amphibians. Great Britain. http://jncc.defra.gov.uk/pdf/csm_reptiles_amphibians1.pdf. Accessed 7.May.2014

Joint Nature Conservation Committee. 2007.Report on the Species and Habitat Review. UK Biodiversity Action Plan. http://jncc.defra.gov.uk/PDF/UKBAP_Species-HabitatsReview-2007.pdf

Joint Nature Conservation Committee. 2008. Common standards monitoring guidance for terrestrial and freshwater invertebrates. Great Britain. http://jncc.defra.gov.uk/pdf/CSM_terrestrial_freshwater_Inverts.pdf. Accessed 3.May.2014

Jule, K.R., L.A. Leaver, S.E.G. Lea. 2008. The effects of captive experience on reintroduction survival in carnivores: a review and analysis. Biological Conservation 141(2): 355-363

King, T., C. Chamberlan, A. Courage. 2012. Assessing initial reintroduction success in long-lived primates by quantifying survival, reproduction , and dispersal parameters: western lowland gorillas (*Gorilla gorilla gorilla*) in Congo and Gabon. International Journal of Primatology 33(1):134-149

Knight, A.J. 2008. "Bats, snakes and spiders, oh my!" How aesthetic and negativistic attitudes, and other concepts predict support for species protection. Journal of Environmental Psychology 28(1): 94-103

Lacy, R.C. 1994. Managing genetic diversity in captive populations of animals. pp. 63-89. In: Restoration of Endangered Species. Cambridge University Press, Great Britain

Lacy, R.C., M. Borbat, and J.P. Pollak. 2005. *VORTEX*: A Stochastic Simulation of the Extinction Process.Version 9.50. Brookfield, IL: Chicago Zoological Society

Lee, H., D. Garshelis, U. S. Seal, and J. Shillcox (editors). CBSG. 2001. Asiatic Black Bears PHVA: Final Report. The Conservation Breeding Specialist Group, Apple Valley, MN,USA

Ligon, J.D. 1999. The Evolution of Avian Breeding Systems. Oxford University Press. Oxford, UK

Lincoln Park Zoo. Avian Reintroduction and Translocation Database. Available at: http://www.lpzoo.org/ARTD. Accessed 10.May.2014

Lokki, M.L. and T. Laitinen. 2001. Role of major histocompatibility complex class III genes in recurrent spontaneous abortions. Frontiers in Bioscience 6: E23-E29

Longcore, J., A. Pessier, D. Nichols. 1999. *Batrachochytrium dendrobatidis* gen.et.sp.nov., a chytrid pathogenic to amphibians. Mycologia 91(2): 219-226

Lynch, C. 2008. How do your data grow? Nature 455(7209): 28-29

Jahdami, M.A., S.Al-Mahdhoury and H.A. Amri. 2011. The re-introduction of Arabian oryx to the Al Wusta Wildlife Reserve in Oman: 30 years on. pp 194-108. In: Soorae, P.S. (ed.).Global re-introduction perspectives 2011: more case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Maloney, R.F. and I.G. McLean. 1995. Historical and experimental learned predator recognition in free-living New Zealand robins. Animal Behaviour 50(5): 1193-1201

Marantelli, G., L. Berger, R. Speare, L. Keegan. 2004. Distribution of the amphibian chytrid *Batrachochytrium dendrobatidis* and keratin during tadpole development. Pacific Conservation Biology 10(3): 173-179

McComb, B., B. Zuckerberg, D. Vesely, C. Jordan. 2010. Data management. p. 179. In: Monitoring Animal Populations and Their Habitats. CRC Press. Boca Raton, FL

McFee, M.E. 2004. Generations in captivity increases behavioral variance: considerations for captive breeding and reintroduction programs. Biological Conservation 115(1): 71-77

Medici, E. P., L.Carrillo, O.L Montenegro, P.S. Miller, F. Carbonell, O. Chassot, E. Cruz-Aldán, M. García, N. Estrada-Andino, A.H. Shoemaker, A. Mendoza, (eds.) 2006. Baird's Tapir Conservation Workshop: Final Report. IUCN/SSC Tapir Specialist Group (TSG) & IUCN/SSC Conservation Breeding Specialist Group (CBSG), Apple Valley, MN, United States

Miller, P.S. and R.C. Lacy. 2003 Chapter 3: Integrating the human dimension into endangered species risk assessment. pp. 41-63. In: Westley, F.R. and P.S. Miller (eds.). Experiments in Consilience. Island Press, Washington, D.C.

Mills, L.S. and M.S. Lindberg. 2002. Sensitivity analysis to evaluate the consequences of conservation actions. pp. 338-366. In: Beissinger, S.R. and D.R. McCullough (eds.). Population Viability Analysis. University of Chicago Press, Chicago, IL

Mills, M.G.L., S. Ellis, R. Woodroffe, A. Maddock, P. Stander, G. Rasmussen, A. Pole, P. Fletcher, M. Bruford, D. Wildt, D. Macdonald, and U. Seal. 1998. Population and Habitat Viability Assessment for the African Wild Dog (*Lycaon pictus*) in Southern Africa. Final workshop report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN

Nair, H.P. and L.J. Young. 2006. Vasopressin and pair-bond formation: genes to brain to behavior. Physiology 21(2):146-152

Osbourne, P.E. and P.J. Seddon. 2012. Selecting suitable habitats for reintroductions: variation, change and the role of species distribution modelling. pp. 74-104. In:.Ewen, J.G, D.P. Armstrong, K.A.Parker, P.J. Seddon (eds.). Reintroduction Biology. Wiley-Blackwell Publishing, Chichester, West Sussex, UK

Palomares, F., A. Rodríguez, E. Revilla, J.V. López-Bao, and J. Calzada. 2011. Assessment of the conservation efforts to prevent extinction of the Siberian lynx. Conservation Biology 25(1): 4-8

Parker, K.A., M.J. Dickens, R.H. Clarke and T.G. Lovegrove. 2012. The theory and practice of catching, holding, moving and releasing animals. pp. 105-137. In: Ewen, J.G., D.P. Armstrong, K.A.Parker, P.J. Seddon (eds.), Reintroduction Biology. Wiley-Blackwell Publishing, Chichester, West Sussex, UK

Pellet, J., V. Helfer, and G. Yannic. 2007. Estimating population size in the European tree frog (*Hyla arborea*) using individual recognition and chorus counts. Amphibia-Reptilia 28(2): 287-294

Pereira, H.M., S. Ferrier, M. Walters, G.N. Geller, R.H.G. Jongman, R.J. Scholes, M.W. Bruford, N. Brummitt, S.H.M. Butchard, A.C. Cardoso. N.C. Coops, E. Dulloo, D.P. Fairh, J. Freyhof, R.D. Gregory, C. Heip, R. Höft, G. Hurtt, W. Jetz, D.S. Karp, M.A. McGeoch, D. Obura, Y. Onoda, N. Pettorelli, B. Reyers, R. Sayre, J.P.W. Scharlemann, S.N. Stuart, E. Turak, M. Walpole, M. Wegmann. 2013. Essential biodiversity variables. Science 339(6117): 277-278

Piper, R.G. 1986. Fish hatchery management. Dept. of the Interior, U.S. Fish and Wildlife Service

Pough, F.H. 1983. Amphibians and reptiles as low-energy systems. pp. 141-188. In: Asprey, W.P. and S.I. Lustick (eds.). Behavioral Energetics. Ohio State University Press, Columbus, Ohio

Pramuk, J. F. Koontz, M. Tirhi, S. Zeigler, K. Schwartz, and P. Miller (eds.) 2013. The Western Pond Turtle in Washington: A Population and Habitat Viability Assessment. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN. pp. 82

Princée, F.P.g. 1995. Overcoming the constraints of social structure and incomplete pedigree data through low-intensity genetic management. pp. 124-154. In: Ballou, J.D., M. Gilpin, and T.J. Foose (eds.), Population Management for Survival and Recovery. Analytical methods and strategies in small population conservation. Columbia University Press, New York

Pullin, A.S. and T.M. Knight. 2001. Effectiveness in conservation practice: Pointers from medicine and public health. Conservation Biology 15(1): 50-54

Pullin, A.S., T.M. Knight, D.A. Stone, K. Charman. 2004. Do conservation managers use scientific evidence to support their decision-making? Biological Conservation 119(2): 245-252

Ragyov, D., A. Dixon and K. Kowalczyk. 2010. Re-introduction of the saker falcon to Bulgaria, South-East Europe. pp. 143-150. In: Soorae, P.S. (ed.). Global Re-introduction Perspectives: additional case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Ralls, K., J.D. Ballou, and A. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. Conservation Biology 2(2): 185-193

Ralph, C.J. and S.G. Fancy. 1994. Demography and movements of the endangered akepa and Hawaii creeper. Wilson Bulletin 106(4): 615-628

Reading, R.P., B. Miller, D. Shepherdson. 2013. The value of enrichment to reintroduction success. Zoo Biology 32(3): 332-341

Robert, A. 2009. Captive breeding genetics and reintroduction success. Biological Conservation 142(12): 2915-2922

Royle, J.A. and J.D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84(3): 777-790

Schmidt, B.R. and J.Pellet. 2010. Quantifying abundance: counts, detection probabilities, and estimates. pp. 466-479. In: Dodd, C.K. Jr. Amphibian Ecology and Conservation. Oxford University Press, New York

Secretariat of the Convention on Biological Diversity .2010. Global Biodiversity Outlook *3*. Montréal, pp. 94

Seddon, P.J. 1999. Persistence without intervention: assessing success in wildlife reintroductions. Trends in Evolution and Ecology 14(12): 503

Seddon, P.J. and T.J. Cade. 1999. RT06: Bird-re-introductions, pre-release preparations, releases and post-release monitoring: Improving the rigour of re-introduction project assessment, planning and execution. In: Adams, N.J. and R.H. Slotow (eds.) Proc. 22 International Ornithology Congress, Durban: 3174-3176. Johannesburg: BirdLife South Africa

Seddon, P.J., P.S. Soorae, and F. Launay. 2005. Taxonomic bias in reintroduction projects. Animal Conservation 8(1): 51-58

Seddon, P.J., D.P. Armstrong, R.F. Maloney. 2007. Developing the science of reintroduction biology. Conservation Biology 21(2): 303-312

Seddon, P.J., W.M. Strauss, and J. Innes.2012. Animal translocations: what are they and why do we do them? pp. 1-32. In: Ewen, J.G., D.P. Armstrong, K.A.Parker, P.J. Seddon (eds.), Reintroduction Biology, Wiley-Blackwell Publishing, Chichester, West Sussex, UK

Setchell, J. M. and E. Huchard. 2010. The hidden benefits of sex: evidence for MHC-associated mate choice in primate societies. Bioessays 32(11): 940-948

Shackleton, D.M. (ed.) and the IUCN/SSC Caprinae Specialist Group. 1997. Wild Sheep and Goats and their Relatives. Status Survey and Conservation Action Plan for Caprinae. IUCN, Gland, Switzerland and Cambridge, UK. pp. 390 + vii

Shaffer, M.L. 1981. Minimum population sizes for species conservation. BioScience 31(2): 131-134

Sinn, D.L., L. Cawthen, S.M. Jones, C. Pukk, and M.E. Jones. 2014. Boldness towards novelty and translocation success in captive-raised, orphaned Tasmanian devils. Zoo Biology 33(1): 36-48

Slotow, R. and G. van Dyk. 2001. Role of delinquent young “orphan” male elephants in high mortality of white rhinoceros in Pilanesberg National Park, South Africa. Koedoe 44(1): 85-94

Smith, R.K. and W.J. Sutherland, W.J. 2014. Amphibian Conservation: Global Evidence For The Effects Of Interventions. Vol. 4. Pelagic Publishing Ltd., Exeter, UK

Somers, M.J. and M. Gusset. 2009. The role of social behaviour in carnivore reintroductions. Pp. 270-281. In: Hayward, M.W. and M.J. Somers (eds.). Reintroduction of Top-Order Predators. Blackwell Publishing, Oxford, UK

Somma, L.A. 2004. Parental behavior in Lepidosaurian and Testudinian reptiles. Quarterly Review of Biology 79(1): 86

Soorae, P.S. (ed.). 2008. Global Re-Introduction Perspectives: re-introduction case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE. pp. 220

Soorae, P.S. (ed.). 2010. Global Re-Introduction Perspectives: additional case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE. pp. 352

Soorae, P.S. (ed.). 2011. Global Re-Introduction Perspectives: more case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE. pp. 250

State of Alaska. Fish Monitoring Program. http://dec.alaska.gov/eh/vet/fish.htm Accessed 3.May.2014

Stoinski, T.S., B.B. Beck, M.A. Bloomsmith, T.L. Maple. 2003. A behavioral comparison of captive-born, reintroduced golden lion tamarins and their wild-born offspring. Behaviour 140(2): 137-160

Sutherland, W.J., D. Armstrong, S.H.M. Butchart, J.M. Earnhardt, J. Ewen, I. Jamieson, C.G. Jones, R.Lee, P. Newbery, J.D. Nichols, K.A. Parker, F.Sarrazin, P.J. Seddon, N. Shah, V. Tatayah. 2010. Standards for documenting and monitoring bird reintroduction projects. Conservation Letters 3: 229-235

Thorbjarnarson, J.B. and G. Hernández. 1993.Reproductive ecology of the Orinoco crocodile (*Crocodylus intermedius*) in Venezuela. II. Reproductive and social behavior. Journal of Herpetology 27(4): 371-379

Thoresson, G. 1996. Guidelines for coastal fish monitoring. National Board of Fisheries. Institute of Coastal Research.Öregrund, Sweden

Turner,C.R., C.C.Y.Xu, M.J. Cooper, D.M. Lodge, G.A. Lamberti. 2012. Evaluating environmental DNA detection alongside standard fish sampling in Great Lakes coastal wetland monitoring (Seed Project). Final Report. Illinois-Indiana Sea Grant. http://www.iisgcp.org/research/reports/Lodge2012_finalreport_eDNA.pdf

U.S. Fish and Wildlife Service. 2004. Draft Recovery Plan for the Coastal-Puget Sound Distinct Population Segment of Bull Trout (*Salvelinus confluentus*), Volume I. Puget Sound Management Unit. Region 1, Portland, Oregon

Van Swaay, C.A., P. Nowicki, J. Settele, A.J. van Strien. 2008 Butterfly monitoring in Europe: methods, applications and perspectives. Biodiversity Conservation 17(14): 3455-3469

Vandewege, M.W., T.M. Swannack, K.L. Greuter, D.J. Brown, M.R.J. Forstner. 2013. Breeding site fidelity and terrestrial movement of an endangered amphibian, the Houston toad (*Bufo houstonensis*). Herpetological Conservation and Biology 8(2): 435-446

Vredenburg, H. and F.R. Westley. 2003. Logic Models for Building Knowledge and Networks: Early Evaluations of the PHVA approach. pp. 83-102. In: Westley, F.R. and P.S. Miller (eds.).Experiments in Consilience. Island Press, Washington, D.C.

Vught, I. A.S. Harzevili, J. Auwerx, and D. De Charleroy. 2007. Aspects of reproduction and larviculture of burbot under hatchery conditions. American Fisheries Society Symposium XX, Bethesda, MD

Wake, D. B. and V. T. Vredenburg. 2008. Are we in the midst of the sixth mass extinction? A view from the world of amphibians. Proceedings of the National Academy of Sciences of the United States of America 105(Supplement 1): 11466–11473

Weber, M.L. 2002. From Abundance to Scarcity: History of U.S. Marine Fisheries Policy. Island Press, Washington, DC. pp. 245

Wesołowski, T. 2004. The origin of parental care in birds: a reassessment. Behavioral Ecology 15 (3): 520-523

Wiley, J.W., N.R.F. Snyder and R.S. Gnam. 1992. Reintroduction as a conservation strategy for parrots. pp. 165-200. In: S.R. Beissinger and N.F.R. Snyder (eds.). New World Parrots in Crisis. Smithsonian Institution Press, Washington, D.C.

Williams, S.E. and E.A. Hoffman. 2009. Minimizing genetic adaptation in captive breeding programs: a review. Biological Conservation 142(11): 2388-2400

Wolf, C.M., T. Garland, Jr., B. Griffith. 1998. Predictors of avian and mammalian translocation success: reanalysis with phylogenetically independent contrasts. Biological Conservation 86(2): 243-255

Woodroffe, R. and A. Vincent. 1994. Mother's little helpers: patterns of male care in mammals. Trends in Ecology and Evolution 9(8): 294-297

Zippel, K., R. Lacy, and O. Byers (eds.). 2006. CBSG/WAZA Amphibian *Ex Situ* Conservation Planning Workshop Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN 55124, USA

Zoological Information Management System-International Species Information System, Version 1.7 Updated 27.Jan.2014. Accessed January 2014

CHAPTER 3 DATA MANAGEMENT TOOLS FOR THREATENED SPECIES CONSERVATION PROGRAMS

Introduction

In working with threatened species, the conservation story for each species, population or ecosystem is dependent on collation and interpretation of data collected from all the components of a conservation program including the stages for planning, implementation, monitoring and finally assessment to drive adaptive management processes (see Figure 2.1). To facilitate a 'one plan approach', both the *ex situ* and *in situ* conservation communities should work together in incorporating all populations of a species when planning and implementing conservation action (Byers *et al.* 2013). Data management processes thus need to be integrated between *ex situ* and *in situ components* of the programs. The data will illustrate species life history, causes of population decline, conservation action planning, program implementation, monitoring for assessment and adaptive management. The data may be derived from research on biology and ecology of the species, methodologies for husbandry and health management under human care, methodologies for release and monitoring the populations in the wild. In order to integrate data management processes between *ex situ* and *in situ* components, it is important to understand the data management tools used to collect and analyze data that are needed for managing and assessing conservation programs (as identified in Chapter

2), and current issues in communication processes between the different components of the programs.

There are a number of different paradigms that connect *ex situ* and *in situ* programs for holistic threatened species conservation action. Data management requirements may differ depending on the objectives of each program, the taxon involved, the methodologies incorporated and the resources available to conduct the program. Research on natural life history parameters, habitat requirements, population status, and health of a species in the wild may be conducted through a collaboration of government wildlife officials, wildlife researchers and *ex situ* specialists as part of the assessment process (e.g. Virgin Island boa, Tolson *et al*. 2010). An 'insurance' captive population may be developed through an *ex situ* breeding management program with the intent on reintroduction for species that are rare or extinct in the wild (e.g., Kihansi spray toad, Lee *et al*. 2006). Similarly, a head-start program may be employed for increasing the survival rate of wild hatchlings that are returned to the wild after a certain developmental stage (e.g., Philippine crocodile, van Weerd 2009). Rescue, rehabilitation and release programs for wild animals may involve a wildlife sanctuary or zoological institution with the focus on returning animals to the wild or caring for them for the remainder of their lives if unreleasable (e.g., greater slow loris, Collins and Nekaris 2008). For all of these programs, the collective data from all the stakeholders will contribute to assessment and management.

Each conservation program has unique challenges for data collection and management depending on the species, habitat, ease of monitoring, and support. Factors such as efficacy of program management, extent of collaboration with supporting partners, and involvement by governing authorities that can implement policies for change will affect the outcomes and point toward the need for data sharing to facilitate effective communication between stakeholders.

Data to determine required parameter values for assessment at each level of a conservation program must be identified *a priori* so that data collection is directed towards providing an evidence-based strategy for conservation action (Pullin and Knight 2001). Precise and accurate data collection is important and in addition, must be available for retrieval for assessment in reaching program objectives. In designing a data management system, it is important to consider what the output needs to be in order to establish the required input (Earnhardt *et al*. 1998). Frequently, the majority of costs for the monitoring component of a program are budgeted for data collection with little attention to costs associated with database development, data entry, data validation, analysis and reporting (Caughlin and Oakly 2001). Thus, a data management plan that identifies data to be collected as well as data management tools should be developed in tandem with the conservation action plan in the design phase of the program.

Data management tools to capture information and facilitate analysis range from paper files to individual institution network databases to international web-based databases. For species that have a listed IUCN Red List status, the IUCN Red List Unit maintains assessments containing species population data in the online IUCN Species Information Service database (IUCN SIS 2014). For well-studied species, background life history information is freely accessible on online global databases such as The

Encyclopedia of Life (EOL) and The Animal Diversity Web (ADW). There are taxon-specific databases such as The Reptile Database (RD), FishBase (FB), and BirdLife International (BLI) and general animal databases that focus on threatened species such as ARKive (ARKive), Amphibiaweb (AW), and Evolutionarily Distinct & Globally Endangered (EDGE). The Global Biodiversity Information Facility (GBIF) is a global biodiversity database that makes primary scientific biodiversity data at the specimen and species level freely accessible and provides global coordination of digitization and networking projects within biodiversity informatics (Lane and Edwards 2007). Finally, the Living Planet Database (LPD) contains information on population trends for vertebrate species around the world and used as the basis for The Living Planet Index (LPI) (Collen *et al*. 2013).

There are a number of national and international biodiversity databases that compile census data on species abundance using survey counts through visual or auditory observations (Dickinson *et al*. 2010). The European Network for Biodiversity collects sets of biodiversity distribution data for native and invasive species within various projects including the National Biodiversity Network (UK), the European Register of Marine Species, Fauna Europaea, and Species-2000 Europe (Los and Hof 2007). In the US, the United States Geological Survey (USGS) hosts the North American Amphibian Monitoring Program and the North American Breeding Bird Survey (BBS) (Sauer *et al.* 2003). All of these online resources are available for background life history information and have the potential for linking with each other and with the ISIS database to facilitate data management processes for conservation programs.

Animal records databases are at the base of all data management processes for *ex situ* populations. Individual specimen records will document an animal's life history with values such as pedigree, growth and development, health, reproductive status and experience, and social behavior that may impact management of the population as a whole. Unless it is difficult to identify individuals, such as for groups of small-bodied species including small invertebrates, fish, or amphibians, animals should be individually identified in order to maintain the most comprehensive data (Earnhardt *et al.* 1998). Group records will only offer data on census numbers, sex ratios (for sexually dimorphic species), births and deaths, and treatments for the whole group (feeding, medical, environmental measures). Individual records afford the opportunity for optimizing individual animal health and development, breeding management, compilation of medical and behavior data to establish husbandry methodologies, and collaboration between local, regional and international institutions.

The International Species Information System (ISIS) is the most widely used global data management system for *ex situ* populations (see Chapter 1, pgs. 34-39). Prior to the deployment of the *Zoological Information Management System* (*ZIMS*), ISIS'*ARKS* (*Animal Records Keeping System*) software was used for core animal records (used internationally) and *MedARKS* (*Medical Records Keeping System*) was used for medical records (mainly in English speaking countries). Institutional animal records were then used to compile single species studbooks or registries using *SPARKS* or alternatively for some species in North American institutions, *PopLink.* With *ZIMS* as a global web-based information system encompassing both core animal and medical records, the real strength of ISIS is the capacity for sharing standardized information. Zoological institutions may contain species endemic to the local region, but many hold species from all over the world. ISIS offers a window into global species *ex situ* management that is critical for institutional, regional and global animal management collaboration and conservation. ISIS has received endorsements from over 20 regional zoological associations around the world for its collaborative nature in sharing animal information (ISIS website) and is used by the majority of institutions in AZA while EAZA member institutions are required to maintain membership in ISIS (EAZA 2013). ISIS is the main information system used in India (Bishan Bonal, personal communication) and for large institutions in the Australasia region (Gert Skipper, personal communication). Some institutions such as wildlife sanctuaries, breeding centers, and rescue and rehabilitation centers may have their own data management systems with the use of *Excel* spreadsheets, *Access* databases, hand-written tables kept on white boards or paper records and files. Collaborative conservation programs often times consist of such institutions working with zoological institutions which require data sharing.

Monitoring of animals translocated or released to the wild is an important component of conservation translocation programs in order to provide data for assessment of the program and apply adaptive management (Nichols and Armstrong 2012). At the population level, surveys using various visual or auditory techniques will result in census counts, yet these methods may only yield an estimate for actual abundance with varying precision (McGrego and Peake 1998). As for *ex situ* populations, individual identification will facilitate collection of more comprehensive data that will document individual life histories to inform management decisions. Detailed life histories of individual animals are needed to decrease the uncertainty in predictive models that are important for conservation action. Analysis of Global Re-introduction Perspectives case studies (see Chapter 2) showed that over 50% of the fish and amphibian programs and 79-89% of the reptile, bird, and mammal programs incorporated individual identification of released animals to facilitate capture of monitoring data (Table 3.1). Only one invertebrate program used individual identification possibly due to the difficulty in marking individuals. These percentages include programs that were managed with dates ranging from 1960 to 2011, so the percentage of programs incorporating individual identification may be higher as technology for marking and tracking individuals improved.

Table 3.1. Percent of translocation programs using individual identification for monitoring (Soorae 2008, 2010 and 2011).

Animal Group	Programs using Individual ID	Total number of programs
Invertebrates	7%	16
Fish	54%	24
Amphibians	53%	13
Reptiles	79%	23
Birds	89%	35
Mammals	74%	42

There should be a specimen record with an identifying number for each individual animal that includes all background information and occurrences of events for that individual. There are a number of methods for identifying individuals. Physical identifiers may be artificial (tags, bands, Passive Integrated Transponder{PIT}tags, tattoos, notchings, artificial coloring markings) or natural (stripe or spot patterns, scars, physical features, deformities, clippings). There are a number of programs that use algorithms to analyze coat patterns of animals with stripes or patches and identify individuals by comparing baseline photographs to new images for an unknown animal (Stripe-Spotter, Lahiri *et al*. 2011; Automate Visual Recognition for African penguins, Burghardt *et al*. 2004; Interactive Individual Identification System, Van Tienhoven *et al*. 2007). There are non-invasive methods such as genetic analysis of feces, feathers or hair samples that can be used for individual identification as well as for identifying sex, genealogy, and genotype (Rudnick *et al*. 2005; Dutta *et al*. 2012). Individuals can be identified by their footprints using WildTrack Footprint Identification Technology (FIT) (Law *et al*. 2013) or by acoustic signals such as ultrasonic echolocations calls in bats using AnaBat™ Detection System (AnaBat™) (Betts 1998). A specimen record for each individual should include the description of the identifier as well as the location on the body for physical identifiers (e.g., for a band - Red 1234, R Leg) and the date it was applied. If visual or auditory recognition software is used, the software should be identified in the specimen record.

Although monitoring individuals results in the capture of specific information, it may not be possible to identify individuals for smaller bodied species. Thus, records may be kept on groups rather than individuals. Whereas the majority of reptile, bird, and mammal programs used individual identification for monitoring, all but one invertebrate program and about half of the fish and amphibian programs monitored the population as a group (Table 3.1). A census count can include population numbers as well as identify sex ratios and number of individuals at each life stage. For species that spend a part of their life in *ex situ* facilities, a cohort may be marked prior to release such that an individual can be identified as part of that group when encountered in the wild. This is useful since unmarked individuals will be considered wild born or hatched, representing successful reproduction or immigration into the area. Tracking life stages will give an indication of the age distribution in the population.

Monitoring released individuals as well as the overall population can be accomplished through a variety of monitoring techniques. Only 14% of the species from case studies in the RSG Global Re-introduction Perspectives were monitored using a single monitoring method (see Chapter 2). In order to assess survival, reproduction and population sustainability as measures of program success, a number of monitoring methods were used in tandem to obtain parameter values.

To evaluate short-term reintroduction success, a mark and recapture method could be used to estimate survival of released animals and their offspring as well as estimate population size (Gusset 2009). The captures offer other data gathering opportunities such as for health parameters (body condition, weight, evidence of disease or injury), sample collection (blood, swabs for bacteria analysis, tissue or hair for genetic analysis), and morphometric measurements. Data for all of these measures provide valuable information if the individuals are identified such that data from each capture will add to an individual specimen record. For species where individuals are hard to identify, data collected on individual captures can be pooled and are still useful.

Camera trap methods can be used to monitor animals that are difficult to observe due to nocturnal behavior, cryptic coloring or present in inaccessible rough terrain (Balme 2009). Cameras will document a time and date stamp for each photograph, and some may record moon phase and temperature (Meek *et al.* 2012). Both photo and video camera traps are useful to determine abundance and density in a particular area through capture/recapture analysis, as well as offer additional information on behavior, health, social groupings and parentage, if the animals are individually identified (Silver *et al*. 2004). Data management for camera trap photos entails storing collected photos and videos in a system that facilitates data recovery for analysis. In addition to the images, data about the project and specific site attributes (GPS coordinates, habitat), camera type, and weather conditions (temperature, relative humidity, etc.) should be recorded. Many researchers use a simple folder system to store the images, yet for most studies, large numbers of images are collected requiring an appropriate database system that can handle the large volume. The most common method for storing images and accompanying data is with the use of a Microsoft *Excel* or *Access* database that is developed with specifications to the particular research. There are a few camera trap database systems developed for use by conservation organizations such as the TEAM Network (Tropical Ecology Assessment and Monitoring Network) which uses an internal database called *DeskTeam* (TEAM Network 2011) or *Camera Base*, a free downloadable software program that uses Microsoft *Access* to manage multiple surveys of photos, batch import data from digital cameras and link photos to the data for analysis (Tobler 2012).

Radio-telemetry provides a method for monitoring movements of individuals within the landscape to generate information on land use and home range sizes, as well as survival and interaction with other conspecifics (for animals located in the same area). Thus, the data includes the GPS location (latitude and longitude) and compass direction at the site where the bearing was taken. For each reading, the date, time of day, and weather are important to record since these parameters may affect the behavior of the animals being monitored (Kenward 2001). A VHF system, transmitters that emit a series of beeps that are detected by receiving antennae, requires that the researcher to be present to take the readings. For GPS tracking, a receiver rather than a transmitter is placed on the animal and picks up signals from special satellites. A computer within the receiver then calculates the location and movement of the animal. The data are expressed as GPS coordinates and either downloaded once the GPS receiver is retrieved or sent to a second set of satellites. The benefit of a GPS system is that the researcher does not have to be in the field since the locations are stored over a period of time within the system.

Law enforcement is a critical component for successful management of protected areas and species (Bruner *et al*. 2001; Byers *et al*. 2007). In order to enforce protection of the biodiversity within protected areas, law enforcement officials monitor location of the species within the area as well as perform routine surveillance to collect data on illegal activities (Stokes 2010). Historically, collected monitoring data were stored in spreadsheets, databases or paper systems that made analysis difficult for enforcement planning or adaptive management. An integrated spatial *Management Information System* (*MIST*) was developed through collaboration between Deutsche Gesellschaft für

Technische Zusammenarbeit and the Uganda Wildlife Authority for use in law enforcement monitoring of threatened species in Uganda's protected areas (Schmitt and Sallee 2002). Patrol units can use *MIST* to document observed species or signs of species (number, sexes, age groups or footprints, nests) or individual animals, illegal activities (weapons/items seen, poached animals) and actions (arrests, confiscations of weapons/items and animals, warning letters or cautions administered) along with geo-referenced data to document location (Mannion 2004). In March 2013, an additional software program, *Spatial Monitoring and Report Tool* (*SMART*) was developed to integrate with *MIST* and add additional functionality for law enforcement monitoring (*SMART*).

A combination of monitoring methods such as radio-tracking, use of camera traps and capture-recapture methods will increase the accuracy of the data collected (Soisalo 2006). A link to individual animal data documenting origin, identifiers, life history attributes, health and reproductive histories should be available to apply to the results of analyses for a complete picture of the status of the population.

The objective of this project was to identify methodology and tools that are currently in use for data collection on animals released to the wild or in wild population management programs. These tools are used to capture data at each level of the conservation translocation cycle and might include database programs (e.g., *Excel*, *Access*), population management programs (such as those used for animals in captivity), medical record programs (such as *MedARKS*), GIS or radio-tracking programs, logbooks, images (such as photographs, videos and diagnostic images) and law enforcement programs. It is important to know about the tools currently in use in order to gain an understanding of the requirements for data management and to ensure that a newly developed integrated system will have the capacity to either encompass the range of data collection needs or to be able to work in conjunction with auxiliary programs that will cover the needs. The data needs are defined as data that reflect the parameters that are needed for management and assessment of the programs (see Table 2.3). In learning about the current tools, it will be possible to reaffirm that the parameters important for assessment are being considered for monitoring animals in the wild. This information will be useful in determining the scope of functionality needed for *ZIMS* to adequately handle the data required for integrating captive and wild population management for threatened species or to link with auxiliary databases that are specific to certain components of a conservation program.

Methods

Current data collection and data management tools used for management of threatened species were identified for different program categories. Five categories of threatened species are defined below, with species examples identified in each category. The programs selected are representative of invertebrate, amphibian, reptile, bird, and mammal species in five regions of the world. Each category is an example of a species that in some way is impacted by the integration of *in situ* and *ex situ* research or management programs.

The five categories with the species surveyed are:

A. Endangered species whose wild population became dangerously low and captive breeding or head-start program was implemented for purposes of release for reintroduction.

American burying beetle (*Nicrophorus americanus*)
Takahē (*Porphyrio hochstetteri*)
Western pond turtle (*Actinemys marmorata*)

B. Endangered species brought into captivity due to threat of extinction in the wild. At one time, listed as IUCN Extinct in the Wild. Reintroduction program well developed through captive breeding with managed release and established monitoring program for assessment.

Kākāpo (*Strigops habroptila*)
Kihansi spray toad (*Nectophrynoides asperginis*)
Red wolf (*Canis rufus*)

C. Endangered species that does not currently have a reintroduction program but future conservation efforts include such a program. Current *ex situ* programs contribute data to PHVA for the species and integrated plan is developed for overall conservation.

Lowland tapir (*Tapirus terrestris*)

D. Endangered species that has a rescue/rehabilitation/release program but no current reintroduction program of captive animals to the wild.

Cheetah (*Acinonyx jubatus*)

E. Endangered species with a research program for the wild populations but no current reintroductions from the captive population (if present).

Giant armadillo (*Priodontes maximus*)
Armenian viper (*Montivipera raddei*)

The categories of programs share overall data needs covering important parameters in the categories of life history, genetic diversity, population dynamics, resource availability, health, methodologies, and monitoring yet each has a specific focus requiring specialized data. Category A relies on a well-managed *ex situ* element including husbandry, health and breeding management components to ensure successful maintenance of small populations and reintroduction and monitoring methodologies are developed over time through research and adaptive management. The breeding management program may include an infusion of new founders from the wild such that meta-population management is utilized to maintain genetic diversity. For programs using head-starting methodologies, monitoring of wild individuals is important in order to collect newborns or hatchlings with documentation of location and if possible, identity of the parents. Category B requires an even more stringent breeding program as the *ex situ* population contained the last remaining individuals of the species for an interval of time and thus there were a limited number of population founders. All of the individuals in the the reintroduction program are thus are descended from the original founders. Category C includes programs where collaborative action planning occurs between *in situ* and *ex situ* components requiring exchange of information on life history, population dynamics, and resource use with the intent for facilitation of a reintroduction program for future conservation action. Category D involves rescue and rehabilitation of wild individuals for release (if possible), thus there are important health or rearing components for *ex situ* care as well as opportunity for collection of samples for other research before (biological, genetic) and after (ecological, population dynamics) release. Category E includes research on poorly-studied species in the wild where biological and ecological parameters are needed to inform conservation action. *Ex situ* partners offer support and benefit from information exchange for species (or similar species) maintained in their collections.

A survey was developed as a template to standardize the approach by the researcher in identifying monitoring systems and technology used for collection of data and management of each species in the wild (see Appendix VII). The survey outlines questions whose answers will elucidate the data collection tools for the different components along the conservation translocation cycle (feasibility assessment, design, implementation, monitoring, outcome assessment, adaptive management), covering the following topics:

1) Individual animal management – health, survivability, mortality, reproduction, *ex situ* husbandry methodologies
2) Population management (genetics, breeding management, population demographics, establishment of new population, integration into wild population or metapopulation management)
3) Monitoring of human interactions (negative or positive)
4) Overall biodiversity management (ecosystem integration**)**

Ex situ species coordinators and registrars were consulted to investigate data management practices for animals in zoological institutions. Data management processes for the *in situ* components of the programs were investigated either through directly working with researchers in the field or by contacting them through electronic communication. For each case study, the data management processes were evaluated for the efficiency for data analyses and integration between *ex situ* and *in situ* components. For each species, a process model illustrating data management flow between *in situ* and *ex situ* components was constructed that formally defined relationships among data elements that make up the data management system for the program. Important parameters covering the main categories of life history attributes, genetic diversity, habitat resources, health assessments, release and monitoring methodologies, and data management are incorporated into the models illustrating the integration required for management of the programs.

Results

For each case study, results include background life history and conservation status history at the conservation situation level, program recovery plan objectives at the design level, and data management processes for each subsequent level of the conservation translocation cycle (for overview of life history, status and data management processes for each case study, see Appendix VIII). All programs have both *in situ* and *ex situ* components in some manner but some may not include a conservation translocation or a period of time when animals are physically contained within a zoological institution.

For each case study, the programs are identified by program name, species taxonomy, IUCN status, IUCN World Region, country where the *in situ* component takes place, and geographic range.

Category A Case Studies

Endangered species whose wild population became dangerously low and captive breeding or head-start program was implemented for purposes of release for reintroduction**.**

Program: American Burying Beetle Reintroduction in Missouri

Species: American burying beetle (*Nicrophorus americanus*)

IUCN Red List Category: Critically Endangered

Figure 3.1. Photo credit: U.S. Fish and Wildlife Service

IUCN World Region: North America & Caribbean   Country: USA

Geographic Range: Nebraska, Rhode Island, Oklahoma and Arkansas, reintroduced population in Missouri

Conservation situation/feasibility/risk assessment

The American burying beetle is an unusual beetle species that exhibits a monogamous mating system and both parents exhibit parental care (Eggert and Sakaluk 1995; Amaral *et al*. 2005). Once abundant in eastern and central United States, the American burying beetle was placed on the U.S. Endangered Species list in 1989 when only two populations in Rhode Island and Oklahoma were known to exist (Amaral *et al*. 2005). Subsequent field surveys showed populations in Arkansas, Kansas, Nebraska, and South Dakota. Habitat loss and fragmentation due to land converted for agriculture led to its extinction in Missouri by the mid 1970s.

Design

The 1991 USFWS American Burying Beetle (*Nicrophorus americanus*) Recovery Plan had the overall objective to reduce the threat of extinction and to establish at least two additional self-sustaining populations of 500 or more beetles in the eastern and western portions of the historical range (Raithel 1991). Actions included protection for the extant populations, maintenance and propogation of a captive population, conducting reintroductions in the historical range and research on habitat requirements and causes of decline. The questions guiding the implementation of the program included the priority recommendations from The American Burying Beetle Population and Habitat Viability Assessment (Amaral *et al*. 2005) to develop research on life history, conduct field surveys to identify new extant populations and develop and implement health and genetic profiling methodologies.

Implementation and Monitoring

The American Burying Beetle Reintroduction Program managed by the Center for American Burying Beetle Conservation at the St. Louis Zoo is part of an AZA SSP® with four AZA institutions (Cincinnati Zoo, St. Louis Zoo, The Wilds and Roger Williams Park Zoo) and Ohio State University Insect Rearing Facility (OSUIRF). The American burying beetles are managed by the SSP® as two separate populations – the western population (Cincinnati, St. Louis, The Wilds and OSUIRF) and the eastern population (Roger Williams Park Zoo). The St. Louis Zoo received beetles from the wild in Arkansas in 2005 to begin the captive breeding program. In June of 2012, American burying beetles from St. Louis Zoo were introduced for the first time to various locations in the 4,040 acre Wah'Kon-Tah Prairie in southwest Missouri, an area jointly owned and managed by the Missouri Department of Conservation and The Nature Conservancy.

As an ISIS member institution, the St. Louis Zoo maintains general records on American burying beetles at the group level in ISIS, registering sex ratio, hatches, acquisitions (received from wild), deaths, dispositions (release to wild) and census counts. In addition, individual records are maintained using an in-house *Access* database system and each beetle is carefully identified and tracked for parentage, hatch and emergence dates, pairing and breeding success, enclosure transfers, weights, health status, and death or disposition dates (see Appendix IX; Figure 3.2). Thus, the pedigree of each beetle is known and breeding is managed such that pairings are with a partner that is no closer than a 2^{nd} cousin. Bob Merz, Director of the Center for American Burying Beetles, maintains a studbook on the AZA SSP® population, although it is mainly a compilation of census statuses at the different holding institutions. Of the three institutions with this species, St. Louis Zoo is the only one that individually identifies each beetle in order to maintain individual records in *Access* as well as the group records kept in the ISIS database. For the reintroduction program, beetles are selected for pairing based on pedigree and marked by notching the elytra (hard, modified forewings) so that they can be distinguished from wild beetles during monitoring. The beetles are taken in pairs to the release area and placed in holes in the ground with a bobwhite quail (*Colinus* virginianus) carcass. The holes are plugged and the area is covered with chicken wire to prevent predation. The sites are then monitored to check for larvae and eventually newly emerged adults. Survey methods include use of traps for mark and recapture studies to determine population densities. General survey records are maintained by the USFWS (Figure 3.2). The Center for American Burying Beetle Conservation continues to conduct research on genetics, reproductive behavior, and reintroduction methodologies that will assist in the conservation of the American burying beetle.

<u>Assessment</u>

In June 2012, 118 pairs of adult American burying beetles captive bred at the St. Louis Zoo were reintroduced to an area in the southern portion of Missouri. In late June, monitoring showed that more than 2/3 of the pairs were successful in producing larvae. In June 2013, 302 additional pairs were released and the release site was closely monitored for production of larvae and emergence of new adults. Successful captive breeding protocols with data management processes using a combination of individual and group records had been developed to produce individuals that were reintroduced to the wild. Integration of specimen records for the beetles while in captivity with monitoring records after release to the wild would answer questions on survival and breeding success as well as contribute to the evaluation of the overall conservation program.

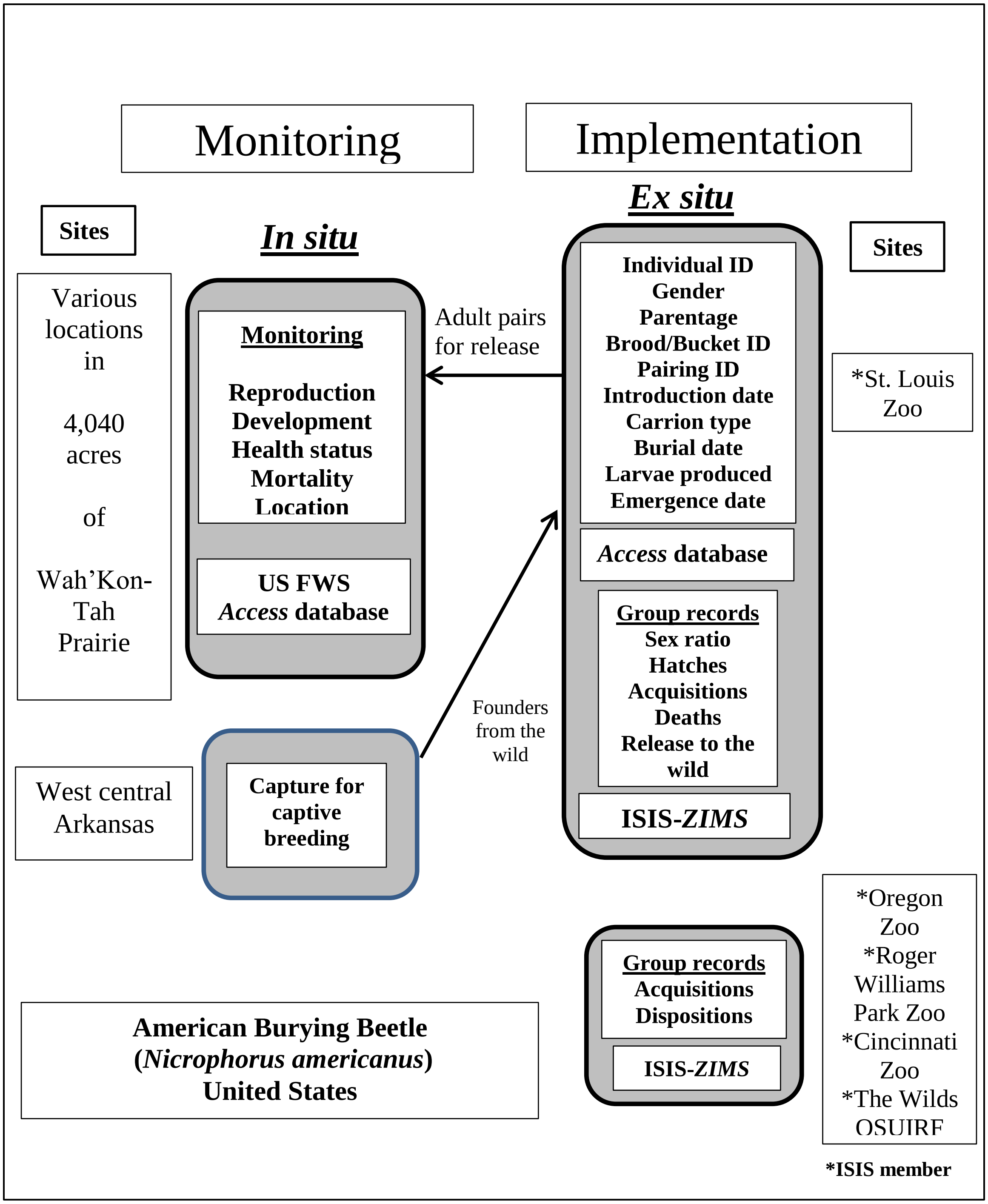


Figure 3.2 Database tools used for *in situ* and *ex situ* components of the American Burying Beetle Reintroduction Program. ISIS-*ZIMS* – International Species Information System – *Zoological Information Management System*. USFWS – U.S. Fish and Wildlife Service; OSUIRF – Ohio State University Insect Rearing Facility.

Program: Takahē Recovery Programme

Species: Takahē (*Porphyrio hochstetteri*)

IUCN Red List Category: Endangered

IUCN World Region: Oceania   Country: New Zealand

Geographic Range: Murchison Mountains of Fiordland on South Island, Kapiti, Mana, Tiritiri Matangi, Motutapu, and Maud Islands. Wildlife sanctuary at Maungatautari Ecological Island

Figure 3.3. Male takahē. Photo credit: Andrew Digby

`

Conservation situation/feasibility/risk assessment

The largest of the rail species, the flightless takahē was thought to be extinct from 1898 until 1948 when a small population was discovered in Fiordland National Park on South Island (Wickes *et al*. 2009). About 250 birds were found in the valleys of the Murchison Mountains in the park and soon after discovery, the area was set aside for their protection as the Takahē Special Area. By 1981, the population declined to a low of 112 birds in spite of a large effort to study the ecological requirements, breeding biology and population dynamics of this species. The main cause of population decline was competition for food resources with introduced red deer (*Cervu elaphus*) and predation by introduced stoats (*Mustela erminea*).

Design

Takahē (*Porphyrio hochstetteri*) Security Aim by 2020 (Andrew Digby, personal communication): The threat classification for takahë improved from Critically Endangered to Nationally Endangered.

Security Goals by 2020:

1) 25 breeding-aged pairs at appropriately managed secure sites

2) At least 2 large and managed recovery sites with capacity for at least 30 breeding pairs in each, one of which is the Murchison Mountains

3) The value of takahēas as taonga (a treasure in the Māori culture) and a conservation icon is recognised and their story is widely known and understood.

The action plan includes augmenting the population through *ex situ* rearing and meta-population management through transfer of individuals with known parentage to the appropriate island. There is action to remove herbivore competitors (red deer, *Cervus elaphus*) and invasive predators (stoats, *Mustela ermine*) to ensure survival of takahē populations.

Implementation and monitoring

The Takahē Recovery Programme is under the authority of the Department of Conservation (DOC), New Zealand, which administers the wildlife centers, rearing facilities, sanctuaries and reserves. Collaborating institutions include the Auckland Zoo and Wildbase, Institute of Veterinary, Animal and Biological Sciences, Massey University. Burwood Captive Rearing Unit was built as a captive rearing facility in Te Anau, Fiordland, in 1985 to provide birds for conservation translocations to the nearby Bush Scientific Reserve and eventually to establish takahē populations on predator-free islands.

Initially, eggs were collected from nests in the wild for incubation and rearing at Burwood, which still maintains a small breeding group. Currently, chicks are collected in the wild and reared at Burwood by conspecific foster parents. Burwood also has a significant number of breeding pairs that are intensively managed to maximize productivity and representation of rare alleles (Glen Greaves, personal communication). From this source, new populations have been established on six islands and in two mainland sanctuaries. As of May 2014, the estimated population size was about 70 birds in the Core Census Area of the Murchison Mountains, 83 on five islands and in the Maungatautari sanctuary, 72 at the Burwood Captive Rearing Unit facility, and 15 display birds at Pukaha Mount Bruce National Wildlife Centre and Te Anau Wildlife Centre.

The Takahē Recovery Programme requires complete integration of *in situ* and *ex situ* populations, previously with eggs collected, and currently with chicks collected from the wild, reared, and returned to the wild where they are intensively monitored. The methodologies used at each component of the programs are recorded, dictating the data for capture, keeping in mind the *a priori* questions that guide the assessment process (Figure 3.4). Research on factors that impact takahē populations include effective husbandry and rearing practices, comparing survival and lifetime productivity of captive-reared versus wild-reared individuals, assessing environmental variables (climate, weather, seed resource availability, habitat restoration) on reproduction, assessing age-specific survival rates, investigation of inbreeding on population productivity, and causes of infertility, embryo death and low chick survival.

Due to the small population size and the distribution on six New Zealand islands, there is intensive meta-population management requiring individual specimen records with accurate parentage records maintained within a studbook using the ISIS program

SPARKS. The records on each individual bird while at a facility or when monitored in the wild are shared with the population managers as health status, reproductive experience and success, and behavior are important considerations for the decisions to transfer birds between sub-populations. The studbook is in the final stages of development by Auckland Zoo staff and studbook data will be used for analysis in a combination of *PMx* (population breeding management program) and *Vortex* (extinction risk program) analysis for developing a meta-population management plan (Caroline Lees, personal communication).

Data management may differ between *in situ* and *ex situ* components of the overall program in terms of databases or information management systems used, yet effective communication is essential (Figure 3.5). The DOC maintains an *Access* relational database that contains the origin and parentage of each individual takahē, individual identifiers, the site where the birds are located (both *in situ* and *ex situ*), limited health records, measurements, monitoring data (nest, bird and egg/chick observations), transmitter information, sample collection and results, mortality, and limited *ex situ* data such as training received prior to release and vaccinations (see Appendix X). Records from birds at Mount Bruce National Wildlife Centre (an ISIS member although not yet using *ZIMS*) and the other two DOC *ex situ* facilities (Burwood Captive Rearing Unit and Te Anau Wildlife) are maintained in the DOC *Access* database that holds the basic information on the whole population.

The Auckland Zoo displays retired breeders or older birds and also contributes staff to perform health assessments on the wild birds. At times, an ill or injured bird will be taken to the Auckland Zoo or to Wildbase for care until recovery merits release back to the wild. Additionally, the veterinary staff at the Auckland Zoo performs necropsies of takahē from some of the northern islands or from *ex situ* facilities. The Auckland Zoo maintains records in ISIS for any takahē that comes into the zoo and also used

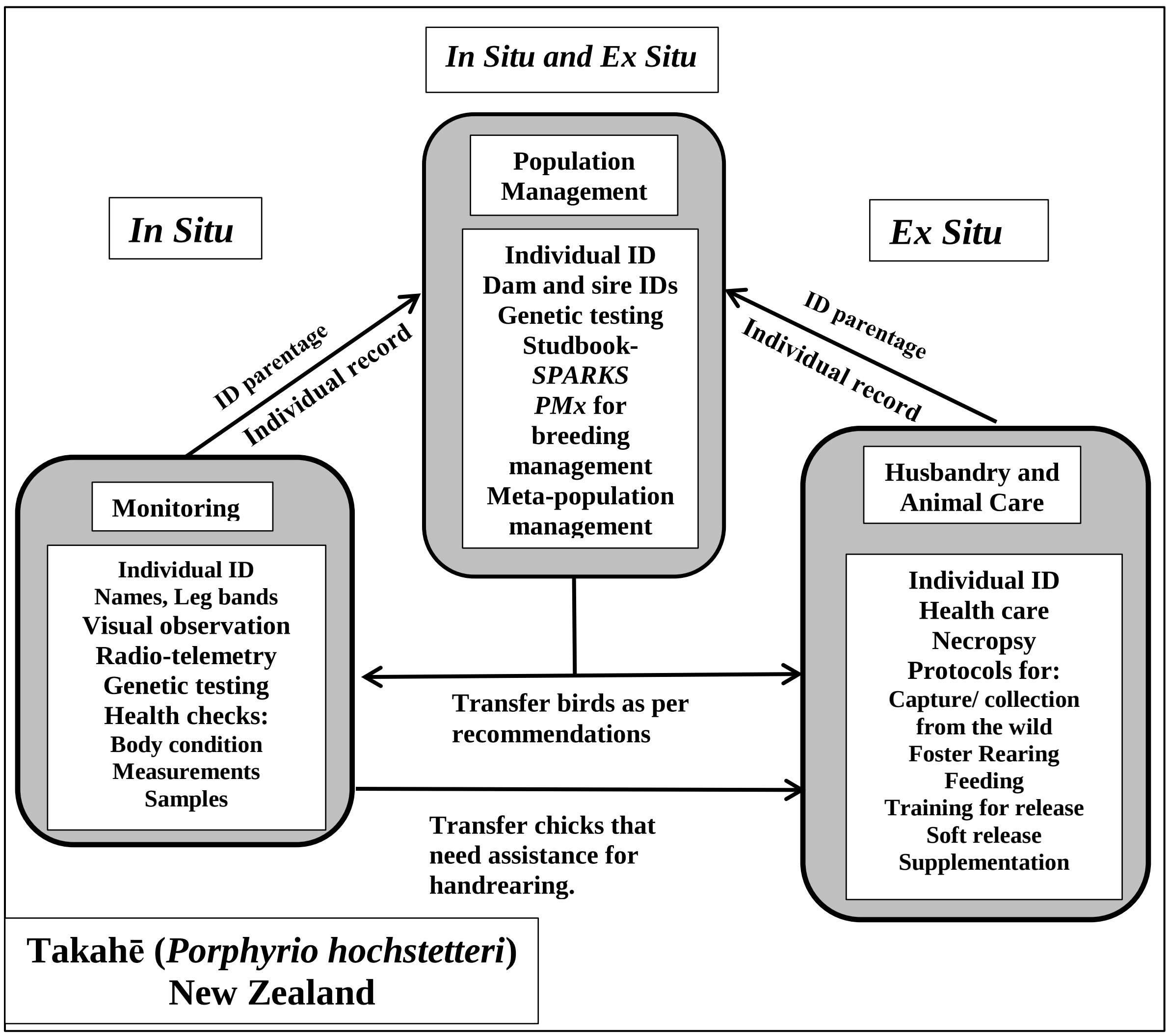


Figure 3.4. Methodologies used for overall management of the Takahē Recovery Programme.

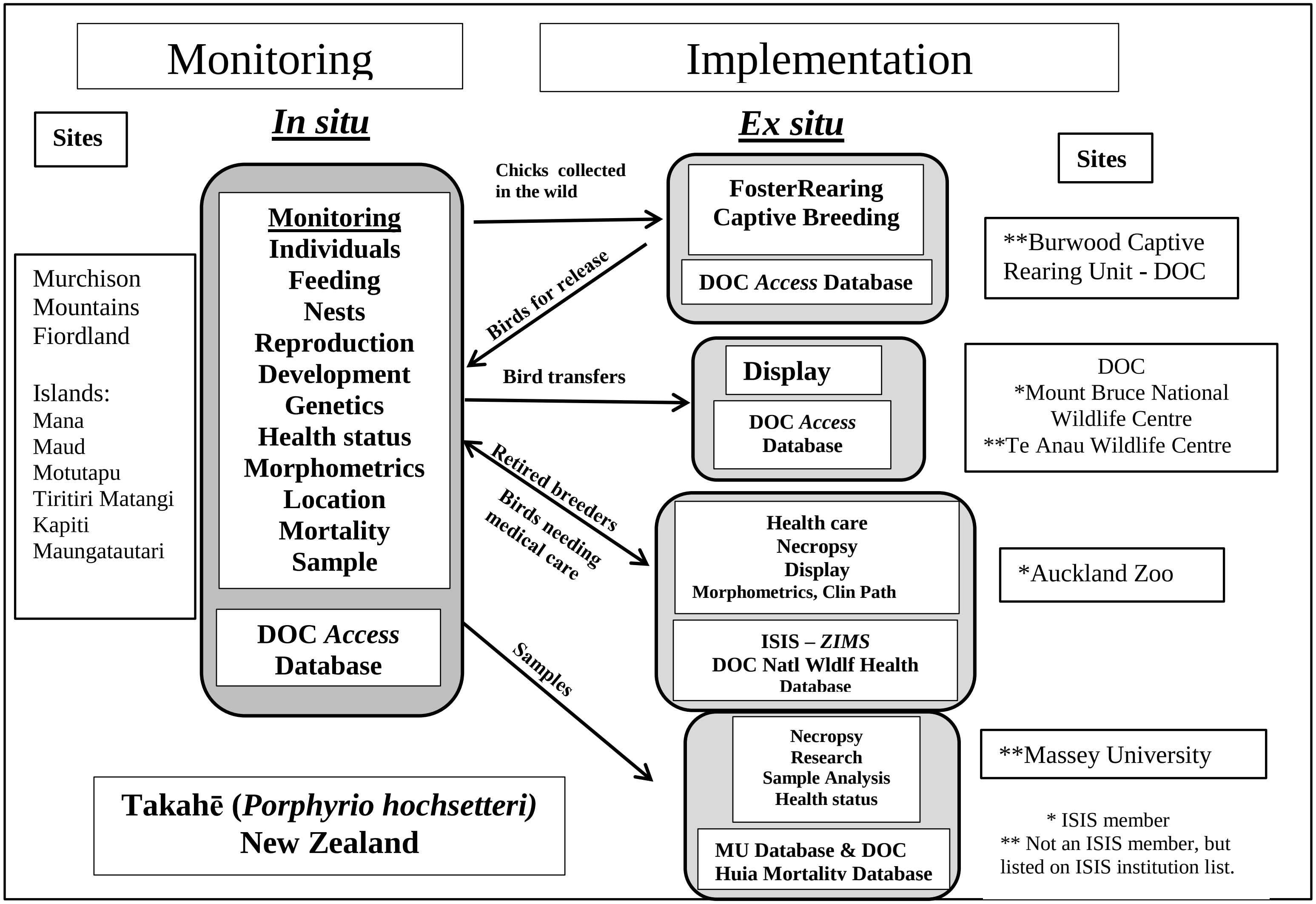


Figure 3.5. Database tools used for *in situ* and *ex situ* components of the Takahē Recovery Programme. For data fields for each component, see Appendix X.

MedARKS for medical and necropsy records prior to the recent deployment of *ZIMS for Medical*. For example, for a young male takahē captured on Tiritiri Island in April 2007, the ISIS Specimen Record shows his origin information (from Tiritiri Mantangi Scientific Reserve), parentage as wild, name (Poncho) and local ID (for Auckland Zoo) (Figure 3.6). While at Auckland Zoo, he was weighed 13 times (see weight graph on Specimen Report; Figure 3.6) and released back to the wild to Maud Island almost three months after capture. The full specimen record in ISIS will contain all core data (see Appendix II) collected on the bird while at Auckland Zoo.

For all health assessments, treatments and necropsies, the Auckland Zoo vets send detailed reports to the DOC, and the necropsy reports are also sent to Massey University, who maintains the Huia Mortality Database containing mortality data from all native endangered species. Wildbase, Massey University's wildlife animal hospital, also performs necropsies and treats injured or sick takahē. None of the DOC facilities are ISIS members, yet they are listed in the ISIS institution list along with Massey University which means that any bird coming from or going to those facilities through Auckland Zoo have a notation in their ISIS record that they were in those locations.

The Takahē Recovery Programme relies on intensive monitoring and management of the wild sub-populations in the Murchison Mountains and on the 6 predator-free islands where the bird have been reintroduced. Currently, chicks are collected from the wild and taken to the Burwood Rearing Unit for rearing by foster parents. Each collected chick has origin data on location and nest number as well as

Specimen Report

ISIS GAN: MIG12-30077868

Porphyrio hochstetteri — South Island takahe

Order: Gruiformes — **Family:** Rallidae

Start Date: Jan 01, 1800 — **End Date:** Jul 03, 2014

Basic Animal Information

Sex - Contraception:	Male -	**Status:**	Released to wild
Birthdate - Age:	~from Sep 15, 2005 to Mar 15, 2006 - 1Y,7M,5D +/-3M at the time of released to wild	**Preferred ID:**	
Origin:	Tiritiri Matangi Scientific Reserve	**Rearing:**	Parent
Birth Type:	Wild Born	**Hybrid Status:**	Not a hybrid
Sire:	WILD/TIRITIRI	**Dam:**	WILD/TIRITIRI
Current Collection:		**Collection Trip:**	
Clutch / Litter:		**Enclosure:**	

Physical Visit History:

Reported By	Date	Source / ID	Holder / ID	Term Type	Recipient / ID
AUCKLAND	Apr 26, 2007		AUCKLAND / A70059	Loan In From(Physical Only)	
AUCKLAND	Jul 20, 2007		AUCKLAND / A70059	Release to Wild(Physical Only)	Maud Island / NONE

Ownership Visit History:

Reported By	Date	Source / ID	Owner / ID	Term Type	Recipient / ID
AUCKLAND	Apr 26, 2007		AUCK CONS / NONE	Reported Owner	

Identifiers:

Reported By	Date	Type	Identifier	Location	Comments
AUCKLAND	Apr 26, 2007	House Name	Poncho		
AUCKLAND	Apr 26, 2007	Local ID	A70059		

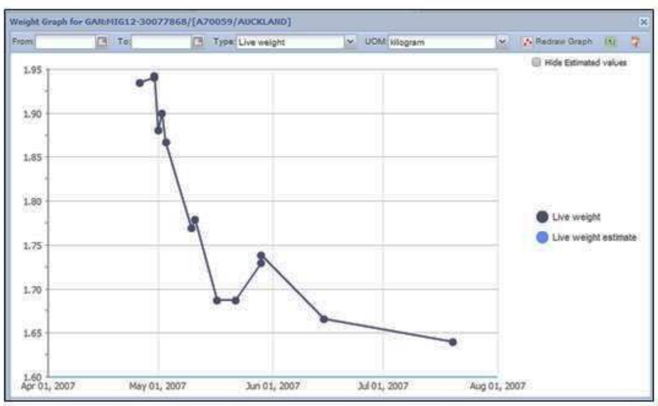
No Permits Found

Sex Information:

Reported By	Date	Sex	Comments
AUCKLAND	Apr 26, 2007	Male	

Parent Info:

In ZIMS	Parent Info	Type / Probability	Birth Date	Reported By
False	WILD/TIRITIRI	Dam/100%		AUCKLAND
False	WILD/TIRITIRI	Sire/100%		AUCKLAND



Printed: Jul 03, 2014 09:20 — International Species Information System — Page: 1 of 1

ISIS ZIMS version 2.0.4.2

Figure 3.6. ISIS Specimen Report for a young wild male takahē that was captured on Tiritiri Island, taken to Auckland Zoo on 26.April.2007, and returned to Maud Island on 20.July.2007. Courtesy of Richard Jakob-Hoff, Auckland Zoo.

parentage in order to track the pedigree for later breeding management. Each chick is individually identified with leg bands (Figure 3.7), named and entered in the studbook. Upon release, many of the birds are fitted with backpack radio-transmitter packages so that they can be tracked and monitored. The sub-populations are managed as a meta-population through manipulations of nests to collect eggs and transfers of birds to different islands to prevent inbreeding. Thus it is important to have information on each individual bird, location of origin, parentage, reproductive success, health status and survival.The monitoring data are maintained in the DOC *Access* database where the total population is listed (see Appendix X). Additionally, the sites are monitored for presence of introduced predatory species (stoats, *Mustela erminea*) as well as adequate habitat resources and thus habitat management is maintained for the conservation of the introduced birds. A separate group within the DOC retains a trapping database for stoat and rat numbers.

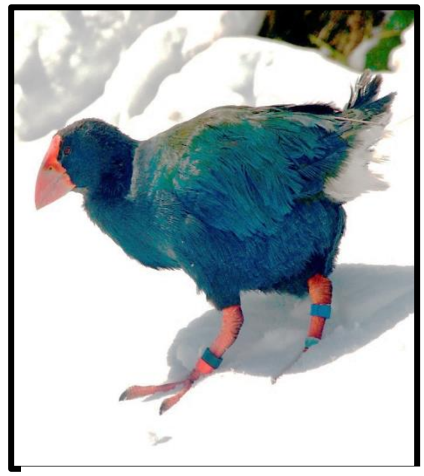


Figure 3.7. Takahē in the wild.
Photo credit: Sanjay Thakur-DOC

<u>Assessment</u>

The success of the Takahē Recovery Programme is dependent on close collaboration between partners and effective information exchange between *in situ* and *ex situ* components. Overall, the goal of increasing the population from 227 to 283 individuals as specified for the Recovery Plan period of 2007-2012 was not achieved, at least in terms of the number of individuals censused by May 2014 (240 birds). The population in the Murchison Mountains continues to decline (Andrew Digby, personal communication) although the number of paired birds that foster wild chicks at the Burwood Captive Rearing Unit has increased. A PHVA has been planned for the near future to address the decline in the population (Caroline Lees, personal communication). One issue noted in the Takahē Recovery Plan was that data collection and monitoring protocols were not standardized between islands (Wickes *et al*. 2009).

Genetic management is done through consideration of the entire meta-population since takahē had gone through a severe bottleneck and exhibit very low genetic variation (Grueber 2005). Adult survivorship is high on the islands but high percentage of egg infertility, embryo death and young chick mortality indicate the possibility of inbreeding depression. The takahē on the islands have lost 7.5% of the genetic diversity compared to the original founding population and without genetic management, will lose an estimated 76% in the next 100 years (Wickes *et al*.2009).Thus, accurate pedigrees are maintained for each individual, either by careful records-keeping for collected eggs, monitoring reproduction in the wild, or through genetic analysis. The pedigree record needs to follow each individual from identified egg (in the wild), to hatched chick (either in the wild or at Burwood), to adult bird (released to the wild or maintained in a facility), thus the records-keeping systems for both *in situ* and *ex situ* localities should be integrated either through close communications or direct linkage (use of the same database). The DOC *Access* database maintains core data for all of the birds in the population including parentage and the studbook is the overall registry for population management planning.

Records on health assessments, critical for all stages of the program, are maintained by veterinarians from the New Zealand Centre for Conservation Medicine (NZCCM) at Auckland Zoo and Wildbase, Institute of Veterinary, Animal and Biological Sciences at Massey University. Due to the transfer of eggs and birds between *in situ* and *ex situ* components, integration of data management processes for health and mortality records is necessary to share between the different facilities and sites. Currently, Auckland Zoo staff use ISIS *MedARKS* for health records for birds maintained at the Auckland Zoo and transfer health information via reports to the DOC and Massey University. The DOC *Access* database contains some basic health information and Massey University maintains their own database for health records, including diagnostic results from biological samples collected during health assessments of birds in the wild. There would be a great advantage to having a web-based platform that would enable efficient exchange of health information in real time between the different factions of the program (Richard Jakob-Hoff, personal communication).

Data management processes for the Takahē Recovery Programme are well-integrated with the DOC maintaining an overall database and pedigrees within a studbook. With the number of facilities and different sites involved, there are different information systems in place requiring exchange of information through reports and meetings. The *ex situ* facilities would benefit from maintaining their animal records within one system so that data management would be done in a standardized fashion and information exchange would be immediate. One health record within that same system for each bird while in an *ex situ* facility for rearing or display, or when released to an *in* *situ* site, would preclude the need for exchange of information via reports and offer real time information exchange. Efficiency in exchange of accurate information is paramount to keep everyone informed and to use for adaptive management in order to reach conservation goals.

Program: Western Pond Turtle Recovery Project

Species: Western pond turtle (*Actinemys marmorata*)

IUCN Red List Category: Vulnerable

IUCN World Region: North America and the Caribbean   Country: United States

Geographical Range: Mexico, United States

Figure 3.8. Western pond turtle.
Photo credit: Ryan Hawk, Woodland Park Zoo

<u>Conservation situation/feasibility/risk assessment</u>

The western pond turtle was once abundant in California, Oregon and Washington, but overexploitation for food and the pet trade in the 1890s and early 1900s decimated western pond turtle populations throughout their historical range (Hays *et al*. 1999). During the 1900s, wetlands were drained for development causing habitat degradation and loss for the turtles. Invasive bullfrogs effectively reduced the small western turtle populations through predation such that by 1980, the turtles were extinct in the Puget Sound area and extirpated through most of the remaining range in Washington. In 1991, Woodland Park Zoo (WPZ) began a head-starting program by collecting hatchlings from the wild, rearing them over the winter and releasing juveniles at 10 months of age. By 1999, only two populations totaling 250-350 individuals remained in the Columbia River Gorge, with about half of those from the head-starting program.

Design

The main goal of the Washington State Recovery Plan for the Western Pond Turtle was to re-establish self-sustaining populations of western pond turtle in the Puget Sound and Columbia Gorge regions (Hays *et al*. 1999). Actions included enhancing the populations through continuation of head-starting of wild hatchlings, monitoring survival and growth, continue captive breeding to reestablish a breeding population, controlling bullfrogs in protected nesting sites and conducting scientific studies on reintroduction methods, nutrition, optimal incubation and rearing protocols, genetic diversity, impact of predation, health assessments and habitat resources.

Implementation and Monitoring

The Western Pond Turtle Recovery Program was implemented by WPZ (and later joined by Oregon Zoo staff) who would survey the areas, trap and fit transmitters on the adult female turtles and then monitor them to find nests which would be covered with a wire exclosure to protect from predators and then left alone to allow for natural incubation. Temperature and humidity sensors in the nests document the nest conditions during incubation. When the hatchlings emerge, they are identified by nest location and clutch, taken to the zoo and cared for over the winter before returning them to their natal area the following summer. Each turtle is individually marked with a Bee dot (a small plastic bead marked with a number) affixed to carapace and implanted with a transponder prior to release. A number of turtles are fitted for radio-transmitters for specific studies on age-specific survival, habitat use, and reproduction (Vander Haegen 2009).

Figure 3.9. Release of a western pond turtle with a radio-transmitter for tracking. Photo credit: Ryan Hawk

WPZ and Oregon Zoo developed husbandry protocols for incubation, rearing, and feeding as well as standards for release sizes and weights. For incubation protocols, light cycles, water and ambient temperatures, and humidity were important variables to standardize. Hatchlings were weighed weekly and placed with others of equal size every few months to reduce feeding competition. They were handled daily to check for illness that might include shell lesions or deformity or noticeable weight loss, which is reported to the veterinarians. When the hatchlings have grown to a size such that bullfrogs can no longer eat them, they are released back to the wild. The turtles are monitored through visual surveys, captures and radio-telemetry (Figure 3.9).

Data from long term studies and monitoring of western pond turtles are maintained by Kate Slavens for the WDFW in an *Access* database that contains records from individuals dating back to the initial reintroductions (Figure 3.10). Many of the biological parameters used in the PHVA were obtained from the field data that was maintained in this database. The database contains collection location, hatch dates, identifiers (transponders, scute notches), weights, capture and release events, medical information, location, reproduction, and mortality information. Reports can be developed to compile information for a set of individuals or for a whole population. For visual surveys, the WDFW maintains maps that are hand-marked with the location and number of turtles observed at each site. This data are submitted for entry in the WDFW Wildlife Resource Data System, a centralized data system that documents the location of wildlife in Washington.

Data management for eggs and hatchlings while at WPZ and Oregon Zoo (both are ISIS members) involves use of in-house daily reports and *ZIMS* (Figure 3.10). WPZ and Oregon Zoo individually accession each turtle that comes into the zoo and include collection location (nest ID), identifiers (transponders, skute notches, Bee dots, nail polish color), weights, dates for capture and release events, animal management events (transfers to different enclosures, identity of individuals in groupings, feeding changes, etc.), medical notes and treatment, and behavior (activity, aggression, etc.). Accession numbers from ISIS become the official ID numbers for the turtles and are cross-referenced in the WDFW *Access* database to link the *in situ* and *ex situ* data on each individual turtle. However, turtles at only one of the two release areas (the Columbia River Gorge sites) are tracked in this manner.

<u>Assessment</u>

After implementing the recovery plan mainly through the head-starting program, the western pond turtle population in Washington rose to an estimated 1,000 to 1,500 individuals. Although this was deemed a successful effort, there were continued threats from predation by invasive bullfrogs, limited habitat and presence of disease that compromised the populations. Thus in 2012, CBSG facilitated a PHVA to evaluate the current status and identify management alternatives that would redirect efforts for improving the program (Pramuk *et al*. 2013). PHVA modeling showed that while improvement of hatchling survival through the head-starting program was important, adult survival was critical in order to save the species from extinction. Adult mortality would mean a loss of as many as 30 years of hatchling production in this long-lived species. The prevalence of an ulcerative shell disease found in as many as 30% of the reintroduced adults in some areas was a major concern. The Husbandry Working Group noted the absence of effective communication and standardization of husbandry and data management protocols between stakeholder institutions. The outcome of the PHVA was to redirect action towards understanding shell disease epidemiology and effects on survival and reproduction, to improve communication between stakeholders through sharing of husbandry and field data, to establish a new site for western pond turtle populations and continue bullfrog eradication at the various sites.

The success of the Western Pond Turtle Recovery Program lies in the close collaboration between *ex situ* and *in situ* partners. Data management processes need to be standardized between the *ex situ* partners and linked between the *Access* database, ISIS records and WDFW for effective communication between the partners and to facilitate analyses on the success of the program.

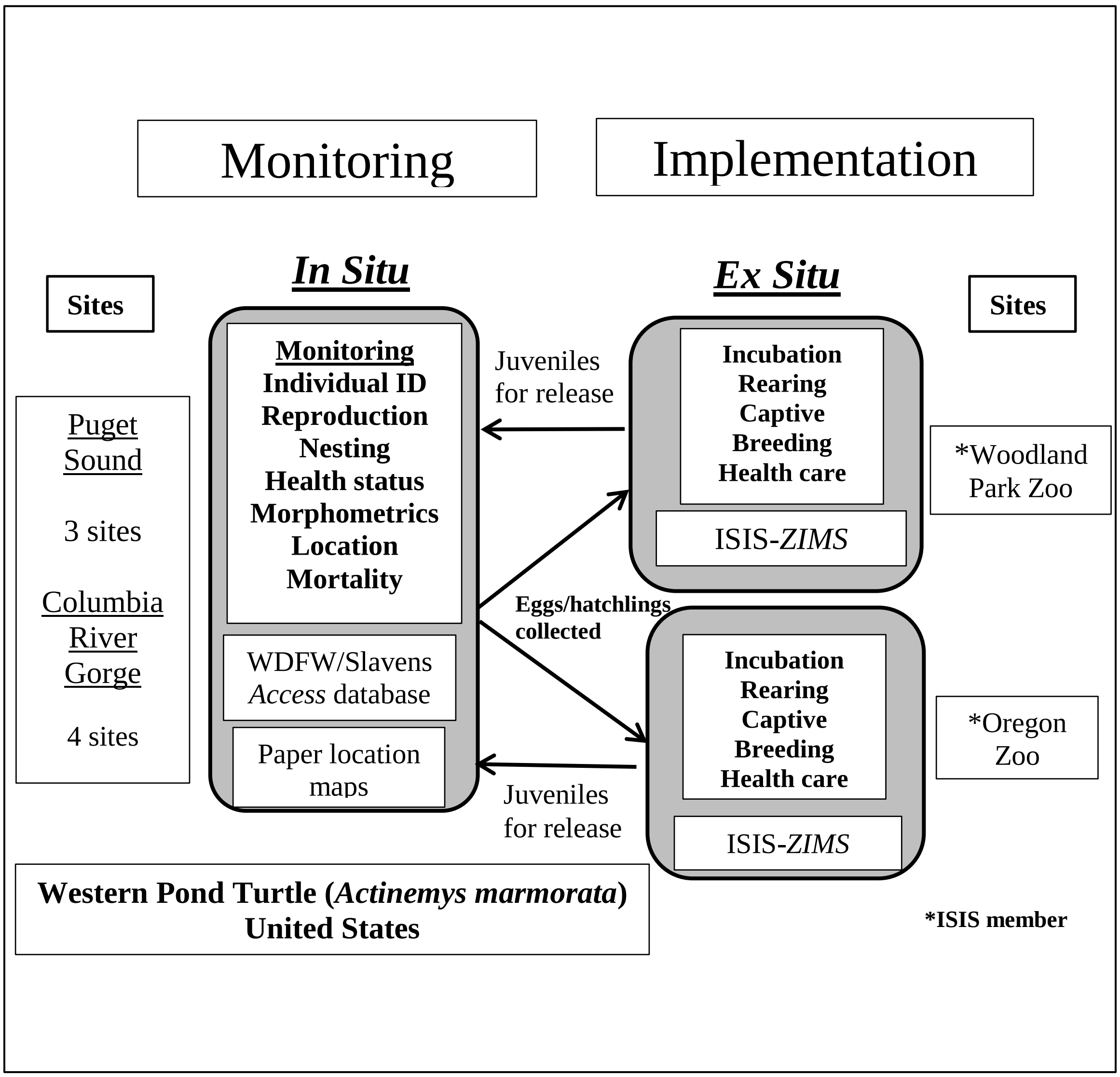


Figure 3.10. Data management processes for the Western Pond Turtle Recovery Program.
WDFW – Washington Department of Fish and Wildlife

<u>Category B Case Studies</u>

Endangered species brought into captivity due to threat of extinction in the wild. At one time, listed as IUCN Extinct in the Wild. Reintroduction program well developed through captive breeding or head-starting with managed release and established monitoring program for assessment.

Program: Kakapo Recovery Programme

Figure 3.11. Kakapo in the wild.
Photo credit: Andrew Digby

Species: Kakapo (*Strigops habroptilus*)

IUCN Red List Category: Critically Endangered

IUCN World Region: Oceania

Country: New Zealand

Range: Anchor Island, Whenou Hou/Codfish Island, Hauturu/Little Barrier Island

<u>Conservation situation/feasibility/risk assessment</u>

The kakapo is a flightless, nocturnal parrot that became functionally extinct by the 1970s due to loss of habitat and predation by introduced mammalian predators, mainly stoats (*Mustela ermine*). In 1977, a small population of 150 birds was discovered on Stewart Island, but due to predation by domestic cats, the population was quickly declining so the birds were translocated to predator-free offshore islands. The population was intensively managed and the IUCN designated kakapo as Extinct in the Wild in 1996. By 1999, the population stabilized and slowly began to increase through intensive management and by 2005, the IUCN status was raised to Critically Endangered (BirdLife International 2013). Adult kakapo survival on the predator-free islands was very high (>99%) however a high percentage of infertile eggs, poor hatching success and high chick mortality due to probable inbreeding depression has compromised the growth of the population (Jamieson *et al*. 2006), exhibiting the importance of intensive genetic management. Due to evolution in relative isolation, the kakapo is not closely related to other parrot species and is the only member of the subfamily Strigopidae. Thus, with such a small population and unique taxonomic status, the kakapo is ranked fourth on the top 100 list of Evolutionarily Distinct and Globally Endangered bird species, requiring extensive conservation action (EDGE 2014).

Design

The Kakapo Recovery Plan 2006 – 2016 (NZDOC 2013) states that the long-term recovery goal is to restore the population to at least 150 adult females by maintaining one self-sustaining, population as a functioning part of the ecosystem in a protected habitat and maintain two or more other managed populations of at least 50 adult females each. For the recovery plan period (2006 – 2016), the goals are to minimize the loss of genetic diversity, and secure, restore or maintain sufficient habitat to accommodate 10% more than the expected increase in the kakapo population.

Implementation and monitoring

The kakapo population is managed on three predator-free islands with collaboration from the DOC center in Invercargill, the Auckland Zoo, Wellington Zoo, Massey University and others. In order to boost the population, eggs may be collected from burrows where there are too many eggs for the mother to handle, or chicks that are either 20% underweight for their age or have other health concerns are captured for transfer to a DOC rearing facility (Richard Jakob-Hoff, personal communication). Chicks are returned to the wild at 4-5 months old through a soft release method where they continue to develop in the company of other chicks thus reducing negative imprinting on humans. The geneology of each individual is known through monitoring of reproduction in the wild or through genetic analysis of biological samples and the birds are finally released to an area where they will best contribute to the genetic diversity of that particular sub-population. As of May 2014, the total population size was 126 birds on the three islands plus a number of surplus males retained in other DOC sanctuaries.

There is ongoing research to answer questions on reproduction, genetics, nutrition, rearing methods, habitat selection, and resource management. Reproductive and genetic studies include evaluation of sperm, identifying the genetic makeup of the population for meta-population management, development of artificial insemination procedures, and artificially induced breeding through the application of reproductive hormones for females. Nutrition questions overlap with reproductive questions as fecal analysis looks at identifying dietary triggers to breeding. Nutrition is also important in rearing studies that include identifying optimal hand-rearing formula for chicks and developing a supplementary food for chicks raised by foster females. *In situ* studies include determination of the carrying capacity of the islands and identifying habitat resources that affect reproduction.

The kakapo population is made up entirely of wild birds as captive breeding of this species is not currently being utilized as a method for increasing the population. There is integration between *in* situ and *ex situ* components due to the importance of genetic management for the whole population, and in addition, eggs and chicks that need assistance are brought into the DOC rearing facility to give them an increased chance of survival (Figure 3.12). The intensive meta-population management requires individual specimen records with accurate parentage records maintained within a studbook using the ISIS program *SPARKS*. Due to the characteristics of a lek breeding system where a few males may breed with the females, and the necessity to manage a number of sub-populations, the "Management Sets" option in *PMx* (Lacy *et al*. 2012) has been used to determine bird transfers since it provides the option for genetic analysis of sub-populations (Caroline Lees, personal communication).

Data management for the program depends on collaboration between *in situ* and *ex situ* partners (Figure 3.13). The DOC maintains an *Access* database to track the basic core data on the whole population, the incubation and chick rearing processes at the DOC rearing facility, and the monitoring data (see Appendix XI). Auckland Zoo participates in the program through occasional health care for a sick or injured bird, performing health assessments of birds in the wild, collaborating in health-related research and also performing the necropsies for all birds from the wild or from the DOC rearing facility. Specimen records (core data and medical) are kept in ISIS for the birds maintained at the zoo with reports going to the DOC at regular intervals, upon release back to the wild or if the bird dies. For the last 7 years, all deceased birds were sent to Auckland Zoo for necropsy with the data maintained in a separate database from ISIS, although some death records may have been duplicated in *MedARKS*. Auckland Zoo sends necropsy reports to the DOC and to Massey University for entry into the Huia mortality database. Prior to 2007, Massey University performed the necropsies, and MU still receives tissue and other diagnostic samples collected at necropsy at Auckland Zoo.The Huia database is in MS

Access and currently the Ministry of Primary Industry is working with the DOC to integrate the wildlife mortality data into a web-based health database for domestic animals. There may be future possibilities for data sharing with *ZIMS* via this platform (Richard Jakob-Hoff, personal communication).

Due to the nocturnal habits and shy nature of the birds, special monitoring methods are required that enable rangers to locate the birds on the islands. Each bird is fitted with a SMART (species movement, acceleration, and radio tracking) transmitter that is used to determine locations and movements from ground-based telemetry. Females are fitted with an "Egg Timer" transmitter that identifies not only her location but also emits pulses according to her activity pattern which identifies incubating behavior or death (Wildtech 2011). Males are fitted with a "Checkmate" transmitter that contains a receiver that will turn on only if the male has mated (i.e., the transmitter has reached a certain movement threshold) and will identify the female that is in close proximity (and thus probable mating partner) by the UHF frequency of her transmitter. Thus, the rangers are able to discern the identity of the mating partners which will give an indication of parentage if chicks are produced. "Sky Ranger" is a new technological advancement by Wildtech NZ Lt. (the maker of Checkmate and Egg Timer transmitters) that can collect the data from the transmitters remotely from a flyover of the island by a fixed-winged plane (Wildtech 2014).

There may be natural intervals of 2-4 years between clutches for females who rely on the pattern of mast fruiting of particular trees to provide enough food for their chicks. Supplemental food is provided at strategically placed supplementary feeding stations with movable lids to ensure males and females are in optimal breeding condition and to help females feed chicks. The feeding stations are controlled by a radio-tracking system, “the snark”, which can detect the identity of any birds within a 20 meter radius. The snark can also be programmed to limit access to the feeding station (which has a mechanical arm to lock the lid) to the birds with the appropriate UHF signal. In addition, the snark can be hooked up to electrical scales at the feeding station and will record the weight of the bird while it is eating. Staff can download the information to a hand-held computer when they visit the feeding station. Data from the snark is recorded in the DOC *Access* database (see Appendix XI).

The kakapo are monitored in a number of different ways which may or may not include visual observation. Each monitoring event, whether by radio-telemetry using triangulation or GPS location, snark monitoring, or capture for transfer or health assessment is documented as a Recovery in the DOC *Access* database (see Appendix XI). Regular health assessments are done by rangers and other Kakapo Team staff and involve capture and assessment of body condition, taking weights and biological samples for analysis (e.g., blood, swabs for bacteria, feathers, feces). Auckland Zoo staff assists with capture at times but more frequently will be involved with analyzing samples, treating sick birds and performing necropsies. Current research questions dictate the data collected and include studies on genetics, artificial insemination (sperm evaluation, freezing techniques, artificial insemination protocols using sperm from males with rare genes), supplementary feeding trials, fecal analysis to identify dietary triggers to breeding, habitat selection, and artificial stimulation of rimu fruiting (Kakapo Recovery 2014).

Assessment

The Kakapo Recovery Programme requires intensive management of three sub-populations and thorough collaboration between *in situ* and *ex situ* partners working together towards conservation of this unique parrot species. Although the overall kakapo population is slowly increasing, thus obtaining the recovery plan goal to maintain or increase the population growth achieved for the last recovery plan period, the population size remains extremely small with only 126 individuals within all the island populations. Slow maturation rates for this long-lived species combined with the slow reproductive rate and high incidence of egg and chick mortality affect the population growth rate even as adult mortality remains low. Research is targeted towards various aspects of diet, habitat, and genetic diversity that affect reproductive processes.

To maintain the highest degree of genetic diversity in this small population, population management tools (documenting parentage through individual records and establishing a studbook) are employed to guide breeding management. Medical records for birds in the wild or eggs/chicks reared in the DOC rearing facility are maintained by the DOC, with involvement by veterinarians from Auckland Zoo. All necropsies are done by the Auckland Zoo with reports sent to the DOC and to Massey University. Some medical records and necropsy results are entered in *MedARKS*, but only for the kakapos that were physically at Auckland Zoo. A unified records-keeping system that is web-based or that links to another web-based system would link the core data and medical records from the DOC rearing facility to the Auckland Zoo and Massey University as well as to the records for the animals in the wild.

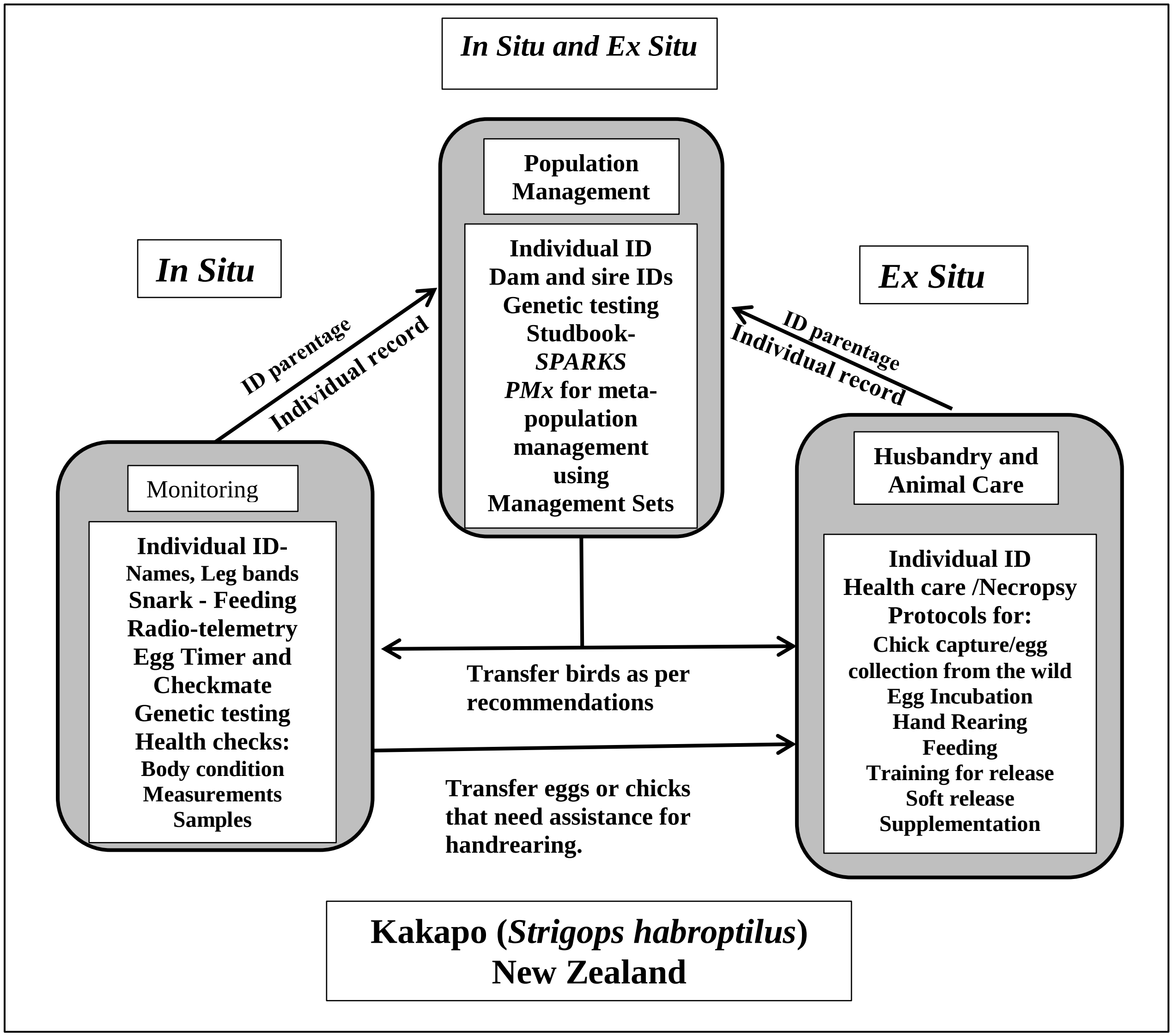


Figure 3.12. Methods for integrated management of the kakapo population.

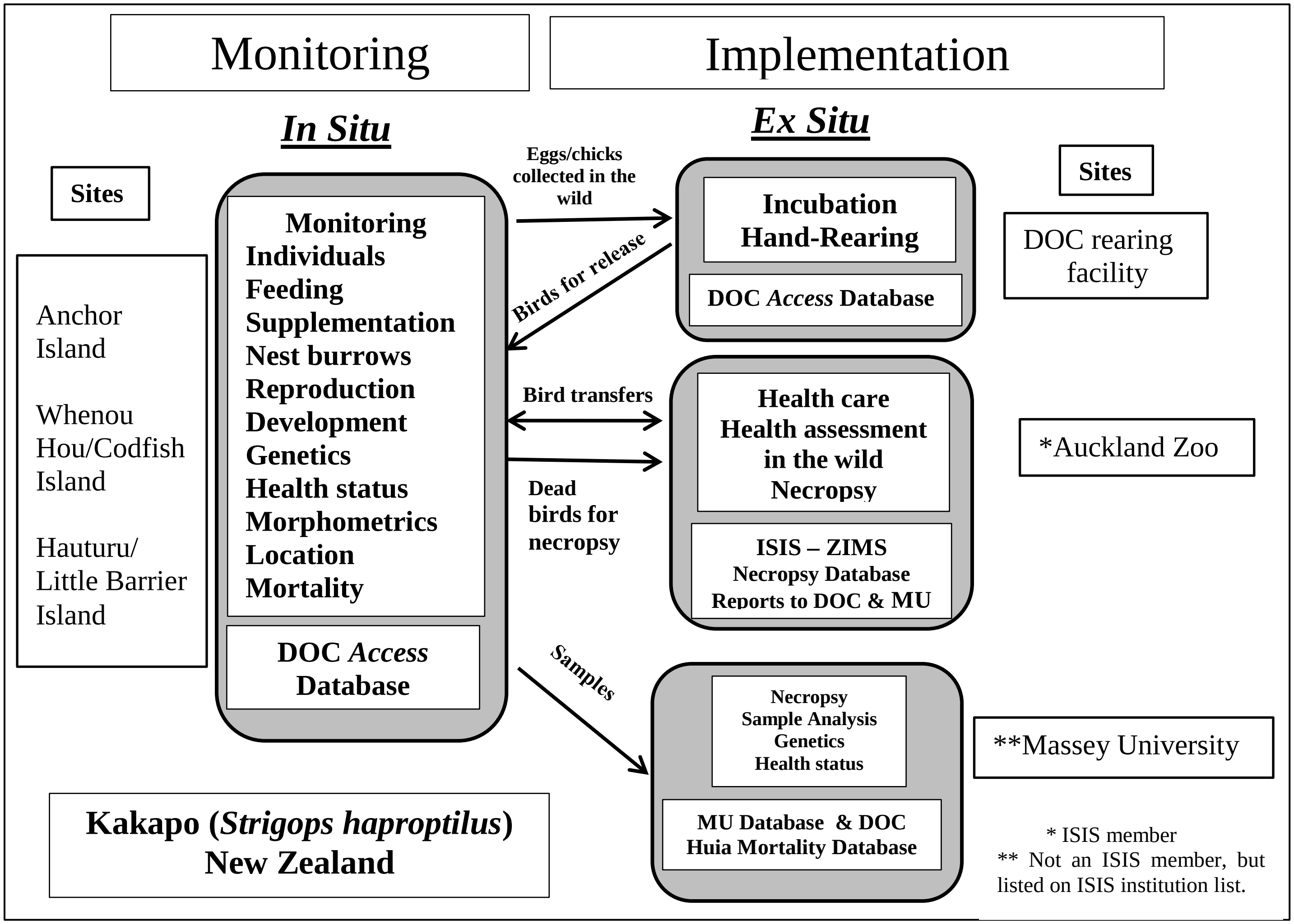


Figure 3.13. Database tools used for *in situ* and *ex situ* components of the Kakapo Recovery Programme.
For data fields for each component, see Appendix XI. DOC – Department of Conservation. MU – Massey University

Program: Kihansi Spray Toad Reintroduction Program

Species: Kihansi spray toad (*Nectophrynoides asperiginis*)

IUCN Red List Category: Extinct in the Wild

IUCN World Region: Africa Country: Tanzania

Range: Kihansi River Gorge

Figure 3.14 Kihansi spray toad
Photo credit: Toledo Zoo

Conservation situation/feasibility/risk assessment

The Kihansi spray toad was endemic to 2.0 hectares in the Udzungwa Mountains of south-central Tanzania, residing solely within the spray zone of the Kihansi River Gorge (CBSG 2008). A hydro-electric facility and dam were constructed along the Kihansi River from 1996 to 2000, diverting the river away from the Kihansi Gorge thus altering the spray zone habitat. To establish an assurance population, 499 toads were captured and sent to Wildlife Conservation Society/Bronx Zoo and Toledo Zoo in the United States. Attempts were made to establish artificial spray systems in the gorge area but by the time these systems were set up, the ecosystem had dried up, changing the plant species diversity. Although the habitat was partially restored over time, the Kihansi spray toad population precipitously declined and with the additional threat of the presence of chytrid fungus (*Batrachochytrium dendrobatidis*) discovered in the area in 2003, disappeared altogether leading to a IUCN designation of Extinct in the Wild by 2009.

The PHVA showed that the small wild population went through an uexplained crash in 2003 (CBSG 2008). The main issues that were proposed were that toxins from flushing of the dam had seeped into the water system, that there was an outbreak of chytridiomycosis (caused by the chytrid fungus), and/or an exotic pathogen had been introduced to the naïve Kihansi spray toad population. There was ongoing modification of the habitat due to the operation of the dam and studies were needed to understand the ecology of the ecosystem. Improved management of natural flow of water was needed as well as an increase in the area where misters were simulating the natural conditions of the spray zone habitat.

For the PHVA, the *ex situ* community noted that the propagation program at Toledo Zoo and WCS encountered a number of issues including disease and lack of effective husbandry practices causing several population crashes. Resolving these issues required improved husbandry management and increased biosecurity and diagnostic protocols in preparation for returning healthy surplus animals to Tanzania for reintroduction. Toledo Zoo contributed basic life history and reproductive parameters for *Vortex* population modeling since these were not available from the wild. Results showed that although the *ex situ* populations were relatively sustainable, there was a 75% chance of survival under the current conditions over a 50 year period with a genetic diversity of 83% (below the desired target of 90%). When considering a reintroduction program, the modeling indicated that for the best case scenario, the *ex situ* populations should be maintained in the USA with surplus animals sent to a facility in Tanzania for breeding and reintroduction. In 2010, the University of Dar Salaam (UDSM) established the *ex situ* facility in Tanzania, opening up the opportunity to serve as a center to facilitate the reintroduction program.

<u>Design</u>

As per the Kihansi Spray Toad Re-introduction Guidelines (Khatibu *et al*. 2010), the overall goals of the Kihansi spray toad reintroduction program are to work towards a sustainable free-ranging population within the historic range of the Kihansi Gorge and restore the habitat and resources critical for survival of this species. To attain these goals, there are four main areas of action: 1) establishing *ex situ* populations at the Toledo Zoo and WCS for propagation and to provide toads for release through UDSM; 2) conduct disease and pathology research on captive assurance populations to establish diagnostic and biosecurity protocols for pre-shipment health/disease screening, quarantine and post-shipment health/disease screening; 3) conduct reintroduction experiments to include impact of release methodologies (soft vs hard release) on survivability, and pathway of chytrid transmission and efficacy of treatment; 4) maintain the misting system to continue habitat restoration and monitor environmental components including microclimate, water quality, soil, vegetation, invertebrate and amphibian species, presence of disease, predators, and fires.

<u>Implementation and monitoring</u>

The Tanzania Wildlife Research Institute, Division of Wildlife, and the National Environment Management Council (NEMC), agencies within the United Republic of Tanzania government, work together with *ex situ* facilities including the University of Dar es Salaam, WCS and Toledo Zoo to manage the Kihansi spray toad reintroduction program.

The total *ex situ* population of Kihansi spray toads present in 7 North American zoos consists of 6710 individuals and only WCS (with 39% of the population) and Toledo Zoo (with 48% of the population) are involved in the reintroduction program (*ZIMS* 2014). Detroit Zoo, Abilene Zoo, Miller Park Zoo, Omaha’s Henry Doorly Zoo and Chattanooga Zoo maintain this species where they play exhibit and conservation education roles. The government of the United Republic of Tanzania maintains ownership of all of the Kihansi spray toads in North American zoos.

When the toads were first brought into zoos in the United States to form the captive breeding program, very little was known about the ecology and biology of this species. Husbandry protocols for enclosures (size, substrates, environmental measures), misting sytems, nutrition, and health care went through an evolution since initially there were high mortality rates for both adults and juveniles and compromises in reproductive success. There were health issues including metabolic bone disease, 'short tongue syndrome' (a condition where Vitamin A deficiency affects the mucus glands of the tongue, preventing the production of enough saliva to enable catching of insect prey), nematode infestations (lungworm, Rhabditiforms), bacterial pathogens (*Aeromonas* spp, *Pseudomonas* spp., and *Klebsiella* spp.) and sepsis leading to death (Lee *et al*. 2006). With the reintroduction program in mind, there was an increased acknowledgement of the threat of chytrid infection and also the issue of spreading disease from captive-born toads when released to the wild. Thus, the *a priori* questions that guided the implementation of the *ex situ* components included testing care and health protocols as well as research on life history attributes (lifespan, reproductive parameters, trophic requirements). Studies were needed on optimal environmental measures (humidity, temperature, light parameters), nutrition, bio-security measures, physical attributes of enclosures, and population management (density within enclosures, groupings, tracking genetics, pairings for reproduction, transfers) for their impact on health, survivability and reproduction.

The data management processes for the breeding programs at the Toledo Zoo and WCS (both ISIS member institutions) consist of a combination of *ZIMS* records for inventory and census data as well as use of *Excel* spreadsheets for tracking reproductive and mortality data and information on specific studies. Due to the small size of adult Kihansi spray toads (with a snout-vent length of 10-18 mm and body mass of 0.45 to 0.66 grams; Lee *et al*. 2006), individuals are difficult to mark and identify. Thus, records are kept on groups rather than individuals. WCS currently has 40 active groups documented in *ZIMS* , keeping track of births, deaths, and transfers in and out for each group. Toledo Zoo uses *Excel* spreadsheets to monitor 77 active groups for births and deaths and to collect data for various studies to determine optimal environmental conditions and husbandry methods (see Appendix XII). The *Excel* spreadsheets are maintained by the the curator who receives a daily report from the keeper staff. The curator sends a monthy report on births, deaths and census numbers for each group as well as transfers out or splitting and merging of groups to the Registrar for recording in *ZIMS* . The group record in *ZIMS* tracks origin and ownership, sex ratios, life stages, births, deaths and necropsy results, enclosures, and transfers in and out (Figure 3.16).

Figure 3.15 University of Dar es Salaam and Toledo Zoo staff perform a census of the Kihansi spray toads at the Toledo Zoo. Photo credit:

There is a protocol for low intensity genetic management for groups where individual pedigrees are unknown (R. Andrew Odum, personal communication). Kihansi spray toads are ovoviparous (embryos develop inside eggs retained in the mother's body

Specimen Report

Group of Animals

ISIS GAN MIG12-29927354

Nectophrynoides asperginis — Kihansi spray toad

Order Anura — **Family** Bufonidae

Start Date Jan 01, 2014 — **End Date** Oct 22, 2014

Basic Animal Information

Sex - Contraception	GP: 6.22.20	**Status**	Alive
Establish Date	May 06, 2009	**Preferred ID**	
Origin	Govt of The United Republc of Tanzania	**Rearing**	
Birth Type	Undetermined	**Hybrid Status**	Not a hybrid
Sire	MIG12-29144410	**Dam**	MIG12-29694006

Physical Visit History

Reported By	Date	Source / ID	Holder / ID	Term Type	Recipient / ID
TOLEDO	May 06, 2009		TOLEDO / 6143	Birth/Hatch (Physical Only)	

Ownership Visit History

Reported By	Date	Source / ID	Owner / ID	Term Type	Recipient / ID
TOLEDO	May 06, 2009		GOVT TANZ / NONE	Birth/Hatch (Physical Only)	

Group History

Date	Event	Adjustment	Net Count	Details
Aug 25, 2014	Census		0.5.20	Method Visual
Aug 24, 2014	Partial Acq. Into Group (Birth / Hatch)	0.0.20	2.5.20	
Apr 14, 2014	Partial Death Event In Group	-1.-1.0	2.5.0	
Feb 13, 2014	Partial Death Event In Group	-3.0.0	3.6.0	
Jan 10, 2014	Census		6.6.0	Method Undetermined

No Sex Information Found

Notes

Reported By	Date	Type	Keyword	Text
TOLEDO	Aug 25, 2014	Group Census Detail	Animal Group Census	2.0 Nectophrynoides asperginis (Kihansi Spray toad) from CRNecto 5 #6143 were unaccounted for during census, New total 0.5.20
TOLEDO	Jan 10, 2014	Group Census Detail	Animal Group Census	7.3 Nectophrynoides asperginis (Kihansi Spray Toad) from Cool Room 5 #6143 were unaccounted for during census, New total 5.6.

No Observations Found

Parent Info

In ZIMS	Parent Info	Type / Probability	Birth Date	Reported By
True	MIG12-29694006 [TOLEDO / 5672]	Dam/100%		TOLEDO
True	MIG12-29144410 [TOLEDO / 5671]	Sire/100%	Feb 21, 2014	TOLEDO

Ancestry Information (calculated by ISIS from shared data)

% Pedigree Known	% Pedigree Certain	Taxonomic Inconsistencies	No. Identified Ancestors
0.00%	0.0000	No	2

Death Information

Printed: Oct 22, 2014 17:11 — International Species Information System — Page: 1 of 2

ISIS ZIMS version 2.1.0.1.0

Figure 3.16 Specimen report for a group of Kihansi spray toads at Toledo Zoo. The report shows ownership, birth, death, and census events, and parentage (group numbers for source of dams and sires). Courtesy of R. Andrew Odum/Toledo Zoo/ISIS.

until hatching and young are live born) and the young toadlets are separated out from the enclosure after birth. They are divided up, depending on numbers, and combined with young from other enclosures. The partial groups are combined under a new ISIS Global Animal Number (GAN) and the location of the group is documented in the enclosure log. Although exact pedigrees for individual toads are unknown, the parent groups are documented and this mixing and tracking by group number offers the probability that genetic mixing occurs and inbreeding is reduced. Other group breeding strategies may be incorporated such as a systematic round-robin protocol to transfer all juveniles or transfer all of one sex to different groups (Schad 2008). A *ZIMS* tool called Group Explorer shows the history of each group including acquisitions, dispositions and transfers in and out which helps in the breeding management process (Figure 3.17).

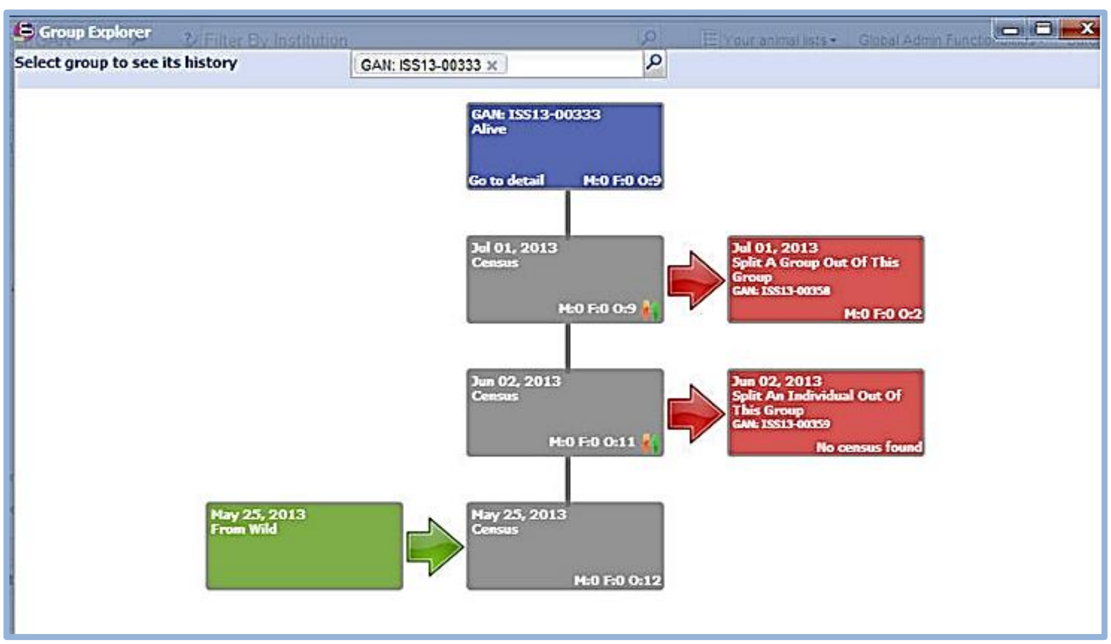


Figure 3.17 The Group Explorer in *ZIMS* tracks the history of each group. Green boxes indicate accessions, red boxes indicate dispositions, and census counts are in grey (ISIS 2014).

Health assessments and documentation of disease are critical factions of the *ex situ* component of this reintroduction program. Due to the threat of chytrid infection, the Toledo Zoo maintains the Kihansi spray toad colony in a biosecure facility. Veterinary staff conduct routine health screenings for chytrid, parasites (enteric nematodes, lungworm, intravascular ciliates) and other pathogens including *Ranavirus* sp., *Rickettsia* sp., and *Mycobacterium* sp. All health data and necropsy reports were maintained in *MedARKS* and now, in *ZIMS for Medical*. Any toads that are sent to Tanzania for release undergo extensive pre-shipment screening to ensure that there is no spread of disease to the wild population.

As part of the management of Kihansi spray toads at Toledo Zoo, the Herpetology Department conducts a number of ongoing studies including impact of environmental measures (humidity, temperature, light levels), diet, and group management (density within enclosures) on health, growth, reproduction and mortality (see Appendix XII for data fields). Data for these studies are captured in *Excel* spreadsheets to compile for analysis.

There are two breeding centers in Tanzania with one at the University of Dar es Salaam and one near the Kihansi Gorge. Founders for the University population came from WCS and Toledo Zoos in 2011 and a number of these animals were then transferred to the Kihansi facility. Neither center is an ISIS member nor are they listed on the ISIS institution list. Dispositions from WCS and Toledo Zoo are noted in *ZIMS* as Loan Return to the United Republic of Tanzania. Animals that are destined for release are sent to the University as a way station for the reintroduction. These facilities have breeding management programs and also conduct research on impact of different environmental variables (humidity, temperature, light) on activity patterns (feeding, resting, breeding behaviors) (Rija *et al*. 2014). Data are collected on duration of time spent on the different activities under variable conditions to gain an understanding of temporal and spatial use of habitat structures.

The reintroduction phase of the program began in October 2012 when 2500 toads from Toledo Zoo and WCS were sent to the University of Dar es Salaam facility for a four-month habituation period (to test potential for disease transmission from the toads to other gorge species) and then released in the Kihansi Gorge (IUCN Redlist News 2012). The program incorporated soft-release methodologies utilizing pens located within various vegetation plots in the misting area so that monitoring protocols could be developed. Initial experiments included set-up of a release pen with individually identified toads marked with flourescent elastimers (two colors), a pen containing unmarked individuals and a third with gravid females. The pens were set up in both the upper and lower wetlands within the artificial misting area and monitored for 120 days (Mohamed 2013). Monitoring protocols were implemented with the use of data loggers to collect ecological information (humidy, temperature, precipitation, wind speed), and physical monitoring of plant and animal species presence as well as for data on the toads (ease of detection, survival, births, deaths, presence of disease) at monthly intervals. Dead toads are collected for necropsy and swabs are taken from dead toads as well as from live toads. The swabs and dead toads are sent for analysis to a veterinary laboratory at Sokoine University of Agriculture in Morogoro, Tanzania (Emanuel Nkombe, personal communication). Data are captured in an ecological monitoring database that is maintained by the NEMC (see Appendix XII for data fields).

Assessment

Designated as Extinct in the Wild by 2009, the recovery of the Kihansi spray toad in Tanzania depended completely on a cooperative effort between the United Republic of Tanzania National Environment Management Council, two Tanzanian universities, the World Bank and two separate breeding management programs in North American zoological institutions. By the end of 2013, over 3800 Kihansi spray toads were returned to Tanzania from Toledo Zoo and Wildlife Conservation Society/Bronx Zoo (Kimati 2014). The breeding programs incorporated research on life history attributes (reproductive parameters) and husbandry methodologies (required environmental parameters, nutrition protocols, and health protocols) combined with low intensity genetic management in developing the successful growth of the *ex situ* population. The two institutions have an ongoing program to send captive-bred spray toads to Tanzania for the reintroduction program with the goal of adding 2000 individuals per year to the wild population. The reintroduction program includes intensive monitoring of released individuals as well as research on optimal release methods, maintenance of the required habitat, and disease surveillance.

Toledo Zoo and WCS/Bronx Zoo are both ISIS member institutions and use *ZIMS* to keep track of groups of toads through census numbers, births, deaths, and dispositions to Tanzania. They also both use the medical component of ISIS to maintain health and necropsy records. Toledo Zoo maintains a tracking system of the groups in *ZIMS* for breeding management purposes through the use of enclosure logs and by documenting parentage groups as well as splitting and merging groups for breeding. All of the Kihansi spray toads in N. American zoos are technically owned by the government of the United Republic of Tanzania (*ZIMS* mnenomic – GOVT TANZ), and whereas all of the Toledo Zoo groups are listed in *ZIMS* as on loan from GOVT TANZ, some of the groups at WCS are listed as owned by WCS. WCS does track groups but Toledo Zoo does more intensive tracking of group histories in *ZIMS* to identify genetic background for breeding management processes. Thus there are discrepancies in the way *ZIMS* is used between the two institutions. The *ex situ* facilities in Tanzania are not ISIS members and thus have a separate records-keeping system to track reproduction, health, mortality and release to the wild.

Monitoring the toads in the wild covers required parameters including release methodologies, survival, reproduction, and presence of disease as well as ecological monitoring of habitat parameters (environmental measures, prey species, vegetation, etc.). These data are maintained in a government ecological monitoring database for use in assessment of the program to provide the opportunity for adaptive management. The data management process for the entire reintroduction program depends on communication between *ex situ* and *in situ* partners for information exchange and assessment at each stage of the program (Figure 3.18).

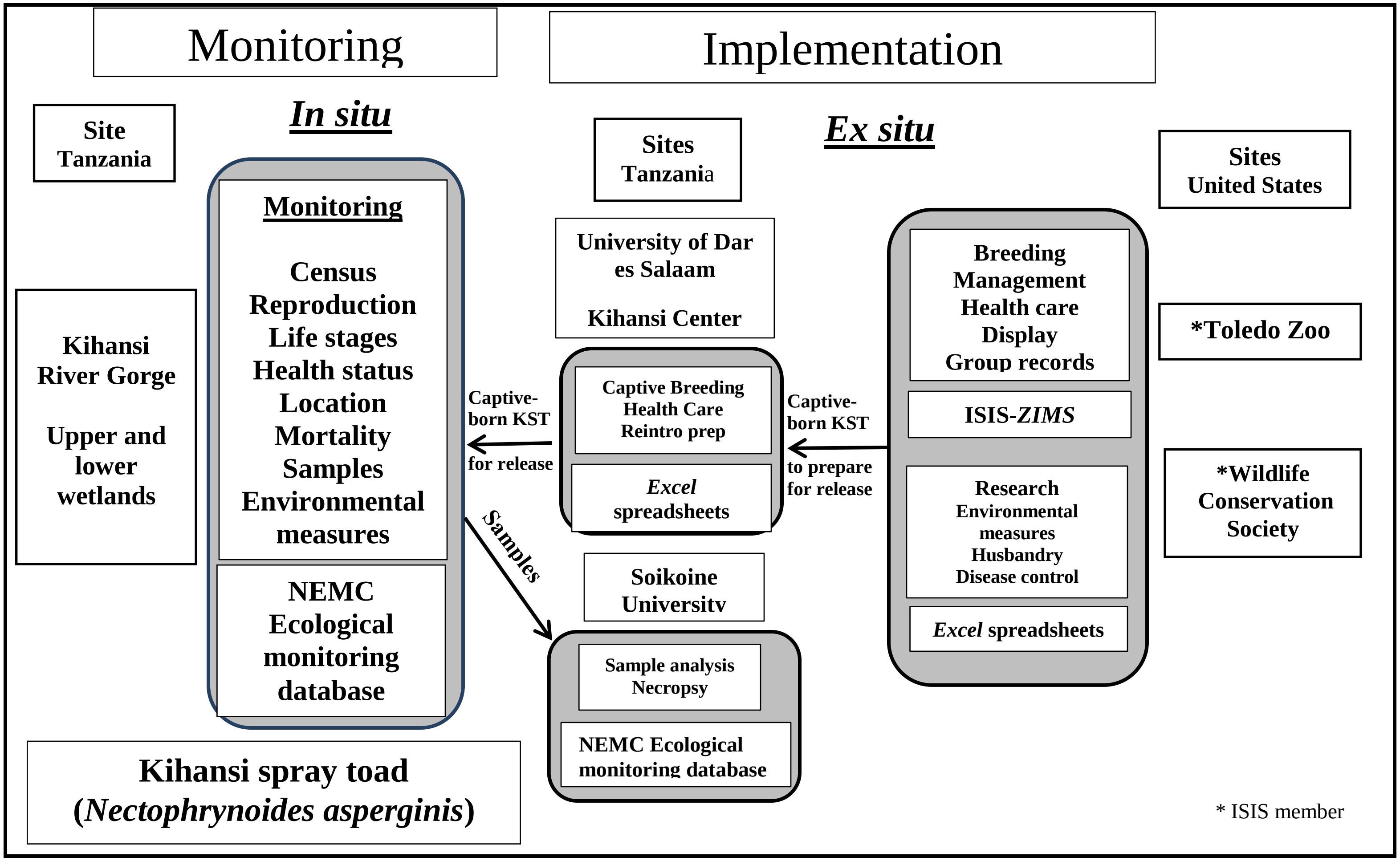


Figure 3.18 Data management processes for Kihansi spray toad reintroduction program. NEMC - National Environment Management Council; KST - Kihansi spray toad

Program: Red Wolf Recovery Program

Species: Red Wolf (*Canis rufus*)

IUCN Red List: Critically Endangered

IUCN World Region: North America & Caribbean

Country: United States

Range: Eastern North Carolina

Figure 3.19. Red Wolf
Photo credit: B. Bartel/USFWS

Conservation situation/feasibility/risk assessment

The red wolf once occurred throughout the southeastern United States with remnant populations extending into northeastern U.S. and into southern Ontario, Canada (Rutledge *et al.* 2010) but has now become one of the most endangered canid species in the world (Bartel and Rabon 2013). Red wolf populations declined through most of their historic range due to extirpation through predator control programs and loss of habitat, with further threat from hybridization with coyotes (*Canis latrans*). The U.S. Fish and Wildlife Service (USFWS) intervened in the early 1970s when very small populations were confined to the coastal prairies and wetlands of south-eastern Texas and south-western Louisiana. Red wolves that were deemed pure (no coyote introgression) were brought into captivity and the captive breeding program began, headed up by the Point Defiance Zoo and Aquarium. Other animals that were possible hybrids were exterminated and thus the red wolf became biologically extinct in the wild by 1980 (Bartel and Rabon 2013). Of the 17 red wolves brought into captivity, 14 became the founders of all the red wolves that exist today. In 1984, the breeding program was formalized as an AZA

Species Survival Plan (SSP®) with the primary objective to establish a population that would form the foundation of a wild population developed through reintroduction back to the wild. In 1987, reintroductions began in the Alligator River National Wildlife Refuge in northeastern North Carolina after extensive feasibility assessments determined that the area lacked coyotes and livestock operations as well as offered abundant prey.

A PHVA in 1999 showed that the most serious threat to red wolf recovery was hybridization in the free-ranging population and as such the primary recovery focus was on sustaining a non-hybridized red wolf population. Breeding management of the captive population became that much more critical as these animals were the only repository for the original genetic composition and re-introductions were needed to continue the gene flow from these animals of known parentage (Kelly *et al*. 1999). Action steps included maximizing the number of releases to suitable sites, lethal control of coyotes in the release areas, and intensive monitoring of all red wolves by incorporating capture, release and radio-telemetry methodologies.

Today, there are about 90-110 red wolves in three national wildlife refuges, a Department of Defense bombing range, state-owned lands and private properties (Bartel and Rabon, Jr. 2013), and 194 in the 43 institutions that make up the Red Wolf SSP® (Waddell and Long 2014). The USFWS is employing adaptive management strategies to handle the ongoing issues with coyote control, threat of hybridization and to garner public support for the program.

Design

The main goal of the Red Wolf Recovery Program, as specified in the Red Red Wolf Recovery/Species Survival Plan (USFWS 1990) and the Red Wolf Adaptive Management Plan (Rabon *et al.* 2013) was to achieve at least three sustainable populations through reintroductions of captive bred animals with the cooperation of at least 30 captive-breeding facilities. The populations should retain 80 – 90% of the genetic diversity found in the founding population (14 individuals) for a period of more than 150 years. The wild population should be at least 220 wolves with a captive population numbering 330 wolves. The future of the red wolf would be insured through embryo banking and cryogenic preservation of sperm (Bartel and Rabon 2013). Adaptive management strategies including sterilization of male coyotes would be incorporated to mitigate coyote gene introgression resulting from interbreeding with coyotes (Rabon *et al.* 2013).

Implementation and Monitoring

The Red Wolf SSP® is the cornerstone of the Red Wolf Recovery Program as all of the red wolves in the wild population are descendants of the 14 original founders. There are 44 facilities that are involved in the SSP® including 28 zoos, 12 nature centers or living museums and 4 wolf conservation centers (Waddell and Long 2014). Through careful breeding management, the gene diversity for this small population was calculated at 89.29% of the founder population. While reproduction protocols for the *ex situ* population are well-established, questions concerning effective contraceptive measures as well as presence of reproductive diseases such as pyometra (uterine infection) and cystic endometrial hyperplasia (bacterial colonization in the uterus)(Waddell and Long 2014) guide research on reproductive health.

Due to the risk of coyote introgression, work is done to eliminate the breeding potential by sterilizing male coyotes and monitoring them through radio-tracking. Thus, tracking genetics of the reintroduced wolf population is an important element to determine if hybridization has occurred. Questions on survivability of reintroduced individuals, evidence of reproduction, health assessments, effect of different release methods, and availability of resources (habitat, prey species) guided research. In 1987, the Alligator River National Wildlife Refuge was chosen as the release site and reintroductions began with four pairs of captive-born wolves, using a soft-release method to acclimate the wolves to the area. The wolves had limited contact with humans and were fed wild prey (dead raccoons, possums, rabbits, road-kill deer) to assimilate wild conditions. Each wolf received a health assessment, was vaccinated (for rabies, distemper, hepatitis, leptospirosis and parvovirus), and received a VHF radio-collar. After release, the wolves were supplemented with deer carcasses for 1-2 months to ensure that they were eating and to encourage them to stay near the release site.

The wolves are monitored several times per week by radio-tracking either by air from a fixed-wing plane or on the ground using hand-held antennae. During the spring when pups are usually born, the females are

Figure 3.20. Red wolf pups are pulled from the den for a health check. Photo credit: R. Nordsven/USFWS

carefully monitored to find dens. When pups are discovered, they are given a health exam, blood samples are drawn to check for coyote introgression, and the pups have a transponder inserted (Figure 3.20). The scientists document the number of pups in the litter and the identity of the mother and father. Individually identifying each pup will assist the USFWS team in developing a better census process that will be based on the pups' capture rates and fates using a mark/recapture method.

Since the release of adults and juveniles from the SSP® population was discontinued in 1994, the current strategy to increase the population size and genetic diversity of the wild population involves transferring captive born pups to the den of a wild female with a similar-aged litter for fostering (usually 10-14 days old). This practice requires intensive monitoring of the females in the wild to determine when the pups are born as well as communicating with the *ex situ* facilities. In order to ensure that the wild and captive pups are not closely related, all of the red wolves (in both *ex situ* and *in situ* populations) are maintained in the Red Wolf Studbook using *SPARKS*, with a user defined field to identify captive vs free-ranging wolves. Except for the pups translocated over the past several years, all of the wolves in the North Carolina recovery area are wild born (Will Waddell, personal communication). The whole population is managed as a meta-population to ensure that genetic diversity is maintained in both *ex situ* and *in situ* populations (Figure 3.21).

Communication between SSP® facilities and the USFWS is paramount in ensuring success for the Red Wolf Recovery Program. The red wolf species coordinator is in constant contact with the breeding facilities to determine if breeding recommendations (transfers and pairings) were carried out and if pups had been born each year. The species coordinator also keeps in close touch with USFWS officials to monitor the status of the wolves in the wild, adding any pups that were discovered to the studbook. Twenty-six of the 27 zoos and four of the eight wildlife centers are ISIS members that use the ISIS central database for maintaining their animal records (Figure 3.22). All of the facilities that are not ISIS members are on the ISIS institution list (except one zoo that uses a different records-keeping system), which is important because the location for any animal transferred from an ISIS member institution to a non-ISIS member facility will be documented in the animal's ISIS record. Some of the wolf conservation centers maintain their records on *Excel* spreadsheets or as paper files due to time or budget constraints that prevent belonging to ISIS for data management.

Data management processes may differ between ISIS member institutions although the basic core data are maintained in the ISIS database. Data entry is standardized for those institutions that are ISIS members through adherence to the Red Wolf (*Canis rufus*) Record Keeping Protocol, which was developed by the AZA Institutional Data Management Advisory Group Government Ownership Task Force (AZA IDMAGGOT 2005). This protocol standardizes correct taxonomic entry, appropriate entry of the studbook number, and process to document mnemonics, birth location, acquisitions and transfers. All red wolves within the SSP® facilities are considered on loan from the USFWS which retains ownership and all transfers are by recommendation from the SSP®. Each institution may have their own internal daily log system to document daily events (either paper or electronic daily reports), but the core data will be kept in ISIS which facilitates information exchange with the species coordinator and the USFWS. For example, Point Defiance Zoo and Aquarium in Tacoma, WA manages the largest group of red wolves (21 males and 35 females) and maintains the basic records in ISIS (birth, sex, acquisition, disposition, identifiers, and weights) but keeps all other notes in another electronic system. PDZA does use *MedARKS* where any medical notes and procedures are documented and with the increased functionality in *ZIMS*, will be documenting complete records in ISIS (Marla Waddell, personal communication). The North Eastern Wisconsin (NEW) Zoo in Green Bay, WI uses a *Word* document for Keeper Observations reports on each animal with minimal information entered into the ISIS specimen record (Carmen Murach, personal communication). Trevor Zoo in Millbrook, NY documents all daily observations in the specimen record for each individual such that all the information on that animal is located in one place (Figure 3.23) (Jessica Bennett, personal communication). Neither the NEW Zoo nor Trevor Zoo use *MedARKS* and while Trevor Zoo documents medical records within individual records in *ZIMS* , the NEW Zoo's medical records are kept separately from the specimen records. Out of the 44 SSP® facilities, only 7 use *MedARKS* for red wolf medical records.

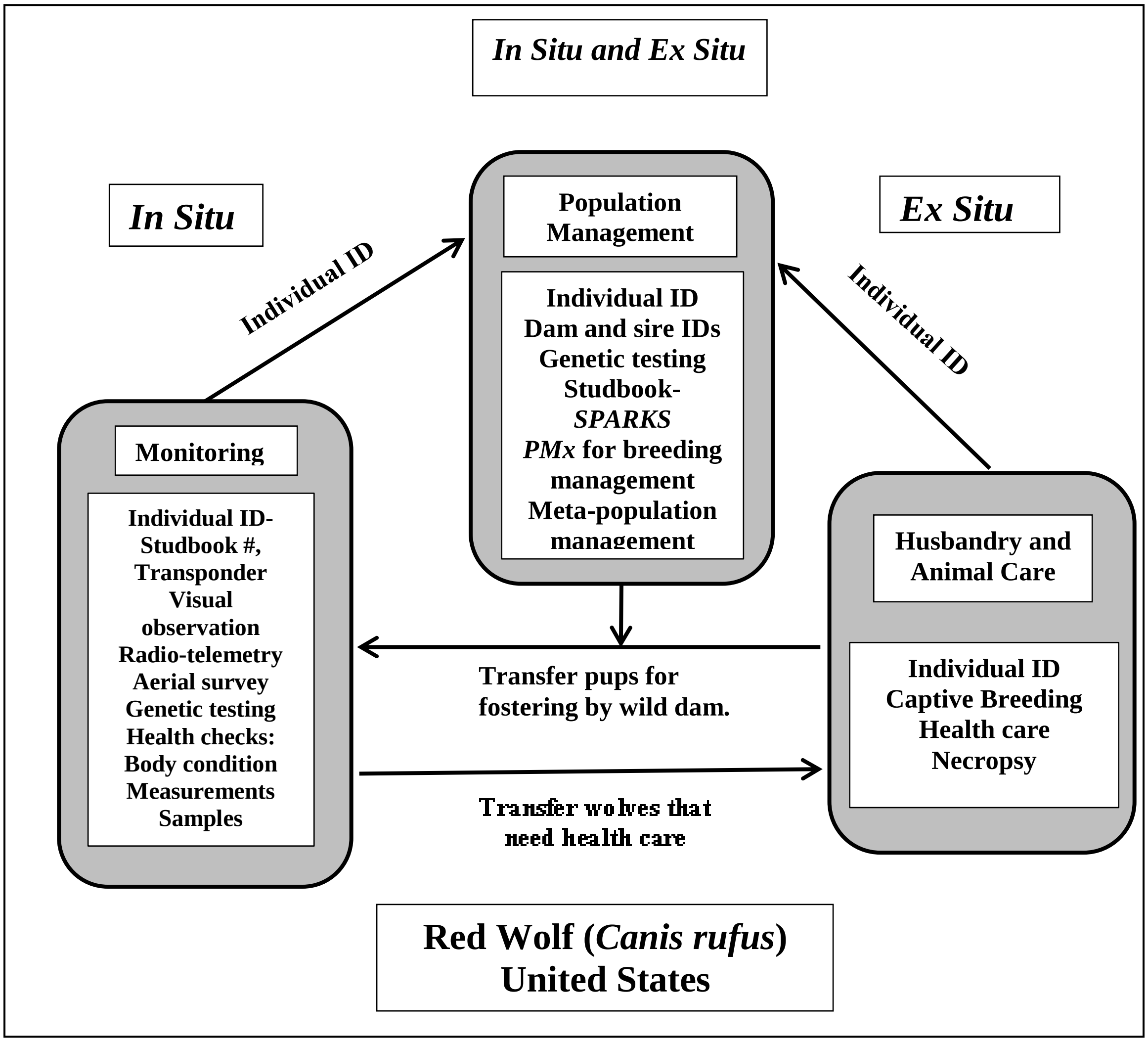


Figure 3.21. Methodologies used for overall management of the Red Wolf Recovery Program.

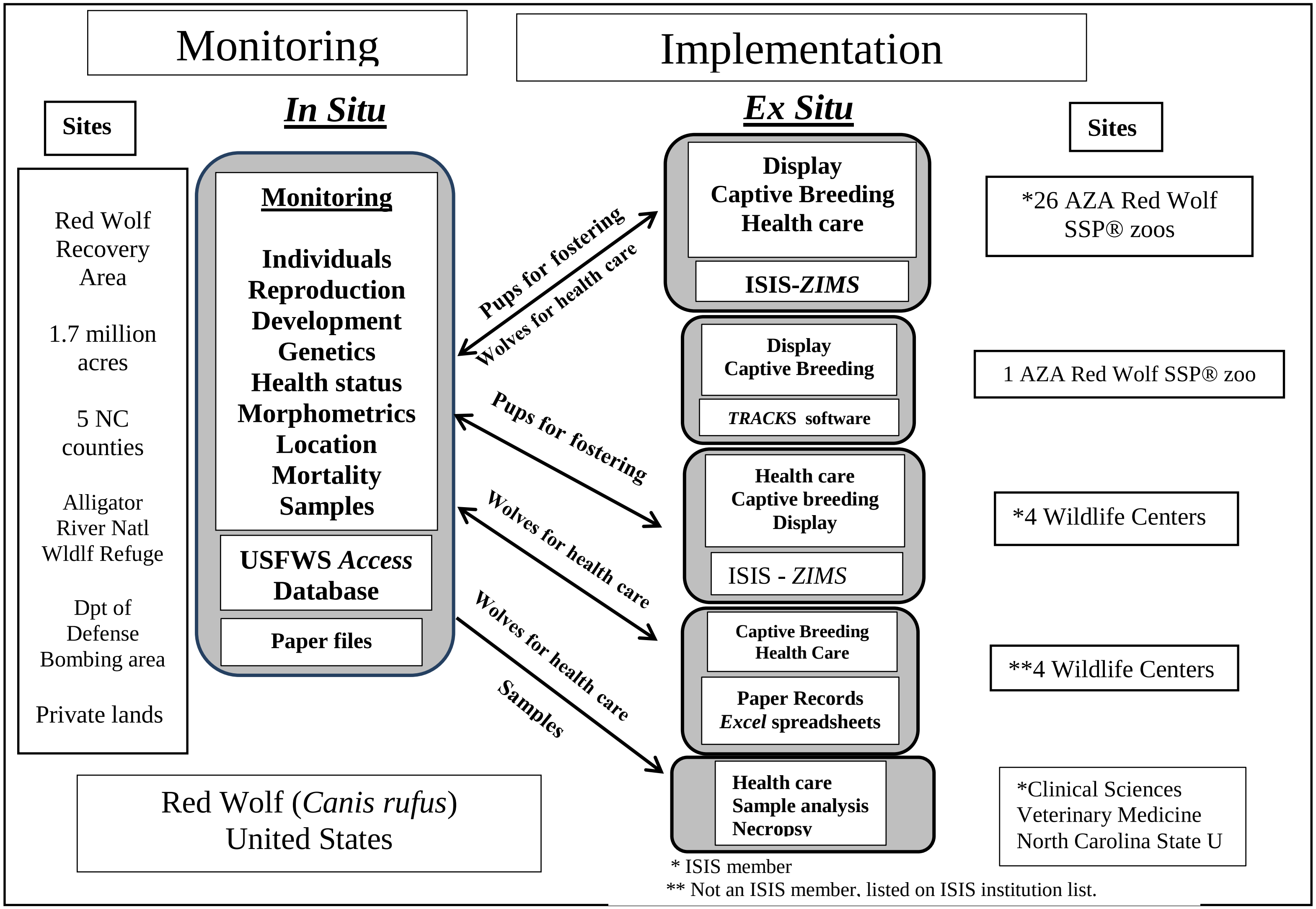


Figure 3.22. Data management tools for the Red Wolf Recovery Program. AZA – Association of Zoos and Aquariums; SSP – Species Survival Program

Specimen Report

ISIS GAN: DSD12-00011 1310

Canis rufus Red wolf Canis rufus

Order: Carnivora Family: Canidae

Start Date: 01/01/1800 End Date: 03/10/2013

Basic Animal Information

Sex - Contraception:	Female -	Status:	Alive
Birthdate - Age:	05/02/2012 - 0Y,10M,7D	Preferred ID:	1310
Origin:	Trevor Zoo at Millbrook School	Rearing:	Parent
Birth Type:	Captive Born	Hybrid Status:	Not a hybrid
Sire:	MIG12-29958747 | TREVOR 1293	Dam:	20931041 | TREVOR 1067
Current Collection:	Main Institution Animal Collection	Collection Trip:	
Clutch / Litter:		Enclosure:	

Physical History:

Reported By	Date	Type	Keyword	Text
TREVOR	01/16/2013	Management		With a large group, locked Shiloh in the wolf house. Plan to transfer Shiloh tomorrow. This note added to the following animals: [1067/TREVOR] [101728/BRIDGEPRT], [1306/TREVOR], [1307/TREVOR], [1308/TREVOR], [1309/TREVOR], [1310/TREVOR], [1311/TREVOR], [1293/TREVOR] [3528/WHEELING] [200821/JACKSON]
TREVOR	01/14/2013	Enrichment		Christmas tree given to the group. Shiloh grabbed the tree and dragged it around the exhibit. Luna and the pups followed and were also playing with the tree. This note added to the following animals: [1067/TREVOR] [101728/BRIDGEPRT], [1306/TREVOR], [1307/TREVOR], [1308/TREVOR], [1309/TREVOR], [1310/TREVOR], [1311/TREVOR], [1293/TREVOR] [3528/WHEELING] [200821/JACKSON]
TREVOR	01/13/2013	Fecal Observation		Dead round worms found in feces for the last two days. This note added to the following animals: [1067/TREVOR] [101728/BRIDGEPRT], [1306/TREVOR], [1307/TREVOR], [1308/TREVOR], [1309/TREVOR], [1310/TREVOR], [1311/TREVOR], [1293/TREVOR] [3528/WHEELING] [200821/JACKSON]
TREVOR	01/11/2013	Medical Treatment (MT)		Treat group with pyrantel pamoate paste PO in mouse: Shiloh-1.2cc, Luna and all pups 0.8cc. Continue for the next three days.

Figure 3.23. ISIS Specimen Report for a female red wolf at the Trevor Zoo. Courtesy of Trevor Zoo.

For the *in situ* component of the program, the USFWS maintains an *Access* database that contains the basic information on each animal in the wild as well as data on specific events that occur in the management of this species (see Appendix XIII for data fields). There are two main tables – a process table that maintains data on captures (basic animal information, capture method, health assessment, measurements, medical information, vaccinations) and an event table that contains genetic analysis, visits (birth, arrival, capture, foster to wild litter, death, GPS coordinates, release) and monitoring data (radio-telemetry start and end dates, reason for ending, collar inventory information). The medical records, necropsy reports and media (x-rays) are kept separately with the majority in hard copy format in individual animal files. Historical data dating back to the beginning of the program in the early 1970s are also retained in paper files.

Assessment

For the Red Wolf Recovery Program there is a strong collaboration between the AZA Red Wolf SSP® and the USFWS that has resulted in a wild population of almost 200 red wolves with the retention of 89% of the original founder genetic diversity. There have been no reintroductions of adults to the wild since 1994 yet pups born in captivity have been inserted in wild litters to add to the population. Thus the program uses a “one plan approach” with both *ex situ* and *in situ* populations documented in the studbook. Genetic analysis of each individual in the wild is done to identify parentage and ensure that no introgression with coyotes has occurred. Health assessments help track disease processes that occur in the wild. Each component of the program requires data collection in order to assess progress toward conservation goals.

Currently the USFWS team is working on analysis of records to determine success of the program and prepare for a PHVA. The *Access* database system was built for management purposes and has a structure that limits the effectiveness for analysis (David Rabon, personal communication). There are many sources for medical records, transfer history, events and reproduction with information gaps such that the information has to be pieced together. For historical records, the team can determine pedigrees and other reproductive information from *SPARKS* but there is little information on behavior or experience prior to release. For the medical records, they have found that there is no efficient way to compile the data. There are many sources containing a wealth of data that have been collected over the history of this program yet they are not in a format that facilitates analysis for assessment of the program.

Category C Case Study

Endangered species that does not currently have a reintroduction program but future conservation efforts include such a program. Current *ex situ* programs contribute data to PHVA for the species and integrated plan is developed for overall conservation.

Program: Pantanal Tapir Program, Lowland Tapir Conservation Initiative

Species: Lowland Tapir (*Tapirus terrestris*)

IUCN Red List Category – Vulnerable

IUCN World Region : South America Country: Brazil

Range: Argentina, Bolivia, Brazil, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Suriname, Venezuela

Figure 3.24. Benjamin, a radio-collared male lowland tapir that is part of the Pantanal Tapir Program.Photo credit: Patrícia Medici.

Conservation situation/feasibility/risk assessment

The lowland tapir occurs naturally at low population densities as a large-bodied species with relatively low reproductive rates and large habitat and nutritional requirements (Sanderson *et al*. 2002). Important as a landscape species (having a significant impact on the structure and functioning of natural ecosystems through an impact on plant communities; Medici 2010), lowland tapir populations are threatened by loss of habitat due to fires, human settlement, large scale agriculture and cattle ranching, road kill and overhunting (Medici 2007). Global IUCN status of the lowland tapir dropped from LowerRisk/Near Threatened in 1996 to Vulnerable in the last assessment in 2008 (Naveda *et al*. 2008). There is little information on population sizes and distribution although the reduction in the populations is estimated at more than 30% in the past 33 years.

Design

With strong financial support and participation from WAZA, EAZA and AZA Tapir Taxon Advisory groups and over 24 zoological institutions in 9 countries, the IUCN/SSC Tapir Specialist Group (TSG) and IUCN/SSC CBSG facilitated a Lowland Tapir Conservation Workshop in 2007. Input reproduction parameters for *Vortex* modelling came mainly from studies of captive tapirs and survival parameters had to be estimated due to the lack of age-specific mortality data. Case studies identified different ranked threats in different countries but overall, sensitivity analysis showed that mortality in sub-adults and adults had the greatest effect on population dynamics. Thus, the possible threats of habitat loss and cattle ranching in the Pantanal would have a great impact on the probability of extinction risk in this slow reproducing species.

The prioritized goals from the outcome of the PHVA were to reduce the loss of lowland tapir habitat due to human impacts on the landscape, establish a management program for subsistence hunting that allowed the recovery of lowland tapir populations, and to have *ex situ* management plans for lowland tapir at international, national and regional levels. Due to the adaptability of tapirs, re-introduction or translocation methods would be a potential paradigm for restoring reduced populations in the wild (Medici *et al.* 2008). Priority actions included standardizing the protocols for monitoring lowland tapir populations, build capacity of field technicians for collecting data and build a database to include monitoring data. Other priority actions were to identify population sizes of lowland tapirs in small and isolated protected areas, include health issues in ongoing research both *ex situ* and *in situ,* and to build an information network on health in both wild and captive populations.

Implementation and Monitoring

The Lowland Tapir Conservation Initiative (LTCI) with Patrícia Medici as Research Coordinator is a program that implements long-term conservation research for lowland tapirs where they occur in the various biomes in Brazil. After a successful research program for lowland tapirs in the Atlantic Forest region of Brazil (Medici 2010), Medici established the Pantanal Tapir Program to lead research on basic ecology, population demography, habitat use and effects of fragmentation, genetics and health status in order to assess population viability and conservation status in the Pantanal region. This will provide scientific information to form the basis to develop a Regional Action Plan for Tapir Research and Conservation in the Pantanal biome.

The Pantanal, the world's largest continuous freshwater wetland, covers approximately 160,000 km^2 spread across Brazil, Boliva and Paraguay (Swarts 2000). About 95% of the Pantanal is privately owned with cattle ranching extending the human footprint into previous wildlife habitat, causing changes in land management practices that threaten wildlife populations. Medici initiated studies to describe and map lowland tapir home range sizes over different seasons, map habitat use and movements through the landscape to investigate habitat connectivity and understand distribution of populations. In addition, she developed studies to assess genetic diversity as well as health status of tapirs and livestock (prevalence of infectious diseases, ecto-and endoparasites and bacteria).

The research site for the LTCI Pantanal Program is Fazenda Baia das Pedras, a family-run working cattle ranch that consists of 15,000 ha of grasslands and forest patches where 6000 head of cattle and 120 horses are free-ranging yet meticulously monitored in a series of fenced-in areas. The whole area of the ranch is maintained such that wildlife shares the natural resources with the livestock and is protected from hunting. The tapir research team consists of Medici, a veterinarian to handle the anesthetizing and monitor health status, a field assistant and a volunteer field assistant. Ten box traps are set up around the natural areas in good tapir habitat for capture events where the tapirs are anesthetized by darting (Figure 3.26).

Each tapir that is caught receives a transponder and is named for future identification. The research team assesses the overall health of the animal, gathers measurement data, takes photographs, collects swabs from nostrils, anus, vagina/prepuce, and mouth to check for bacteria, collects hair and a tissue sample for genetic analysis and collects external parasites such as ticks for later identification (Figure 3.25). The tapir is radio-collared if it is old enough such that further growth will not cause discomfort from the radio-collar. The animal then becomes part of the research program and is closely monitored through radio-telemetry every month for three years.

Figure 3.25 Patrícia Medici documents the capture event of a young female tapir while Paulo Rogerio Mancini checks the heart rate.
Photo credit: Karin Schwartz

Each evening, the research team goes out to track the collared tapirs through radio-telemetry. The radio-collars are either VHF or a combination of VHF/GPS transmitters. At the end of 2013, the team was tracking 14 tapirs and 4 had the GPS collars. The GPS collars were removed periodically (during capture events for those animals) so that the data could be downloaded. For the others, the radio-telemetry involved biangulations to locate the individuals and documenting the coordinates for the locations. The radio-telemetry data are analyzed to determine land use, home range sizes and overlap between individuals and on the population level, to determine abundance and density within the landscape. Camera traps are also used to provide additional data on individual animal

Figure 3.26 Wire mesh box trap with trough of salt to attract the tapirs.
Photo credit: Karin Schwartz

social behavior and reproduction as well as adding to the data to determine abundance and density. Individual identification is critical and is done by recognizing scar patterns, ear notches, spot or coat patterns, size of the animals in the photos or presence of a radio-collar.

Data management for the lowland tapir research consists of a series of *Excel* spreadsheets for each component of the program (see Appendix XIV for data fields). A Master datasheet (titled Capture, Anesthesia, Manipulation, Health) contains data on the capture events including general information on location and the individual captured, chemical/physical restraint parameters, body condition, and results from sample analyses including hematology, biochemistry, bacteria from swabs, feces, ectoparasites, urine, milk, minerals, and presence of infectious diseases. This datasheet has 214 columns for the different fields with each row representing one capture event for an individual animal. There is a separate *Excel* spreadsheet for corporal measurements for the captured animals, a spreadsheet to identify the expedition (capture rounds - date range, methods used) and a Capture Summary spreadsheet that includes not only the captures but the number of direct sightings, camera trap photos, and locations for each animal as well as the number of times a collar fell off and if the animal died. Camera trap photos are organized by study area and year in Microsoft Windows, with an *Excel* spreadsheet that documents the identity of the tapir, GPS coordinates of the camera, location, date, time, moon phase, and temperature. Radio-tracking data are maintained in a radio-telemetry *Excel* spreadsheet that documents bearings: date, time, X & Y coordinates, angle and activity level (of animal) for each radio collar. Fecal samples collected for genetic analysis from different areas of the landscape (or at capture events) are documented in a spreadsheet that contains date, X & Y coordinates, person collecting the sample, purpose and freshness.

The amount of collected data daily is enormous and the researchers keep up with data entry each day. The researchers check the box traps early each morning to ensure that a tapir would not be contained during the heat of the day and spend the evenings from dusk to about 9:30 p.m. (or later) radio-tracking the collared animals. The afternoons are spent entering the data for the previous night's radio-tracking sessions and the box trap-capture data, downloading, organizing and analyzing camera trap and capture event photos, and processing samples collected from the captures. There are usually five expeditions (capture rounds) per monitoring season (the dry season from May through December) with each expedition lasting 16-19 days and thus the data management process requires constant daily attention. Medici has a well-organized system while she is in the field that facilitates data analysis for results that she immediately conveys to her research partners and to the membership of the Tapir Specialist Group.

Assessment

The Lowland Tapir Conservation Initiative conducts careful research guided by *a priori* questions to study lowland tapir biology and ecology in the Pantanal of Brazil. Through a combination of monitoring methods involving camera trapping, radio-telemetry, capture for health assessments and collection of biological samples, the LTCI team is addressing questions on life history parameters, habitat and resource use, and adaptation to natural and anthropogenic environmental changes. Results from this and other long term studies have shown that tapirs have large spatial requirements and reside in habitats containing water bodies such as marshes, lakes and streams which are important for foraging, for protection against predators, and for regulating body temperature in hot weather (Garcia *et al*. 2012). The Tapir Specialist Group is exploring reintroduction as a conservation strategy and has developed the Guidelines for Tapir Re-introductions and Translocations (Medici *et al*. 2008) in preparation for employing this strategy. The current research will build a solid framework for understanding habitat and resource needs that will facilitate any future reintroductions that may be done. Tracking individuals has opened a window on home range sizes, social interactions, reproduction, health, genetic diversity and development that will assist in understanding population viability and to model risk of extinction for the future.

As the chair of the Tapir Specialist Group (TSG) since 2000, Medici has fostered a close link between the *in situ* and *ex situ* communities in order to facilitate exchange of ideas and participation in international strategic action planning for conservation of tapirs in the wild (Figure 3.27). Europe has 122 zoos that have lowland tapirs and participate in the EEP (captive breeding program) and there are 8 North America zoos with this species (ISIS 2014). Both the EAZA Tapir Taxon Advisory Group (TAG) and AZA Tapir TAG are integrally involved in the TSG for exchange of information and to participate in the development of Tapir Strategic Action Plans. All of EAZA and the majority of AZA institutions maintain their animal records in ISIS and EAZA utilizes ISIS software for maintenance of their regional studbook. There are zoos in South

America, Asia and Oceania that also utilize ISIS to maintain their records. Research on tapirs in zoological institutions has contributed to knowledge of life history, reproduction and behavior that has been used in PHVA processes since data from the wild had been limited. Through the TSG, results from studying tapirs in the wild have been relayed to *ex situ* professionals to improve husbandry and health management of tapirs in human care. Linking or integrating data management processes between *in situ* and *ex situ* partners would facilitate information exchange benefitting overall lowland tapir conservation.

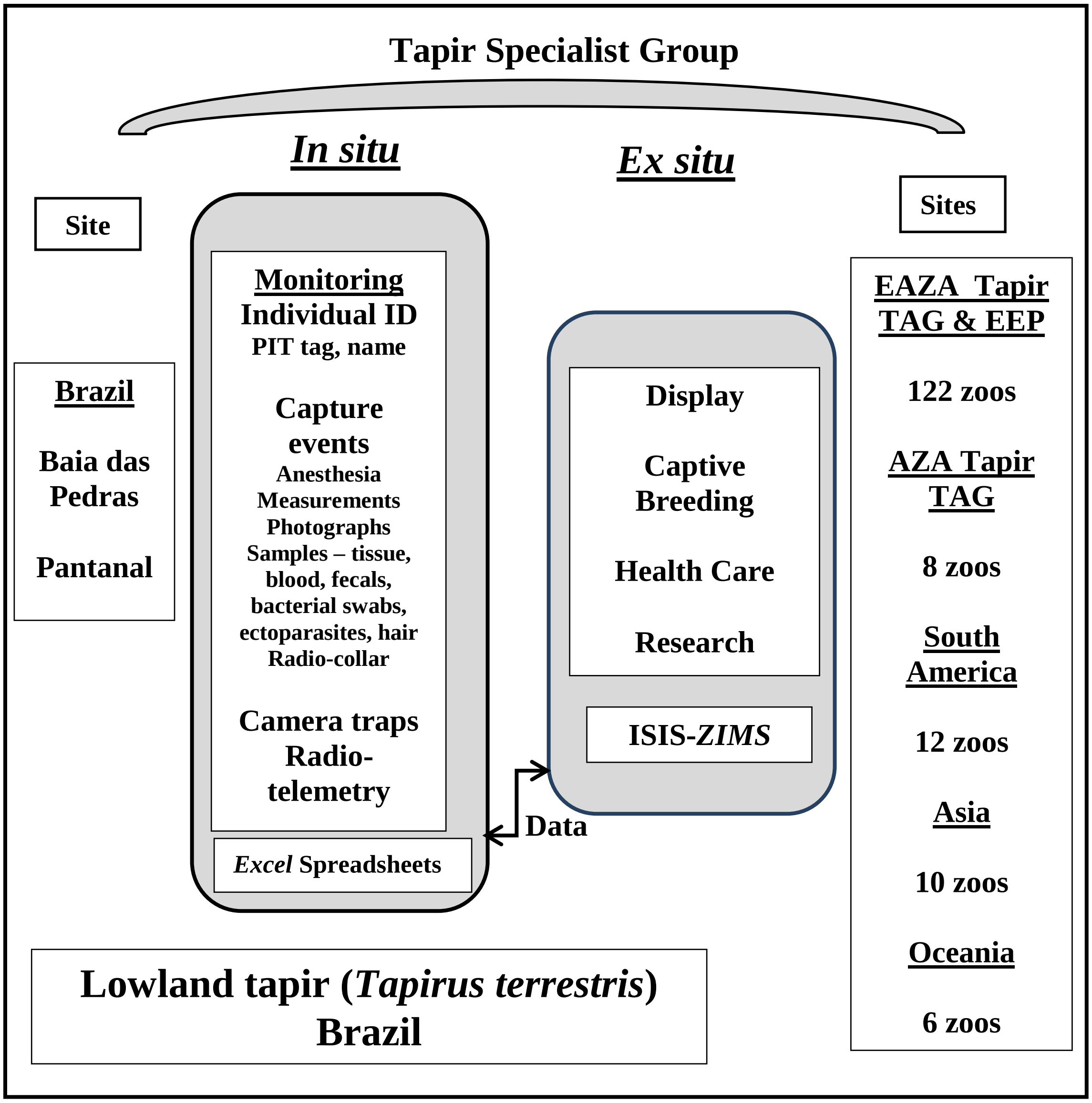


Figure 3.27. Methodologies and database tools for *in situ* and *ex situ* components of lowland tapir conservation

Category D Case Study

Endangered species that has a rescue/rehabilitation/release program but no current reintroduction program of captive animals to the wild.

Program: Cheetah Conservation Fund Program

Species: Namibian Cheetah (*Acinonyx jubatus jubatus*)

IUCN Red List Category – Vulnerable

IUCN World Region: Africa Country: Namibia

Range: Southern and Eastern Africa with largest free-ranging population in Namibia

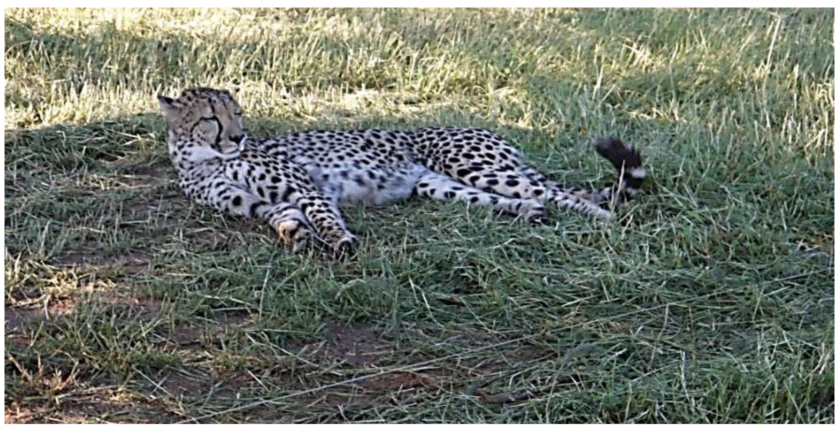


Figure 3.28. Cheetah relaxing after chasing a lure (see cable at bottom of picture) at the Cheetah Conservation Fund Research and Education Center in Namibia
Photo credit: Karin Schwartz

Conservation situation/feasibility/risk assessment

Cheetahs were formerly found in many areas of Africa and in some countries of Asia but are no longer found in 76% of their historic range (Durant *et al*. 2008). The known population is about 7500 adults with the main cheetah populations existing in the southern half of Africa. There are still remnant populations in the Sudan, Ethiopia and Somalia of North East Africa. Iran supports less than 100 cheetahs in the more remote areas, largely due to strong conservation efforts. The number of cheetahs in Namibia declined by over 50% during the 1980s from over 6000 to about 2500 today, and this remains the largest free-ranging population throughout its range (Marker *et al*. 2003).

CBSG facilitated a PHVA for Namibian cheetah and lion in 1996 to address the threats and model extinction risk for these species (Berry *et al*. 1997). Input parameters for *Vortex* simulations (see Table 2.1) were obtained from studies of cheetah in the wild. Results showed that at the annual rate of decline (4 to 7%) for the previous 15 years, there was a 50 – 100% probability of extinction within 100 years. Without human-caused mortality, the population would have a growth potential of 10 – 15% per year. Recommendations for management of the cheetah population on the farmlands were for removal of less than 10% of the adult females and less than 20% of the males to reduce the extinction risk. Additional research was needed to understand population dynamics and biological parameters affecting population growth.

Design

The Global Cheetah Conservation Action Plan (Bartels *et al*. 2002) included action towards improved coordination for censusing cheetah populations, standardizing methodologies for health research (necropsy and data recording in the field and in captivity), and working with different cultural groups to develop improved conflict resolution. A Conservation Action Plan for Cheetahs and Wildlife in Namibia was drafted in 2013 with the overall goal to improve the status of cheetahs and secure the current population in Namibia (Ministry of Environment and Tourism, Government of Namibia 2013). The main objectives and actions include improving knowledge on cheetah conservation biology by conducting research and disseminating results on population numbers, conflict, and threats, and developing mechanisms for the transfer of information relevant to cheetah conservation to all stakeholders

Implementation and monitoring

The Cheetah Conservation Fund Research Centre (CCF) was founded in Namibia in 1990 and incorporates strategies to save cheetah populations through a combination of research, conservation, education and economic development for local communities. CCF is a leader in researching questons on cheetah genetics, biology, ecology, health and reproduction that has had far reaching effects on cheetah conservation as well as benefitting management of cheetahs in human care. CCF works with local farmers to relocate trapped cheetahs or rescue confiscated animals that had been held in unhealthy conditions or orphans whose mother had been killed. Each animal that comes to CCF receives a full medical examination prior to release that includes measurements, samples taken for genetic and health analysis, and body condition assessment. Those that are injured or too young to survive in the wild remain at CCF’s sanctuary. On average, at any time there are about 45-50 cheetahs at CCF. Each cheetah has an annual medical workup where blood is taken for cortisol research, semen is collected for CCF’s sperm bank, and samples or physiological values are taken for other biomedical research. Recovered animals that were maintained at CCF for a sustained period of time go through a re-wilding process where they are placed in a 4000 ha enclosure that contains prey species. These cheetahs are monitored and fed daily until they are able to capture wild prey on their own. They are then released to their final area using a soft release paradigm. After release, they are monitored intensively through radio-telemetry as part of a long-term program to assess survival and reproduction.

Laurie Marker connects with the *ex situ* community in her role as the studbook keeper for the International Cheetah Studbook which contains data on all cheetahs, both dead and living, in zoological institutions worldwide. She is active in both the AZA Cheetah SSP® and the EAZA Cheetah EEP, and recently facilitated a renewed ISIS membership for CCF. Marker maintains a holistic approach in maintaining the International Cheetah Studbook by incorporating wild cheetahs that have been identified, treated or cared for at CCF into the studbook with the global *ex situ* cheetah population (Marker and Cunningham 2012). Wild cheetahs rescued by the N/a'an ku sê Reserve near Windhoek, Namibia and Africat Foundation at Okanjima, Namibia are also included in the studbook. Although these rescue centers do not do any breeding (which is against the law in Namibia), it is valuable to have these animals maintained in the studbook in order to track statistics on numbers and also length of time in the rescue center as well as survival rate once they are released back to the wild.

CCF's mission to return as many cheetahs as possible back to the wild after recovery requires coordination of *in situ* and *ex situ* processes and efficient information flow to track progress of the program. Research is at the center of the whole program with *a priori* questions guiding the data collection such that methodologies (for husbandry and animal care as well as monitoring after release) and resulting data are assessed to evaluate progress towards conservation goals (Figure 3.29). Individual specimen records are important in order to track the progress of each individual as well as overall success of the program so each cheetah is implanted with a transponder and given a name. This information is relayed to the studbook keeper who maintains the overall *ex situ* population records.

Data management processes at CCF have changed over the years along with changes in records-keeping technology. Basic animal records were kept in paper files until the late 1990s when there was an increase in use of personal computers to track the health and management of the cheetahs coming into the Centre. CCF became a member of ISIS in 1999 and used ISIS software mainly for medical records (*MedARKS*) although *ARKS* was used to accession the cheetahs treated and/or maintained at the Centre. Animal records were not kept in *ARKS* but were maintained in an electronic Master Daily Log using *Excel* with individual records cut and pasted to *Excel* spreadsheets for each animal. Health records were kept separately in a clinical file for each animal. CCF's ISIS membership ended in 2009 and they continued to manage their records in a combination of paper files and a series of *Excel* spreadsheets (Figure 3.30).

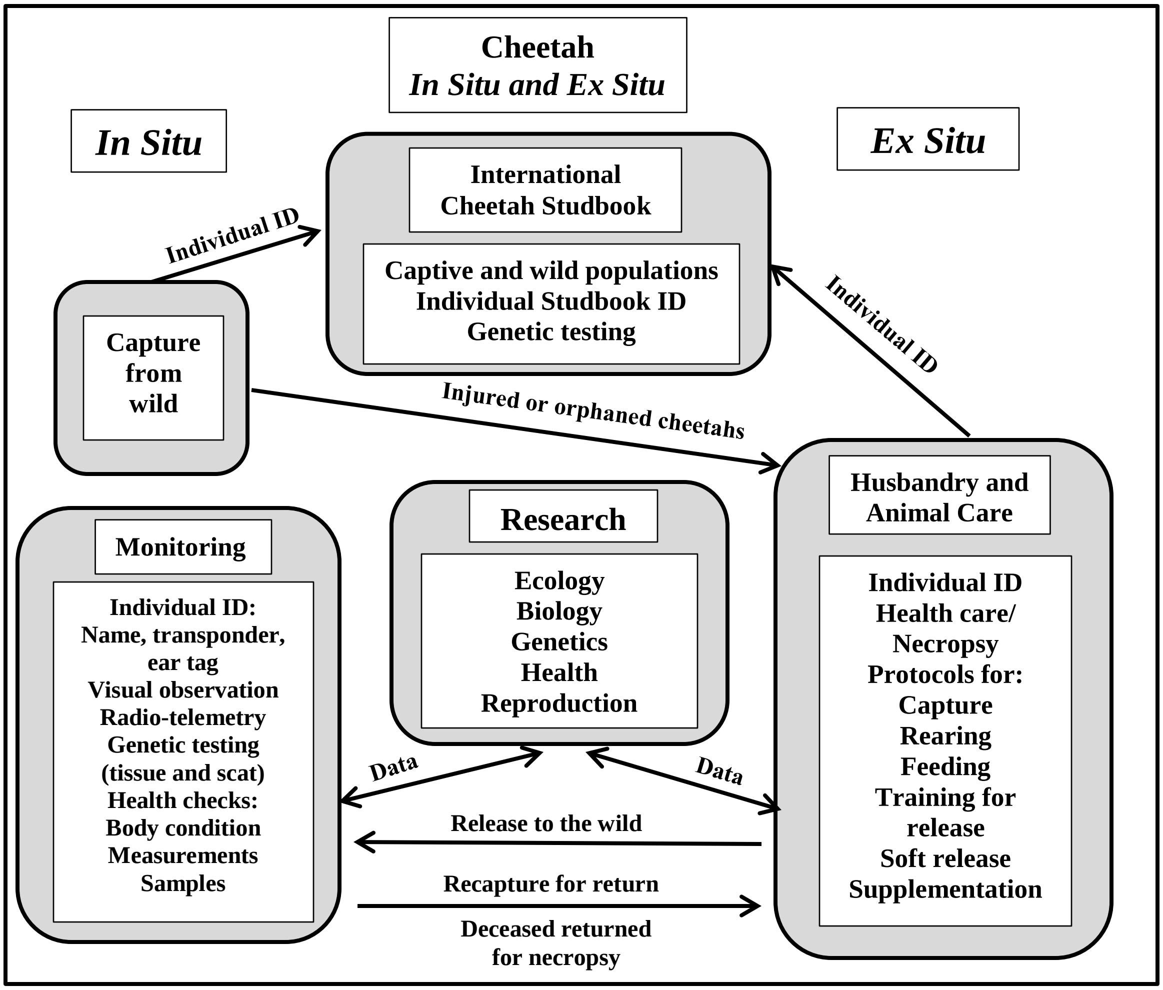


Figure 3.29. Methodologies used for overall management of the Cheetah Conservation Fund recovery program. The arrows designate transfer of animals or data between components of the program.

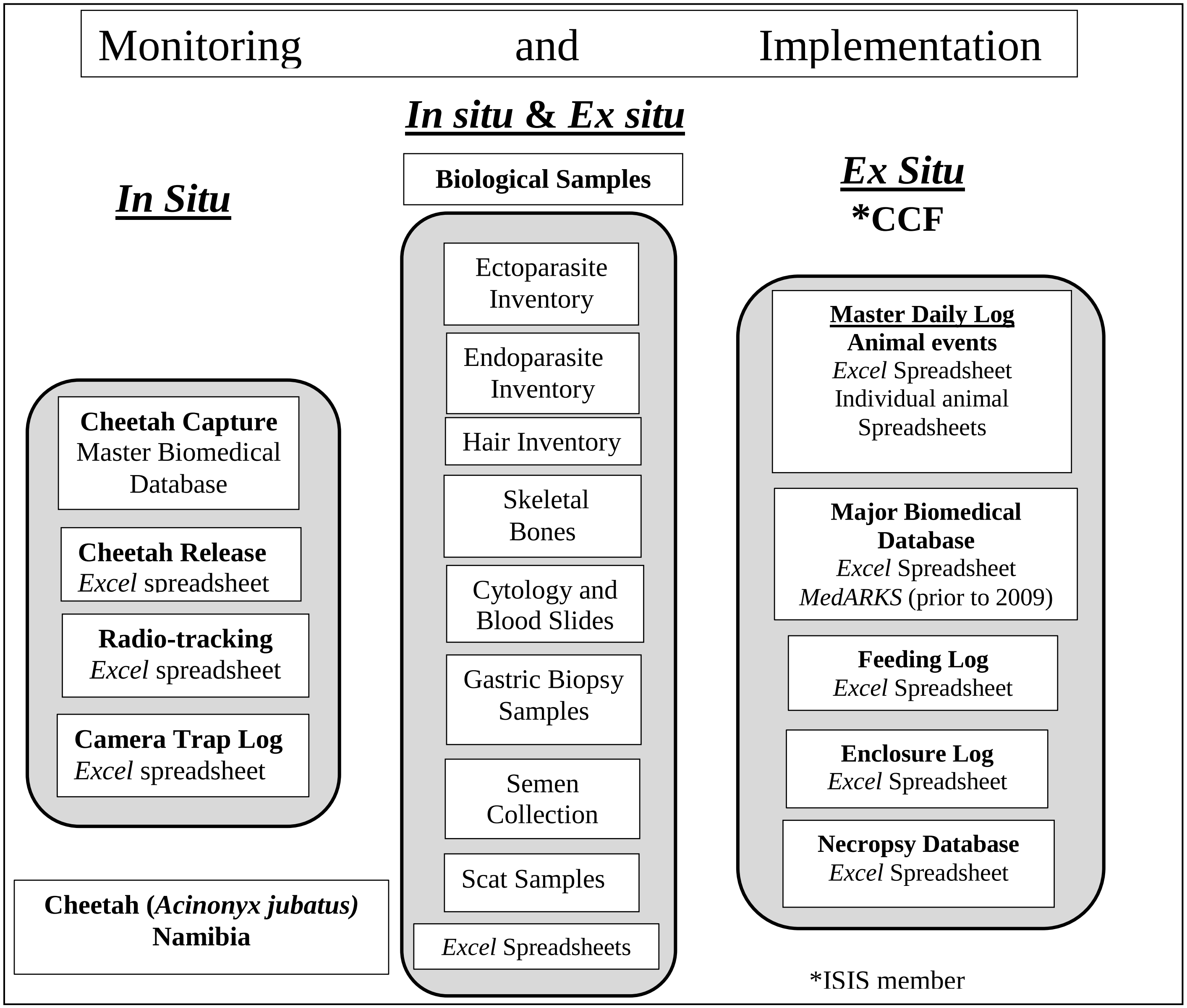


Figure 3.30. Cheetah data management map. For data fields in each category, see Appendix XV.

The Master Biomedical Database contains a collection of data associated with each animal such as capture data, diet, health exam (including vaccinations, injuries, body condition and necropsy information), identification, measurements, and biomedical data (blood analysis, antibody levels, anesthesia, necropsy results) (see Appendix XV). This database is organized with over 200 columns for the different fields with each row representing one event for one animal. There is an *Excel* spreadsheet used for a Feeding Log to document food consumption that also contains fields for anesthesia and treatment as well as enclosure location (see Appendix XV). An Enclosure Log is used to identify the location of each animal within CCF (updated bi-annually). A Necropsy Database contains general necropsy information about each cheetah that died which includes animals at CCF, dead animals from the wild turned in by local people, or CCF-released cheetahs that died in the wild.

Cheetahs that are released are closely monitored through use of VHF radio-transmitters attached by a radio-collar. Releases are documented in the Cheetah Release database that includes information on location, supplementation provided, behavior of the released animal, if there has been a successful kill, and habitat characteristics where the cheetah was found. There is a separate *Excel* spreadsheet for the Radio-tracking information on location, movement, livestock or game presence, and changes in the radio-collar. There is also an *Excel* spreadsheet to manage the camera trap photos that document many species that are present in the Waterberg Conservancy area. Any cheetahs that are found dead are returned to the Centre for necropsy, which is documented in the Master Biomedical Database and the Necropsy Database.

The Conservation Genetics Laboratory conducts on-going research on genetics of the population, incidence of disease, stress hormone levels and reproductive health of the population. The research involves collection of biological samples from cheetahs brought to CCF during health exams and also from cheetahs that die in the wild. CCF maintains banks for sperm, serum, plasm, white and red blood cells, hair and skin samples and additionally, collects scat (fecal) samples from the release areas and the farms. Scat samples are analyzed to obtain genetic identification of individuals for population size estimation and also to determine stress levels, levels of reproductive hormones, identify parasites and prey species. Inventory of the samples is maintained in a number of *Excel* spreadsheets (Figure 3.30). The research increases the understanding of cheetah biology and ecology with benefits to both *in situ* and *ex situ* cheetah populations.

Assessment

The Cheetah Conservation Fund Centre has an extensive network of research and conservation measures to improve the conservation status of cheetahs in Namibia as well as link with the *ex situ* conservation community for holistic conservation action. Over the years, data management processes at CCF have evolved along with new technology. There is a wealth of collected data for many different aspects of cheetah behavior, health, genetics, population dynamics, reproduction, and ecology that is managed in a system that includes *Excel* spreadsheets, *Word* documents, and ISIS software. Additionally, CCF compiles the International Cheetah Studbook thus collaborating with the zoological institutions worldwide to maintain the overview of the cheetah population that includes cheetahs in captivity and those in the wild in Namibia.

The data management system is currently in a state of flux with medical records prior to 2009 retained in *MedARKS* (which is no longer accessible), clinical records held separately from individual animal records, and various datasets in *Excel* spreadsheets that are no longer in use due to changes in the records-keeping processes as time went on. Some of the *Excel* spreadsheets have fields that overlap with other spreadsheets, requiring data entry (or cutting/pasting) in more than one place. To compile records for analysis or reporting, CCF has to access a number of different sources for the information. Recently (early in 2014), CCF acquired *FileMaker Pro*, a network system to manage the array of spreadsheets and data that will help to centralize the data for easier access. Additionally, CCF has renewed their ISIS membership to get the most benefit of maintaining certain records in *ZIMS for Medical*. Laurie will also benefit as the International Cheetah Studbook Keeper with a real-time view of the *ex situ* cheetah population through *ZIMS* . Through these changes, CCF will be able to more efficiently access the wealth of data they have collected which will further their conservation mission.

Category E Case Studies

Endangered species with a research program for the wild populations but no current reintroductions from the captive population (if present).

Program: Armenian Viper Research

Species: Armenian viper (*Montivipera raddei*)

IUCN Red List Category: Near Threatened

IUCN World Region: West Asia Country: Armenia

Geographical Range: Armenia, eastern Turkey, Azerbaijan, and northwestern Iran.

Figure 3.31 Armenian viper (*Montivipera raddei*).
Photo credit: Mark Wanner

Conservation situation/feasibility/risk assessment

The Armenian viper is a medium-sized venomous snake threatened by habitat loss and fragmentation due to agricultural expansion with additional threats from human persecution and overcollection for the pet trade. Armenian viper populations have decreased by 88% over the past 40 years, declining from 20-50 individuals/ha in the mid 1960s to current estimates of 4-10 individuals/ha (Nilson *et* al. 2009).

The *ex situ* population in ISIS member institutions currently stands at 60 specimens with 55 in 8 North American institutions and 5 in one European institution (ISIS 2014). St. Louis Zoo, the holder of the largest *ex situ* population (37 individuals) had conducted research on Armenian viper captive management and reproduction since 1994, compiling important information on reproduction and behavior of the species in captivity (Ettling 1996). St. Louis Zoo had acquired some of the breeding stock from the Tula Exotarium in Russia and the Skansen Akvariet in Sweden, and had a successful breeding program. Very little was known about the species ecology and biology in the wild and research focus by St. Louis Zoo herpetologists turned to studying the species in the wild.

Design

There is no national action plan for conservation of Armenian vipers although the species was listed in the Biodiversity Assessment for Armenia in 2000 (Chemonics International Inc. 2000). The Biodiversity Strategy and Action Plan for Armenia, developed in participation of the CBD agreement, mentions Armenian vipers only in the context of unsustainable harvest for collection of venom but offers no action plan for conservation of this species (Republic of Armenia 2001). The Center for Conservation of Near East Mountain Vipers (which became the Center for Conservation in Western Asia) was developed as part of the Wildcare Institute at the St. Louis Zoo in 2004, with initial focus on the Armenian viper. The overall goal for this program is to “implement conservation management and public education to ensure the future of mountain vipers in the wild” (Ettling 2014).

Implementation and Monitoring

Although there were some early studies on the ecology and reproductive behavior of the Armenian viper in the mountains of Armenia (Darevsky 1966; Bozhanskii and Kudryavcev 1986), there were no published studies on spatial ecology including home range size, movement patterns or habitat use. Partnering with zoological and academic institutions in Russia, the US, Sweden, and Armenia, Jeff Ettling, Director for the WildCare Institute's Center of Conservation in Western Asia, initiated research on spatial ecology and habitat selection of Armenian vipers in two different habitats: 1) a habitat fragmented by agricultural croplands and overgrazing by cattle; and 2) a recovered natural habitat (Figure 3.32). In addition, the research focuses on population dynamics and genetics to provide data that could provide guidelines for conservation management. An initial study conducted in 2007 - 2009 investigated the correlation between home range size and amount of cropland within that area and the vipers' habitat preferences (Ettling 2013a). Results showed that agricultural croplands were mainly avoided and natural steppe habitat was preferred. Rocky, steppe habitat provides the natural resources needed for breeding, hibernating, and feeding activities.

Figure 3.32. Radio-tracking Armenian vipers in Shikahogh Reserve. Photo credit: Erika Travis

The Armenian viper studies are part of a long-term program to monitor population dynamics and genetic diversity within the viper's habitat in order to learn more about the ecology and biology of this species. Individual identification is important for mark-recapture studies for estimation of population sizes, to learn about home range sizes and habitat use and to monitor population dynamics. Captured vipers receive PIT tags or in some cases, are marked by clipping scales on the left or right side. For the captures and recaptures, the researchers take measurements and weights as well as collect blood for genetic and health analyses. Very little is known of normal physiological values so these studies are ongoing to compare with the physiological values of Armenian vipers in captivity. One study is looking at Vitamin D levels in the blood of wild vipers that live at high elevations since Vitamin D deficiency has been known to occur in this species in captivity. This study includes the use of UV light meters to record natural light at the high elevation in order to compare the natural environment to light levels in captivity. For radio-telemetry studies, the vipers are surgically implanted with Holohil temperature-sensitive transmitters that will indicate location and body temperature by the frequency of the pulses (Figure 3.33). Vipers that are found dead are examined to determine cause of death.

Figure 3.33 Surgical implantation of radio-transmitter.
Photo credit: Erika Travis

Data management for this research involves the use of *Excel* spreadsheets for health, measurement and weight data as well as maintaining PIT tag and radio-transmitter inventories (Figure 3.34). For spatial analysis, the recorded geographic coordinates from radio-telemetry are displayed using Geographical Information Systems (GIS; *ArcView*

3.2 and *ArcMap 9.2*). Results of ongoing analyses of the data are used to provide guidelines for conservation management decisions.

<u>Assessment</u>

The spatial ecology and habitat preference studies of Armenian vipers have identified key issues for this species that inhabits natural landscapes fragmented by human land use for agriculture. The results of these studies have been used to inform government environmental authorities resulting in enlarged boundaries of the Khosrov Forest State Reserve and Shikahogh State Reserve as well as the establishment of the Zangesur Sanctuary and Arevik National Park in Armenia. Continued genetic research will be done to understand the impact of human-modified landscapes on gene flow in the population. The research compliments the work done on Armenian vipers in zoological institutions and information exchange is imperative to benefit both *in situ* and *ex situ* communities in understanding the biology and ecology of this rare species. There is a current effort to develop a captive breeding population in conjunction with the Scientific Center of Zoology and Hydroecology, National Academy of Sciences in Yerevan, Armenia as an insurance population for future augmentation of the wild population (Jeff Ettling, personal communication). Population management practices and husbandry protocols are well established in North American zoos and sharing of data and information will be important in developing the new facility. Information sharing is crucial to overall conservation of the Armenian viper.

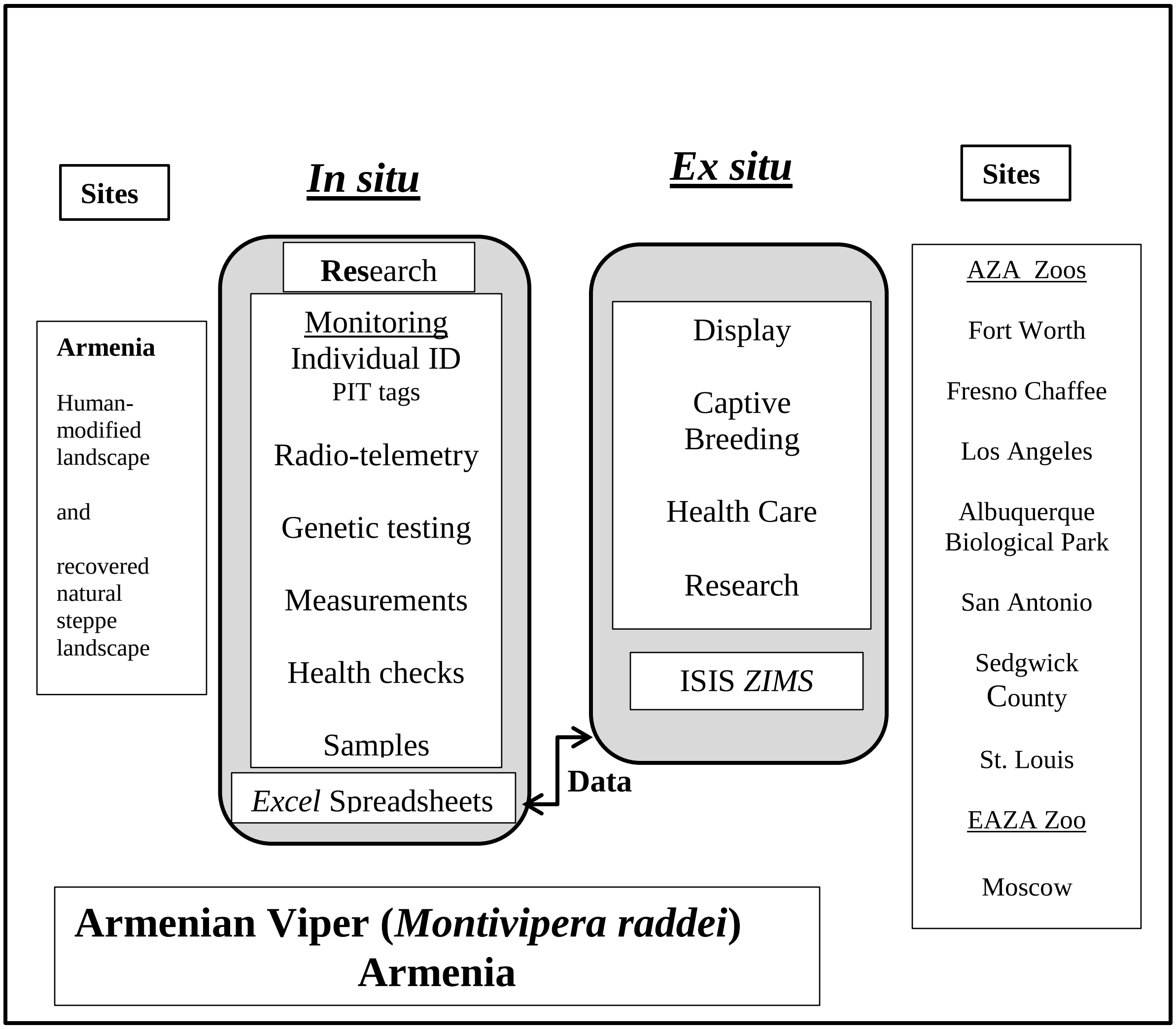


Figure 3.34. Methodololgies and database tools for *in situ* and *ex situ* components of Armenian viper programs. AZA – Association of Zoos and Aquariums; EAZA – European Association of Zoos and Aquaria

Program: Giant Armadillo Project

Species: Giant armadillo (*Priodontes maximus*)

IUCN Red List Category: Vulnerable

IUCN World Region: South America

Country: Brazil

Geographic Range: East of the Andes in northern Venezuela and the Guianas, south to Paraguay and northern Argentina. Reduced population in southeastern Brazil.

Figure 3.35. Lactating giant armadillo female emerging from her burrow.
Photo credit:
Kevin Schafer/Giant Armadillo Project

Conservation situation/feasibility/risk assessment

Although giant armadillos are fairly widespread throughout South America, they occur at very low population densities and are rarely seen due to their fossorial habits. Most of the available information is anecdotal and until recently, no young had ever been seen (Meritt Jr. 2006). There is very little information on life history with reproductive parameters such as gestation, number of young per litter, period of maternal care, and role of male in parental care unknown. The main threats are hunting for its meat and habitat loss as well as capture for the pet trade although they do not live long in captivity. With the low population densities, these threats have a large impact and have led to an estimated population decline of at least 30% within 3 generations (about 21 years) (Anacleto *et al*. 2014). They are nocturnal and spend almost 75% of their time in burrows, constructing a new burrow or resting hole every two days (Desbiez and Kluyber 2013). Desbiez and Kluyber (2013) showed that these giant armadillo burrows (usually constructed every two days) and the area surrounding the openings are used by at least 24 other species as resting spots, for foraging, or as refuge against predators or from high or low temperatures. Thus, giant armadillos have been dubbed as an "ecosystem engineer" species (a species that alters the physical habitat which changes the resources available to other species) making their conservation important for the maintenance of biodiversity of the ecosystem.

There currently are no giant armadillos in ISIS member zoological institutions although there may be some unregistered animals in zoos in South America (ISIS 2014; Meritt Jr. 2006). There are 18 giant armadillos documented in ISIS dating back to 1934 and the last captive animal died in 1988. Behavior of five giant armadillos at Lincoln Park Zoo between 1972 and 1982 was observed daily and records kept on weights, body measurements, temperature and respiratory rates (Meritt Jr. 2006). These records were maintained at Lincoln Park Zoo, then an ISIS member but this was prior to the computerization of the ISIS database, thus the records were not entered in ISIS.

Design

There is no national action plan for conservation of giant armadillos in Brazil and this is the first long-term ecological study of the giant armadillo in the Pantanal. The overall goal is to study the ecology and biology of this rare species and understand how it fits in to the web of biodiversity in the ecosystem (Desbiez 2012). The main objectives include estimating population density, mapping habitat use and movements, describing social and reproductive behavior and assessing health and genetic status of the population. Giant armadillo information will be used to inspire conservation action and turn giant armadillos into ambassadors for biodiversity conservation.

Implementation and Monitoring

The research site for the Giant Armadillo Project is Fazenda Baía das Pedras in the Nhecolândia sub-region of the Pantanal (the same site as for the Lowland Tapir Conservation Initiative - see the description of the site in the LTCI case study). Seven additional ranches adjacent to Baía das Pedras have also joined in to allow research on their properties. The research methods on individual animals include capture, anaethesthetizing them for a health work-up and placement of a radio-transmitter. The health workup includes insertion of a PIT tag for individual identification, collection of ear tissue sample for genetic analysis, blood, urine, feces (collected at top of burrow), external parasites (ticks), and nasal, oral, rectal, vaginal or preputial swabs for bacteria culture (Figure 3.36). The biological samples will be tested for a study of infectious diseases and to determine physiological normal values. Due to the armadillo's fossorial nature, external transmitters would soon fall off so implanted Telonics telemetry transmitters are used. The transmitters, inserted inside the abodominal cavity, offer a 600-800 m detection distance although when the animals are inside a burrow, that distance is reduced to 300 m. At the time of the investigation for this study, there were five animals that had been captured and one with an implanted telemetry device. Following release from the capture event, the team monitors the animal intensively for 30 days and then 10 days per month afterwards. Telemetry continues each night until the animal stops moving. The burrow is

Figure 3.36. Veterinarian Danilo Kluyber and Program Director Arnaud Desbiez perform a work-up on a giant armadillo. Photo credit: Giant Armadillo Project

located by triangulation and in the morning the researchers place a camera trap (video or still) at the burrow entrance which will record the activity that next evening.

Camera traps are placed around the study area near burrows with some sign of recent activity. The photos identify individuals and aid in estimating population density, identifying activity patterns, learning about social behavior and reproduction and identify other species using the burrows. The sex of giant armadillos can be visually identified and individuals can be recognized by the shape and width of the light band around the edge of the carapace armor. The burrows were also the subject of much study to determine physical characteristics, location in the the landscape, and use by giant armadillos as well as other species. Researchers walked line-transects randomly through the ranch to locate burrows, mapping them by GPS location, and measuring for diameter, depth, orientation of hole, and slope.

Giant armadillo data are managed in a series of *Excel* spreadsheets with radio-tracking and camera trap photos organized in a manner similar to those of the lowland tapir research program (see Appendix XVI). For the capture events, data are collected on biometrics, containment and clinical evaluation parameters, and sample analysis, all maintained in separate *Excel* spreadsheets. Data on burrow location and physical characteristics are contained in its own spreadsheet (see Appendix XVI for data fields). Genetic work will be starting in the near future and be the basis of a doctoral thesis of a student from the University of Sao Carlos.

Assessment

The Giant Armadillo Project is researching basic life history parameters and population demographics for a threatened that has been poorly studied. This species could quietly slip into extinction as they occur at low population densities and are secretive such that even local people have never seen them. With current monitoring techniques, researchers are making new discoveries about giant armadillo behavior, health, and reproduction as well as how they provide ecosystem services to support the biodiversity in the Pantanal. The health assessments are being extended to other species of armadillos such as the southern naked-tail armadillo (*Cabassous unicinctus*) and the six-banded armadillo (*Euphractus sexcinctus*) that live in the same area as well as the giant anteater (*Myrmecophaga tridactyla*) in order to understand disease processes within the Superorder Xenarthra. In November 2012, a camera trap caught a photo of a female giant armadillo named Isabelle emerging from a burrow with a baby (Figure 3.37). This was the first observation of a baby giant armadillo and offered the opportunity to discover information about reproduction in this species. A second baby was registered in July 2013. Ongoing monitoring of mother and young will bring additional insight into reproductive processes including length of maternal care, age of independence and dispersal and burrow use for raising young.

Figure 3.37. Giant armadillo female with her baby in the Pantanal. This is the first young giant armadillo ever documented.
Photo credit: Arnaud Desbiez/Giant Armadillo Project

The giant armadillo research is well supported by numerous zoos in Europe, the USA, Australia and South America. Zoological institutions also support conservation by bringing conservation issues to light for their visitors. Recently Arnaud launched a National Armadillo Education Campaign for the Brazilian Zoo and Aquarium Association by distributing a packet of educational materials on armadillos to raise awareness of the threats they are facing. The packet contains an overview of all 21 armadillo species, their range, IUCN status, threats and photos as well as information on the Giant Armadillo Project. A fun, informative booklet, games, illustrations and information pamphlets are provided for each zoo to create their own educational program (www.vivatatu.com.br). The packet will be distributed to zoological institutions that exhibit armadillos around the world. Another connection is that the research in the Pantanal has started to study epidemiological processes in two other armadillo species as well as the giant anteater, which will be valuable information to share with those institutions that maintain those species (there are 300 giant anteaters in 123 institutions and 86 six-banded armadillos in 46 institutions worldwide; ISIS 2014).

With the support of the *ex situ* community, the Giant Armadillo Project is opening up a window into the world of the giant armadillo. While there is no *ex situ* population of giant armadillos, there are closely related species in zoos and information exchange is important to raise awareness of threats facing armadillos in the wild and to effect conservation action (Figure 3.38).

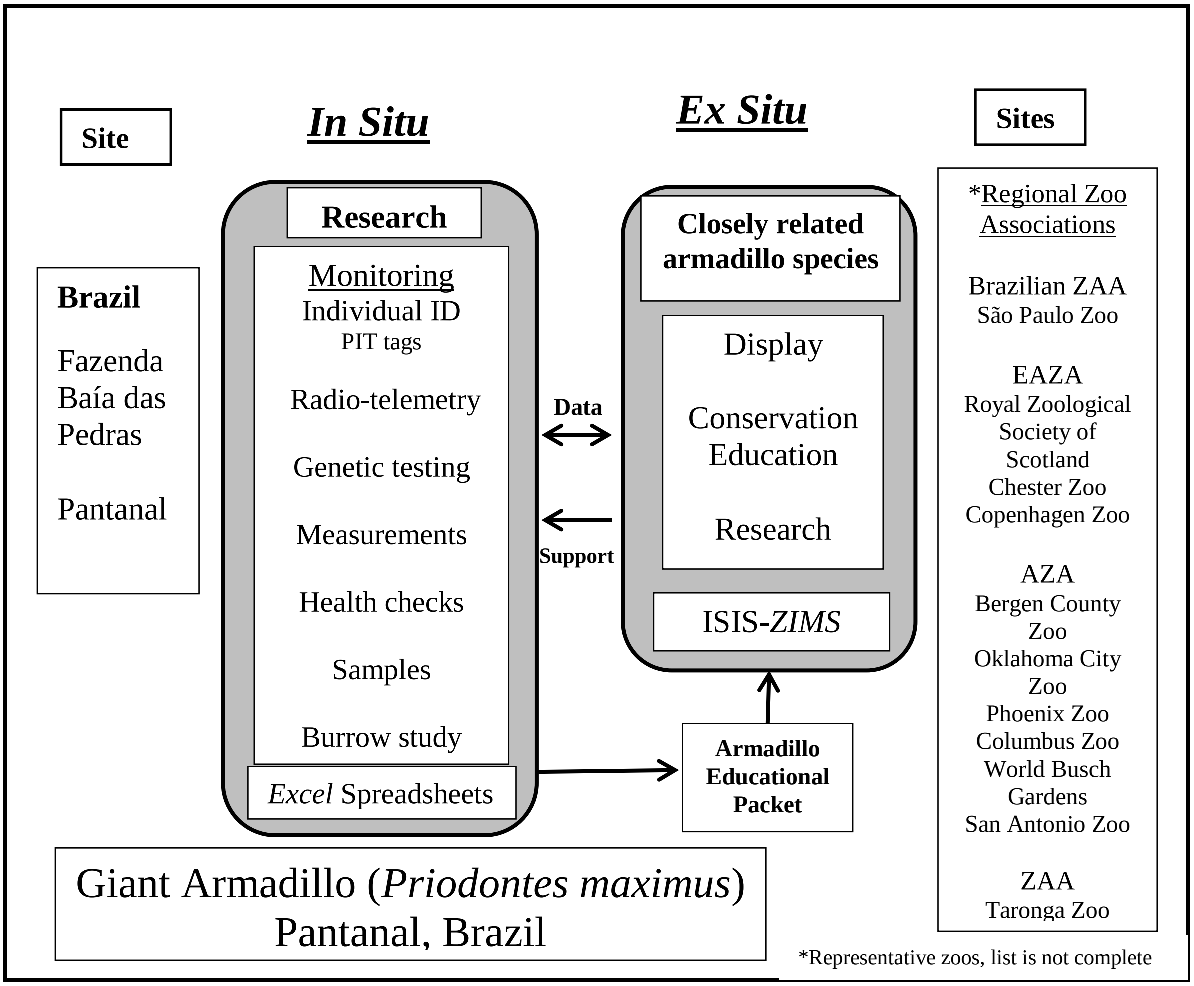


Figure 3.38. Methodologies and data management for the Giant Armadillo Project. ZAA – Zoo and Aquarium Association; EAZA – European Association of Zoos and Aquaria; AZA – Association of Zoos and Aquariums

Discussion

Every conservation story is constructed by combining data from the various components and the trajectory to a successful conservation outcome may be altered requiring adaptive management strategies. The data management practices must meet the requirements to handle the data needed to answer *a priori* questions that lead the way to the conservation goal. In addition, the data management tools used must make the data accessible for analysis. In implementing a "one plan approach" where both *in situ* and *ex* *situ* components are integrated for conservation action, efficiency of data flow between components will impact the trajectory in a certain direction. Improving communication between multiple-disciplinary stakeholders through integration of data management processes will serve to smooth the path towards conservation goals.

Each of the ten case studies of threatened species recovery programs contained both *in situ* and *ex situ* components. In each program the methodologies used and data that was collected depended on the taxon's life history, habitat requirements, threats causing population decline, population size, health status, genetic status, prior scientific knowledge, and program objectives. Data management tools for tracking animals differed among the different components yet all used to some extent records for animals that were individually identified in order to obtain the most comprehensive data. Each program had a connection to ISIS member institutions whether it was for incorporating a captive-bred population into the wild (American burying beetle, red wolf), head-starting young at an institution prior to release back to the wild (takahē, western pond turtle, kakapo), investigating life history for a species whose conservation action plan included reintroductions in the future (lowland tapir), offering care and rehabilitation within an institution prior to release back to the wild (cheetah) or undergoing research on a little known species in the wild to understand life history and habitat requirements that would benefit captive husbandry (giant armadillo, Armenian viper).

Data management tools used in the programs included *Excel* spreadsheets, *Access* databases, hard copies (paper), electronic documents and media (*Word*, PDF, JPEG and other media files), ISIS *ZIMS* database, or other records-keeping systems. For all of the programs, comprehensive data were collected using these various tools whereas efficiency of accessing data for analysis or sharing of data between components was variable depending on the data management processes incorporated by each program.

For the takahē and kakapo programs, genetic diversity of the populations is tracked by entering the individuals (all of wild origin) in a studbook for use in breeding management (translocation to specific island). For both programs, the federal government authority (Department of Conservation) overseeing the program maintains an overall *Access* database containing records for each individual bird. The *ex situ* rearing facilities are also managed by the DOC, with records maintained in the same database. The database is not set up for easy access to an individual specimen record (all information for a particular individual) although the structure of the relational database allows for development of queries that could pull out that information. The Auckland Zoo veterinary staff is closely involved with performing necropsies and health care for sick or injured birds, and records on those individuals that are cared for at the zoo are kept within ISIS (core data and medical/necropsy data). In addition, Massey University maintains necropsy and biosample data within a federal mortality database. While exchange of information through reports and meetings serve to inform the different partners, time lags and duplication of records-keeping in the various databases prevent the complete efficiency of the records-keeping system.

The western pond turtle program involves two ISIS member institutions that handle the head-starting portion of the program and the turtles are released to various sites in two regions of Washington (Columbia River Gorge and Puget Sound regions). A comprehensive *Access* database, which cross-references the turtle records through an ISIS number, is used to track individual turtles in the wild but only for the Columbia River Gorge region. Recent PHVA results showed that husbandry protocols and data management between the ISIS institutions was not standardized, and in addition, one of the priority issues is lack of data exchange between the *in situ* and *ex situ* partners of the program.

The red wolf program involves numerous *ex situ* facilities including zoos, wildlife or nature centers, living museums, and government breeding centers. Four of the eight wildlife or breeding centers and 26 of the 27 zoos are ISIS members. Some of the wildlife centers maintain paper records while some use *Excel* spreadsheets and *Word* documents and even the ISIS member institutions use the records-keeping system to different extents. Some institutions use the medical component of ISIS whereas most do not such that medical and necropsy records are not kept in a standardized fashion. All the facilities are part of the AZA Red Wolf SSP® and all wolves, both in the wild and those in the *ex situ* facilities, are carefully monitored and managed for genetic diversity through documentation in the studbook. The AZA species coordinator keeps in constant contact with the SSP® institutions and works closely with the USFWS for management of the program. The USFWS maintains an *Access* database that covers monitoring data for animals in the wild and also has paper files with historical data. Much of the medical and necropsy data remain in paper files that are difficult to access.

The cheetah program has a valuable research program in addition to the rescue and rehabilitation work for injured cheetahs. With 40+ cheetahs maintained at the facility at any time, in-house records on all aspects of care and maintenance are important to keep. The data management program containing the large amount of data consists of numerous *Excel* spreadsheets as well as historical medical records that were maintained in ISIS during the membership period that ended in 2009. The main database spreadsheet consists of over 200 fields for each event entered, and it is difficult to isolate all the records on one individual from this database as well as from all the other spreadsheets. It is also difficult to recover data for an animal both when it was in the facility and after release to the wild. There is some overlap in data fields between the spreadsheets, requiring duplicate entries. Clinical records have been kept separately and in many cases are in paper format, making access for analysis difficult. Recent renewal of membership in ISIS will allow access to historical records after a period of data clean-up and the use of *ZIMS* will streamline the data management process.

The three wildlife research programs (lowland tapir, giant armadillo and Armenian viper) all had clear objectives in pursuing information on species that were not well studied. Their connection to *ex situ* programs included collaboration for exchange of information that would lead to a better understanding of the species. The data management processes included use of *Excel* spreadsheets to maintain records on long-term monitoring of individuals (health, genetics, spatial ecology, morphometrics, population dynamics). Since the spreadsheets are not linked in a relational database, the researcher has to access many separate spreadsheets to piece together a report on one individual. Thus, there is duplication of data between the spreadsheets that affects the efficiency for analysis. All three programs are exploring new territories and working out methodologies that would best provide the data needed for analysis.

Conclusions

As the data are contributed from all the components of a program, the chapters of each conservation story come together to show measures of success - in understanding of species biology and ecology, in perfecting methodologies, in reducing threats and effecting conservation. Yet challenges still exist on many fronts such that constant attention is needed to adapt strategies by taking advantage of new methodologies and technologies that will maximize efficiency and facilitate the collaboration necessary to succeed. For each program, data management processes involved a combination of database programs (*Access*, *Excel*), *Word* documents, paper forms, and media (camera trap photos) such that compiling data for analysis was inefficient. Communication between *ex situ* and *in situ* partners required duplicate efforts in reporting and lag times compromised effective conservation action. Providing direct linkages between *in situ* and *ex situ* data management processes would promote an integrated approach to species conservation. Chapter 4 will examine the potential for this integrated approach for each of the case studies by aligning their data requirements with the functionality of *ZIMS* .

References

Amaral, M., R. Morgan, C. Davidson, H. Dikeman, K. Holzer, and O. Byers (eds.) 2005. American Burying Beetle (Nicrophorus americanus) Population and Habitat Viability Assessment: Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN. pp. 77

Amphibiaweb. amphibiaweb.org. Accessed 12.June.2014

AnaBat™ System. http://www.titley-scientific.com/us/index.php/anabat_home. Accessed 18.June.2014

Anacleto, T.C.S., F. Miranda, I. Medri, E. Cuellar, A.M. Abba, and M. Superina.2014.*Priodontes maximus*. The IUCN Red List of Threatened Species. Version 2014.1. www.iucnredlist.org. Accessed 19 July 2014

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/about/. Accessed 12.June.2014

ARKive. www.arkive.org. Accessed 12.June.2014

AZA Institutional Data Management Advisory Group Government Ownership Task Force. 2005. Red Wolf (*Canis rufus*) Record Keeping Protocol. https://www.aza.org/uploadedFiles/Animal_Care_and_Management/Animal_Management/Animal_Data_and_Recordkeeping/IDMAG_Documents/RecordsWolfRed(1).pdf. Accessed 25.July.2014

Balme, G.A., L.T.B. Hunter, and R. Slotow. 2009. Evaluating methods for counting cryptic carnivores. Journal of Wildlife Management 73(3): 433-441

Baran, İ and M. Atatür.1998. Turkish herpetofauna: amphibians and reptiles. Ministry of Environment. Ankara, Republic of Turkey

Bartel, R.A., and D.R. Rabon Jr. 2013. Re-introduction and recovery of the red wolf in the southeastern USA. pp. 107-115. In: Soorae, P.S. (ed.). 2013. Global Re-introduction Perspectives: 2013. Further case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Bartels, P., V. Bouwer, A. Crosier, D. Cilliers, S. M. Durant, Y. Friedmann, J. Grisham, L. Marker, and D. E. Wildt. (eds.). 2002. Global Cheetah Action Plan Review final workshop report. Global Cheetah Conservation Action Plan-Workshop held at Shumba Valley Lodge in South Africa from the 27th to the 30th of August 2001 Apple Valley, MN: IUCN/SSC Conservation Breeding Specialist Group. pp. 78

Beeland, T.D. 2013. The Secret World of Red Wolves. University of North Carolina Press. Chapel Hill, NC. pp. 256

Berry, Hu, M. Bush, B. Davidson, O. Forge, B. Fox, J. Grisham, M. Howe, S. Hurlbut, L. Marker-Kraus, J. Martenson, L. Munson, K. Nowell, M. Schumann, T. shille, F. Stander, K. Venzke, T. Wagener, D. Wildt, S. Ellis, and U. Seal. (eds.).1997. Population and Habitat Viability Assessment for the Namibian Cheetah (*Acinonyx jubatus*) and Lion (*Panthera leo*). Conservation Breeding Specialist Group. Otjiwarongo, Namibia

Betts, B.J. 1998. Effects of interindividual variation in echolocation calls on identification of big brown and silve-haired bats. Journal of Wildlife Management 62(3): 1003-1010

Beyer, A., P.W. Sumner, C. Olfenbuttel, and C. Proctor. North Carolina Wildlife Resources Commission. http://www.ncwildlife.org/portals/0/learning/documents/profiles/redwolf.pdf. Accessed 24.July.2014

BirdLife International. www.birdlife.org. Accessed 12.June.2014

BirdLife International 2013. *Strigops habroptila*. The IUCN Red List of Threatened Species. Version 2014.1. <www.iucnredlist.org>. Accessed 5.July.2014

Bozhanskii, A.T. and S.V. Kudryavcev. 1986. Ecological observations of the rare vipers of the Caucasus. pp. 495-498. In: Rocek, Z. (ed.). Studies in Herpetology. Prague, Czech Republic

Bruner, A., R. Gullison, R. Rice, and G. Fonseca. 2001. Effectiveness of parks in protecting tropical diversity. Science 291(5501): 125-128

Burghardt, T., B. Thomas, P.J. Barham and J. Ćalić. 2004. Automated visual recognition of individual African penguins. Firth International Penguin Conference. Ushuaia, Tierra del Fuego, Argentina

Bury, R.B. and D.J. Germano. 2008. *Actinemys marmorata* (Baird and Girard 1852) – Western Pond Turtle, Pacific Pond Turtle. In: Rhodin, A.G.J., P.C.H. Pritchard, P.P. van Dijk, R.A. Saumure, K.A. Buhlmann, and J.B. Iverson (eds.). Conservation Biology of Freshwater Turtles and Tortoises: A compilation project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group.Chelonian Research Monographs (ISSN 1088-7105) No. 5, doi: 10.3854/crm.5.001.marmorata.v1.2008. Chelonian Research Foundation

Byers, J.E. and E.G. Noonburg. 2007. Poaching, enforcement, and the efficacy of marine reserves. Ecological Applications 17(7): 1851-1856

Byers, O., C. Lees, J. Wilcken, and C. Schwitzer. 2013. The One Plan Approach: the philosophy and implementation of CBSG's approach to integrated species conservation planning. WAZA Magazine 14: 2-5

Caci, G., A. B. Biscaccianti, L. Cistrone, L. Bosso, A.P. Garonna, D. Russo. 2013. Spotting the right spot: computer-aided individual identification of the threatened cerambycid beetle *Rosalia alpine*. Journal of Insect Conservation 17(4): 787-795

Caughlin, L. and K.L. Oakly. 2001. Cost considerations for long-term ecological monitoring. Ecological Indicators 1(2): 123-134

Chemionics International Inc.2000. Biodiversity Assessment for Armenia: Task Order under the Biodiversity & Sustainable Forestry IQC (BIOFOR). USAID Contract Number: LAG-I-00-99-00014-00. Chemionics International Inc. Washington, D.C.

Collen B., L. McRae, J. Loh, S. Deinet, A. De Palma, R. Manley, and J.E.M. Baillie. 2013. Tracking changes in abundance: Living Planet Index. In: Collen B, Pettorelli N, Baillie JEM & Durant SM. (eds.) Biodiversity Monitoring & Conservation: Bridging the gap between global commitment and local action. Wiley-Blackwell: Cambridge, U.K.

Collins, R. and K.A.I. Nekaris. 2008. Release of greater slow lorises, confiscated from the pet trade, to Batutegi Protected Forest, Sumatra, Indonesia. pp. 192 – 196. In: Soorae, P.S. (ed.). Global Re-introduction Perspectives: 2008. Re-introduction case-studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Conservation Breeding Specialist Group (CBSG). 2008. Population and Habitat Viability Assessment for the Kihansi Spray Toad. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN

Darevsky, I.S. 1966 Ecology of rock-viper (*Vipera xanthia raddei* Boettger) in the natural surroundings of Armenia. Memorias Instituto Butantan Simposio Internacional 33: 81-83

De Thoisy, B, A.G. da Silva, M. Ruiz-García, A. Tapia, O. Ramirez, M. Arana, V. Quse . C. Paz-y-Miño, M. Tobler, C. Pedraza, A. Lavergne. 2010. Population history, phylogeography, and conservation genetics of the last Neotropical mega-herbivore, the lowland tapir (*Tapirus terrestris*).BMC Evolutionary Biology 10(1): 278

Desbiez, A.L.J. 2012. Studying a living fossil: Conservation and ecology of the giant armadillo in the Brazilian Pantanal. Proposal to the Royal Zoological Society of Scotland, Scotland

Desbiez, A.L.J. and D. Kluyber. 2013. The role of giant armadillos (*Priodontes maximus*) as physical ecosystem engineers. Biotropica 45(5): 537-540

Dickinson, J.L., B. Zuckerberg, and D.N. Bonter. 2010. Citizen science as an ecological research tool: challenges and benefits. Annual Review of Ecology, Evolution, and Systematics 41: 149-172

Diggle, R. 2006. Feasibility for a community-based wildlife monitoring system for the Srepok Wilderness Area, Cambodia. Report. International Institute for Environment and Development and WWF. http://pubs.iied.org/pdfs/G02323.pdf. Accessed 22.June.2014

Durant, S., L. Marker, N. Purchase, F. Belbachir, L. Hunter, C. Packer, C. Breitemoser-Wursten, E. Sogbohossou and H. Bauer. 2008. *Acinonyx jubatus*. The IUCN Red List of Threatened Species. Version 2014.1. <www.iucnredlist.org>. Accessed 10 July 2014

Dutta, T., S. Sharma, J.E. Maldonado, T.C. Wood, and J. Seidensticker. 2012. A reliable method for individual identification and gender determination of wild leopards (*Panthera pardus fusca*) using non-invasive samples. Conservation Genetics Resources 4(3): 665-667

Earnhardt, J.M., S.D. Thompson, G. Turner-Erfort (eds.). 1998.Standards for Data Entry and Maintenance of North American Zoo and Aquarium Animal Records Databases©. Lincoln Park Zoo, Chicago, IL, USA

EAZA. 2013. The Modern Zoo: Foundations for Management and Development. EAZA Executive Office. Amsterdam, the Netherlands

Ecological Software Solutions LLC (ESS). 2009. MIST Version 2.2.3.4. Hegymagas, Hungary. http://www.ecostats.com/web/MIST Accessed 21.June.2014

Eggert, A.K and S.K. Sakaluk. 1995. Female-coerced monogamy in burying beetles. Behavioral Ecology and Sociobiology 37(3): 147-153

Embarcadero Technologies. 2010. Delphi XE. San Francisco, CA. http://www.embarcadero.com/products/delphi Accessed 22.June.2014

Encyclopedia of Life. http://eol.org/. Accessed 12.June.2014

Esri. ArcGIS. http://www.esri.com/software/arcgis. Accessed 18.June.2014

Ettling, J. 1996. Natual history, husbandry, and captive reproduction of mountain vipers (*Vipera bornmuelleri* and *Vipera wagneri*). pp. 139-144. In: Strimple, P. D. (ed.). Advances in Herpetoculture, International Herpetological Symposium, Inc.

Ettling, J. 2005. Saint Louis Zoo WildCare Institute: Center for Conservation of Near East Mountain Vipers. Herpetological Review 36(3)

Ettling, J. 2013a. Conservation efforts for the Armenian viper, *Montivipera raddei* in Armenia.Year of the Snake News 9: 1, 4-5. http://www.parcplace.org/images/stories/YOS/YearoftheSnakeNewsSeptember.pdf

Ettling, J. 2013b. Spatial ecology of Armenian vipers, *Montivipera raddei*, in a human-modified landscape. Copeia 1(1): 64-71

Ettling, J. St. Louis Zoo WildCare Institute website: http://www.stlzoo.org/conservation/wildcare-institute/mountainvipersinarmenia/. Accessed 16.July.2014

FishBase. www.fishbase.org. Accessed 12.June.2014

Forster, B., M. Vogt, T. Zeigler, D. Schrudde, M. Raffel. 2010. Langurs in Vietnam: rescued at the very last minute? pp. 133-138. In: Dick, G. and M. Gusset (eds.). Building a Future for Wildlife: Zoos and Aquariums Committed to Biodiversity Conservation, World Association of Zoos and Aquariums (WAZA), Gland, Switzerland

Garcia, M.J., E.P. Medici, E.J. Naranjo, W. Novarino, and R.S. Leonardo. 2012. Distribution, habitat and adaptability of the genus *Tapirus*. Integrative Zoology 7(4): 346-355

Germano, D.J. and R.B. Bury.2001. Western pond turtles (*Clemys marmorata*) in the Central Valley of California: status and population structure. Transactions of the Western Section of The Wildlife Society 37:22-36

Gordon, Rebecca A.2009. Effects of incubation temperature on the embryonic development and hatching success of the western pond turtle *(Emys marmorata)*. Diss. Department of Biology, Sonoma State University

Grueber, C.E. 2005. Pedigree and microsatellite analysis of genetic diversity in the endangered New Zealand takahē (*Porphyrio hochstetteri*). M.Sc. thesis, University of Otago, Dunedin. pp. 117

Gusset, M.2009. A framework for evaluating reintroduction success in carnivores: lessons from African wild dogs. pp. 307-320. In: Hayward, M.W. and M.J. Somers (eds.).Reintroduction of top-order predators. Ltd.Blackwell Publishing, West Sussex, UK

Harrison, M. Evolutionarily Distinct and Globally Endangered (EDGE) website. http://www.edgeofexistence.org/birds/species_info.php?id=1946. Accessed 5.July.2014

Hays, D. W., K. R. McAllister, S. A. Richardson, and D. W. Stinson. 1999. Washington state recovery plan for the western pond turtle. Washinton Department of Fish and Wildlife, Olympia, WA pp. 66

International Species Information System (ISIS).2014. zims.isis.org

International Species Information System (ISIS) Conservation Partners. http://www2.isis.org/AboutISIS/Pages/Conservation-partners.aspx. Accessed 15.June.2014

IUCN Red List. www.iucnredlist.org. Accessed 12.June.2014

IUCN Red List News. 2014. Kihansi spray toad returns to the wild. http://www.iucnredlist.org/news/kihansi-spray-toad-returns-to-the-wild. Accessed 15.October.2014

IUCN Species Information Service (SIS). http://www.iucnredlist.org/technical-documents/red-list-training/species-information-service. Accessed 2.June.2014

Kakapo Recovery website. http://kakaporecovery.org.nz/research/. Accessed 7.July.2014

Kelly, B.T., A. Beyer, & M.K. Phillips. 2008. *Canis rufus*. The IUCN Red List of Threatened Species. Version 2014.2. www.iucnredlist.org. Accessed 25 July 2014

Kelly, B.T., P.S. Miller, and U.S. Seal (eds.). 1999. Population and Habitat Viability Assessment Workshop for the Red Wolf (*Canis rufus*).Conservation Breeding Specialist Group (IUCN/SSC). Apple Valley, MN

Kenward, R. 2001. A Manual for Wildlife Radio Tagging. Academic Press. San Diego, CA. pp.331

Khatibu, F.H.A. *et al*. 2010. Kihansi Spray Toad Re-introduction Guidelines. CBSG. Apple Valley, MN

Kimati, B. 2014. Tanzania: Kihansi spray toads belong to unique trait in Tanzania. Tanzania Daily News. http://www.dailynews.co.tz/index.php/features/30386-kihansi-spray-toads-belong-to-unique-trait-in-tanzania

Lacy, R.C., J.D. Ballou and J.P. Pollak. 2012. PMx: software package for demographic and genetic analysis and management of pedigreed populations. Methods in Ecology and Evolution 3(2): 433-437

Lahiri, M., C. Tantipathananandh, R. Warungu, D.I. Rubenstein, T.Y. Berger-Wolf. 2011. Biometric animal databases from field photographs: identification of individual zebra in the wild. Proceedings of the ACM International Conference on Multimedia, Trento, Italy, 2011

Lane, M.A. and J.L. Edwards. 2007. The Global Biodiversity Information Facility (GBIF). pp.1-4. In: Curry, G.B. and C.J. Humphries (eds.). Biodiversity Databases: Techniques, Politics, and Applications. CRC Press. Boca Raton, FL

Law, P.R., Z.C. Jewell, and S.K. Alibhai. 2013. Using shape and size to quantify variation in footprints for individual identification: Case study with white rhino (*Ceratotherium simum*). Wildlife Society Bulletin 37(2): 433-438

Lee, S., K. Zippel, L. Ramos & J. Searle.2006. Captive-breeding programme for the Kihansi spray toad *Nectophrynoides asperginis* at the Wildlife Conservation Society, Bronx, New York. International Zoo Yearbook. 40: 241–253

Lee, W.G. and I.G. Jamieson. 2001. The Takahē - Fifty Years Of Conservation Management and Research. University of Otago Press, Dunedin. pp. 132

Lomolino, M.V., J.C. Creighton, G.D. Schnell, and D.L. Certain. 1995. Ecology and conservation of the endangered American burying beetle (*Nicrophorus americanus*). Conservation Biology 9(4): 605-614

Los, W. and C.H.J. Hof. 2007. The European Network for Biodiversity Information. pp. 5-12. In: Curry, G.B. and C.J. Humphries (eds.). Biodiversity Databases: Techniques, Politics, and Applications. CRC Press. Boca Raton, FL

Luhunu, S. and M. Bechem. 2010. Challenges in implementing MIST (Management Information System) in Central Africa. Pachyderm 47: 115-117

Mannion, O. 2004. MIST-GIS Step-bystep User Guide. http://www.ecostats.com/web/data/_uploaded/file/software/mist/MISTGIS_User_Guide_English.pdf. Accessed 21.June.2014

Marker, L. and S. Cunningham. 2012. International Cheetah (*Acinonyx jubatus*) Studbook. Cheetah Conservation Fund. Otjiwarongo, Namibia

Marker, L.L., A.J. Dickman, M.G.L. Mills, D.W. Macdonald. 2003. Aspects of the management of cheetahs, *Acinonyx jubatus jubatus* trapped on Namibian farmlands. Biological Conservation 114(3): 401-412

Marker, L. A. Dickman, C. Wilkinson, B. Schumann, E. Fabiano. 2007. The Namibian cheetah: status report.Cat News: 4-13

McGregor, P. and T. Peake. 1998. The role of individual identification in conservation biology. pp. 31-55. In: Caro, T. (ed.). Behavioral Ecology and Conservation Biology. Oxford University Press, Inc. New York, New York

Medici, E.P. 2010 Assessing the viability of lowland tapir populations in a fragmented landscape. Ph.D. Dissertation, University of Kent, Canterbury, United Kingdom

Medici, E.P., A. L. J. Desbiez, A. Gonçalves da Silva, L. Jerusalinsky, O. Chassot, O.L. Montenegro, J.O. Rodríguez, A. Mendoza, V.B. Quse, C. Pedraza, A. Gatti, L.G.R. Oliveira-Santos, M.A. Tortato, V. Ramos Jr., M.L. Reis, G. Landau-Remy, A. Tapia and A.A. Morais. 2007. Lowland Tapir (*Tapirus terrestris*) Population and Habitat Viability Assessment (PHVA): final Report. IUCN/SSC Tapir Specialist Group (TSG) and IUCN/SSC Conservation Breeding Specialist Group (CBSG), Apple Valley, MN, USA

Medici E.P., K. Flesher, B.M. Beisiegel, A. Keuroghlian, A.L.J. Desbiez, A. Gatti, A.R. Mendes-Pontes, C.B. Campos, C.F. Tofoli, E.A. Moraes-Junior, F.C. Azevedo, G.M. Pinho, J.L.P. Cordeiro, T.S. Santos-Junior, A.A. Morais, P.R. Mangini, L.F. Rodrigues, L.B. Almeida. 2012. Avaliação do Risco de Extinção da Anta Brasileira *Tapirus terrestris* Linnaeus, 1758, no Brasil. Biodiversidade Brasileira, Instituto Chico Mendes de Conservação da Biodiversidade (ICMBIO), Número Temático: Avaliação do Estado de Conservação dos Ungulados, Ano II, Nº 3, pp.103–116

Medici, E.P., P. Rogerio Mangini, A. Gonçalves da Silva, L. A. Salas (eds.). 2008. Guidelines For Tapir Re-introductions and Translocations. IUCN/SSC Tapir Specialist Group. Campo Grande, Brazil

Meek, P.D., G. Ballard and P. Fleming. 2012. An introduction to camera trapping for wildlife surveys in Australia. PestSmart Toolkit publication. Invasive Animals Cooperative Research Centre. Canberra, Australia

Meritt Jr., D. 2006. Research questions on the behavior and ecology of the giant armadillo (*Priodontes maximus*). Edentata 7: 30-33

Ministry of Environment and Tourism, Government of Namibia. 2013. National Conservation Action Plan for Cheetahs in Namibia. http://www.met.gov.na/SiteDirectory/Documents/Final%20draft_Cheetah%20NAP_Namibia_Sep%202013.pdf. Accessed 13.July.2014

Mohamed, Nassoro. 2013. Reintroduction of an Extinct-in-the-Wild amphibian: the return of the Kihansi spray toad to its habitat in the Udzungwa Mountains of Tanzania. p. 145. In: 26th International Congress for Conservation Biology: Connecting Systems, Disciplines and Stakeholders. Society for Conservation Biology. 21-25.July.2013, Baltimore, Maryland, USA

Moore, M., G. Early, K. Touhey, S. Barco, F. Gulland, R. Wells. 2007. Rehabilitation and release of marine mammals in the United States: risks and benefits. Marine Mammal Science 23(4): 731-750

Naveda, A., B. de Thoisy, C. Richard-Hansen, D.A. Torres, L. Salas, R. Wallance, S. Chalukian, and S. de Bustos. 2008. *Tapirus terrestris*. The IUCN Red List of Threatened Species. Version 2014.1. www.iucnredlist.org. Accessed 15 July 2014

New Zealand Department of Conservation (NZDOC). 2013. Kakapo Recovery Plan: 2006-2016. Invercargill, New Zealand

New Zealand Department of Conservation (NZDOC). http://kakaporecovery.org.nz/meet-the-kakapo/. Accessed 5.July.2014

New Zealand Department of Conservation (NZDOC). http://www.doc.govt.nz/conservation/native-animals/birds/birds-a-z/takahe/facts/. Accessed 25.June.2014

Nichols, J.D. and D.P. Armstrong. 2012. Monitoring for reintroductions. pp. 223-255. In: Ewen, J.G., D.P. Armstrong, K.A.Parker, P.J. Seddon (eds.). Reintroduction Biology. Wiley-Blackwell Publishing, Chichester, West Sussex, UK

Nilson, G., C. Andrén, A. Avci, F. Akarsu. 2009. *Montivipera raddei*. The IUCN Red List of Threatened Species. Version 2014.1. www.iucnredlist.org. Accessed 16 July 2014

Parker, P.G., S.L. Deem, R.E. Miller. 2010. Pathogens and parasites of Galapagos birds: a proactive approach to conservation. pp. 111-116. In: Dick, G. and M. Gusset (eds.). Building a Future for Wildlife. World Association of Zoos and Aquariums (WAZA), Gland, Switzerland

Pledger, S., K.H. Pollock, and J.L. Norris. 2010. Open capture-recapture models with heterogeneity: II. Jolly-Seber Model. Biometrics 66(3): 883-890

Pramuk, J., F. Koontz, M. Tirhi, S. Zeigler, K. Schwartz, and P. Miller (eds.).2013. Western Pond Turtle (*Actinemys marmorata*) Population and Habitat Viability Assessment: Workshop Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN

Pullin, A.S. and T.M. Knight. 2001. Effectiveness in conservation practice: pointers from medicine and public health. Conservation Biology 15(1): 50-54

Rabon, Jr., D.R., R. Bartel and A. Beyer. 2013. Red Wolf Adaptive Management Plan FY13-FY15. U.S. Fish and Wildlife Service, Manteo, North Carolina.pp-14

Raithel, C. 1991. American Burying Beetle (*Nicrophorus americanus*) Recovery Plan. New England Field Office, U.S. Fish and Wildlife Service. Concord, New Hampshire

Reptile Database. http://www.reptile-database.org/. Accessed 12.June.2014

Republic of Armenia. 2001. Biodiversity Strategy and Action Plan.Ministry of the Natural Environment, Republic of Armenia. https://www.cbd.int/doc/world/am/am-nbsap-01-en.doc

Rexstad, E. and K.P. Burnham. 1991 User's guide for Interactive Program CAPTURE. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, USA

Rija, A.A., E.M. Goboro, K.A. Mwamende, A. Said, E.M. Kohl, and S.N. Hassan. 2014. Activity patterns and fine-scale resource partitioning in the gregarious Kihansi spray toad *Nectophrynoides asperginis* in captivity. Zoo Biology 33: 411-418

Robins, J.G., M. Ancrenaz, J. Parker, B. Goossens, L. Ambu and C. Walzer. 2013. The release of northeast Bornean orangutans to Tabin Wildlife Reserve, Sabah, Malaysia. pp. 215-221. In: Soorae, P.S. (ed.). 2013. Global Re-introduction Perspectives: 2013. Further case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Rudnick, J.A., T.E. Katzner, E.A. Bragin, O.E. Rhodes Jr., J.A. DeWoody. 2005. Using naturally shed feathers for individual identification, genetic parentage analyses, and population monitoring in an endangered Eastern imperial eagle (*Aquila heliaca*) population from Kazakhstan. Molecular Ecology 14(10): 2959-2967

Rutledge, L.Y., K.I. Bos, R.J. Pearce, and B.N. White.2010. Genetic and morphometric analysis of sixteenth centry *Canis* skull fragments: implications for historic eastern and gray wolf distribution in North America. Conservation Genetics 11(4): 1273-1281

Sanderson, E.W., K.H. Redford, A. Vedder, P.B. Coppolillo, and S.E. Ward, 2002. A conceptual model for conservation planning based on landscape species requirements. Landscape and Urban Planning 58(1): 41-56

Sandoval Cañas, L., J.P. Reyes Puig, A. Tapia, and D. Bermúdez Loor, D. 2009. Manual de campopara el estudio y monitoreo del tapir de montaña (Tapirus pinchaque). Grupo Especialista de Tapires UICN/SSC/TSG, Fundación Oscar Efrén Reyes, Centro Tecnológico de Recursos Amazónicos- Centro Fátima, Finding Species. Quito, Ecuador

Sauer, J.R., J.E. Fallon, R. Johnson. 2003. Use of North American Breeding Bird Survey data to estimate population change for bird conservation regions. Journal of Wildlife Management 67(2): 372-389

Schad, K., editor. 2008. Amphibian Population Management Guidelines. Amphibian Ark Amphibian Population Management Workshop; 2007 December 10-11; San Diego, CA, USA. Amphibian Ark, www.amphibianark.org. pp. 31

Schmitt, K. and K. Sallee. 2002. Information and knowledge management in nature conservation: supporting planning, decision-making, monitoring and evaluation in wildlife management in Uganda with a spatial management information (MIST). Uganda Wildlife Authority and Deutsche Gesellschaft für Technische Zusammenarbeit. http://www.ecostats.com/web/data/_uploaded/file/software/mist/mist.pdf

Silver, S.C., E.T. Linde O., L.K. Marsh, L. Maffei, A.J. Noss, M.J. Kelly, R.B. Wallace, H. Gomez and G. Ayala.2004. The use of camera traps for estimating jaguar *Panthera onca* abundance and density using capture/recapture analysis. Oryx 38(2): 148-154

Spatial Monitoring and Reporting Tool (SMART). Smartconservationtools.org. Accessed 22.June.2014

Soisalo, M.K. 2006. Estimating the density of a jaguar population in the Brazilian Pantanal using campera-traps and capture-recapture sampling in combination with GPS radio-telemetry. Biological Conservation 129(4): 487-496

Soorae, P.S. (ed.). 2008. Global Re-Introduction Perspectives: re-introduction case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Soorae, P.S. (ed.). 2010. Global Re-Introduction Perspectives: additional case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Soorae, P.S. (ed.). 2011. Global Re-Introduction Perspectives: more case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Stokes, E.J. 2010. Improving effectiveness of protection efforts in tiger source sites: Developing a framework for law enforcement monitoring using MIST. Integrative Zoology 5(4): 363-377

Swarts, F. (ed.). 2000. The Pantanal of Brazil, Bolivia and Paraguay. Hudson MacArthur Publishers. London, UK

TEAM Network. 2011. Terrestrial Vertebrate (Camera Trap) Monitoring Protocol Implementation Manual. Tropical Ecology Assessment and Monitoring Network, Centre for Applied Biodiversity Science, Virginia, USA

Tolson, P.J., M.A. Garcia, J.J. Pierce. 2010. Reintroduction of the Virgin Islands boa to the Puerto Rico Bank. pp. 69-74. In: Dick, G. and M. Gusset (eds.). Building a Future for Wildlife. World Association of Zoos and Aquariums (WAZA), Gland, Switzerland

TRACKS® Software. http://trackssoftware.com/ Accessed 15.June.2014

US Fish and Wildlife Service (USFWS). 1990. Red Wolf Recovery/Species Survival Plan. U.S. Fish and Wildlife Service, Atlanta, GA

U.S. Fish and Wildlife Service.2007. Red Wolf 5-Year Status Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Manteo, North Carolina. pp. 58

U.S. Fish and Wildlife Service. 2012. Endangered beetle reintroduction a success in Missouri. U.S. Fish and Wildlife Service Newsroom. http://www.fws.gov/midwest/News/561.html. Accessed 27.July.2014

USGS. A critique of wildlife radio-tracking and its use in national parks. http://www.npwrc.usgs.gov/resource/wildlife/radiotrk/convent.htm. Accessed 18.June.2014

Van Tienhoven, A.M., J.E. den Hartog, R.A. Reijns, and V.M. Peddemors. 2007. A computer-aided program for pattern-matching natural marks on the spotted ragged tooth shark *Carcharias taurus* (Rafinesque, 1810). Journal of Applied Ecology 44(2): 273-280

Vander Haegen, W.M., S.L. Clark, K.M. Perillo, D.P. Anderson, H.L. Allen. 2009. Survival and causes of mortality of head-started western pond turtles on Pierce National Wildlife Refuge, Washington. Journal of Wildlife Management 73(8): 1402 - 1406

Viscaíno, S.F. and N. Milne. 2002. Structure and function in armadillo limbs (Mammalia: Xenarthra: Dasypodidae). Journal of Zoology 257(1): 117-127

Waddell, W. and S. Long. 2014. Population Analysis & Breeding and Transfer Plan for Red Wolf (*Canis rufus*). AZA Species Survival Plan®. Yellow Program. Association of Zoos and Aquariums, Silver Spring, MD

White, G.C. and K.P. Burnham. 1999 Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement: 120-138

Wickes, C., D. Crouchley and J. Maxwell. 2009. Takahē (*Porphyrio hochstetteri*) Recovery Plan 2007-2012. Threatened Species Recovery Plan 61. Department of Conservation. Wellington, New Zealand. pp. 56

Wildtech.2013. User manual for kakapo “Checkmate” transmitters. V8.2 Accessed courtesy of Andrew Digby, Department of Conservation, New Zealand

Wildtech. 2011. User manual for kakapo “Egg Timer” transmitters V6.3. www.wildtech.co.nz/downloads/Kakapo%20ET%20V6.3.pdf Accessed 6.July.2014

Wildtech.2014. Sky Ranger Flight Case. http://www.wildtech.co.nz/SkyRanger.aspx#tx1. Accessed 5.July.2014

WildTrack. Non-invasive Wildlife Monitoring Footprint Identification Technology (FIT). http://wildtrack.org/citizen-science/a-global-challenge-fit-database/. Accessed 17.June.2014

Wilson, E.O. 1998. Consilience. Random House of Canada Limited, Toronto. pp. 367

CHAPTER 4 INTEGRATION OF DATA MANAGEMENT PROCESSES FOR CONSERVATION USING THE ZOOLOGICAL INFORMATION MANAGEMENT SYSTEM

Introduction

In accordance with a "one plan approach" to conservation action, the *in situ* and *ex situ* conservation communities combine forces to effect programs that mitigate biodiversity loss (Byers *et al.* 2013). This collaboration requires effective communication through sharing of data for each step along the progression of the programs. Each conservation program has basic components that require knowledge backed up by scientific research including threats causing the decline, an understanding of the taxon's life history, population dynamics, genetic diversity, health, reproduction, and survival in the wild. The *ex situ* community has established standardized data management processes through the use of the International Species Information System (ISIS), the global records-keeping database that is the largest global network of animal professionals in the world (ISIS September 2014). Over 900 *ex situ* conservation partners in 85 countries utilize ISIS' *Zoological Information Management System* (*ZIMS*) to maintain records on health, husbandry, behavior, reproduction, and population management for the animals in their care. When a relationship with an *in situ* partner is established, these records can then be shared when the animals are released to the wild. As a system specifically developed for maintaining animal records and considering the size and scope of the ISIS network, *ZIMS* has great potential as a platform for providing direct information links between *ex situ* and *in situ* partners. Additionally, *ZIMS* would be very useful for research on monitored wild populations with animals that are identified individually or as a group thus linking data on wild populations with data on the *ex situ* populations of those same species.

As a global database with records for more than 3 million animals (living and deceased), ISIS has already had an active role in contributing to several areas of animal research including comparative genomics (as a member of the Integrated Primate Biomaterials and Information Resource; IPBIR 2014), species aging studies (Young *et al*. 2012, Müller *et al*. 2010; Weigl 2005), and biodiversity conservation (Conde *et al*. 2011). With the launch of *ZIMS for Medical* in April of 2014, veterinarians are now entering medical data in real-time, enabling research on bio-surveillance of new and emerging infectious diseases and safety of therapeutic treatments for wildlife (ISIS 2014).

ISIS has a 40 year history of connecting conservation organizations through shared animal records. There are over 900 zoos and aquariums that are ISIS members and also a number of other types of organizations including educational institutions (that maintain animals or who teach animal records-keeping), botanical gardens, research centers, breeding centers, and a few wildlife reserves and sanctuaries (Table 4.1). ISIS includes non-member institutions in the list if member institutions have sent or received animals from them. This is helpful since animals that are received from or go to a non-member institution or private individual, have the transfer documented in their specimen record, even if that record is not continued. Professional organizations that do not maintain animal collections have read-only access at the population level in order to keep informed. These include global associations such as International Union for Conservation of Nature (IUCN), Conservation Breeding Specialist Group (CBSG), World Association of Zoos and Aquariums (WAZA), the Amphibian Ark and regional zoo associations.

Table 4.1. Institution list of organizations in ISIS including total number listed, number that are ISIS members and number of members that have deployed *ZIMS* (ISIS 2014)

Institution Type	Total	ISIS Member	*ZIMS*
Biological Institutions			
Aquarium	464	62	51
Botanical Garden	37	4	4
Breeding Center	7	7	6
Circus/Traveling Show	88	0	0
Confiscation Center	5	0	0
National Park	71	2	2
Pet Store	58	0	0
Private Collection/Individual	>500	1	1
Quarantine	7	0	0
Ranch/Farm	142	1	0
Reintroduction Facility	11	0	0
Research Center	85	6	5
Sanctuary	85	3	3
Wildlife Reserve	112	1	1
Zoo	>1500	752	>600
Other Organizations			
Professional Association	2	0	0
Educational Institution	15	15	8
Global Association	4	4	0
Regional Zoo Association	27	27	0

Functionality of *ZIMS*

ZIMS is a comprehensive information system that offers a global platform for managing animal records in real time, supporting animal management activities and cooperative population management programs (see Appendix XVII for *ZIMS* data fields). *ZIMS for Medical* was released in April 2014 and incorporates previous *MedARKS* functionality within the system. *ZIMS* is based on individual specimen or group records where all the information and events for each animal or group are maintained in one record. Entities in *ZIMS* may be an individual animal, a group of animals, an egg, egg mass or group of eggs, a fetus or an incomplete accession. Egg and fetus entities (pre-birth entities) will be transformed to an individual upon hatching or birth, or can be dispositioned as a death if they don't survive. Incomplete accessions are generally placeholders entered with a simple set of details and can be converted to a full accession to one of the aforementioned entity types in the final state although some may remain as incomplete. Wild individuals are sometimes received and remain as incomplete accessions when rehabilitation and release is the intent and there is no desire to include them in the main collection inventory. Each animal (entity) is entered only once in the system, receiving a Global Animal Number (GAN) that is retained throughout its lifetime. The record is built upon that original entry wherever the animal is transferred, thus eliminating the need for linking data between institutions and minimizing errors in re-entering data. Data standards, developed by subject matter experts, form the basis of drop-down lists for many fields and the use of free text fields is limited. These standards are backed up by business rules that ensure that the user does not record data that is illogical. Thus the technical structure of *ZIMS* enforces standardized data entry by participating institutions which facilitates the data sharing capabilities of the system.

Collection management and husbandry

Every animal or group entered into *ZIMS* is assigned to a specific collection type (Miller 2014). The animals within all of these collection types are globally visible except for animals in the "research" and "feedstock" collections for which this is optional. Incomplete accession collections are not globally visible. Animals can be transferred between collection types at any time and retain the same GAN such that all the records for that particular animal will be contained under that ID number no matter where the animal is located or in which collection it resides.

- **Main collection** – the main collection for the institution in which the majority of its live specimens are held. These will be your exhibit and breeding animals.
- **Education** – animals used for educational programs, off grounds presentations and on grounds educational programs.
- **Rescue/Rehabilitation** – animals in from the wild temporarily housed for the purpose of rehabilitation for release back into the wild.
- **Research** – animals and/or samples used for research.
- **Quarantine** – animal(s) you are quarantining on behalf of another regional institution because they do not have the required facility required by an outside agency.
- **Confiscation** – animal(s) you are holding pending legal action for a third party.
- **Temporary Holding** – holding temporarily for another institution or agency for reasons other than confiscation or rescue/rehabilitation or quarantine.
- **Wild** – animal(s) that are part of a re-introduction program or that you want to track after release to the wild.
- **Non-institutional Medical** – domesticated or privately held non-domestic animals that are not managed by the institution but are presented for medical treatment such as staff pets.
- **Feedstock** – animals held to be fed to other animals such as mice, rats or fish.
- **Incomplete Accession** – used as a holding area for partial records until they are converted to a full accession.

Individual entity information (see “individual record” fields in Appendix XVII) forms the core of the record and the system contains all reproduction, behavior, development milestones, husbandry and medical data as well as transfers between enclosures within the institution and transfers between institutions for each animal or group. There are specialized screens for feeding logs, training event logs, weights and measurements, and notes and observations. Customized templates can be developed and imported to capture specific data for each program (e.g., GPS locations for monitoring sessions). The “enclosure log” offers standardized terms to categorize each enclosure (Table 4.2) and documents attributes of each enclosure (GPS location, dimensions, substrates, barriers, environmental measures such as temperature and humidity) as well as tracks individuals in the enclosure. Although intended for use to document the location of animals in an *ex situ* facility, the terms could be applicable for documenting the sites and location of animals in the wild.

Table 4.2 Enclosure types in the *ZIMS* Enclosure Log.

Enclosure Log					
Aviary	Burrow	Emergence Chamber	Island	Open range	Shelter
Barn	Cage	Enclosure Group	Jar	Paludarium	Sky kennel
Beehive	Cave	Exhibit	Log	Pen	Stall
Bin	Coop	Flight-cage	Mews	Petrie dish	Test tube
Brooder	Crate	Hot Box	Moat	Pit	Vehicle
Box	Cup	Incubator	Nest	Room	Vivarium
Building	Den	Insulated box	Nursery	Shed	

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ZIMS maintains institutional information to organize staff (assign roles for access), maintains list of permits, transponder inventory, life support component inventory (aquatic – environmental quality, water chemistry, filtration; terrestrial – air exchange, humidity, temperature regulation, lighting; incubation – air exchange, humidity, rotation, temperature regulation), and collection trip information (GPS location, equipment and vehicle types used, trip personnel, permits, species collected). There is a built-in alert system that will notify the user of time-sensitive processes for animals or enclosures such as maintenance issues, time ranges for treatments, durations of prescriptions, husbandry management and reproduction due dates. *ZIMS* was built as a comprehensive information management system to cover data management needs for zoological institutions, yet also with the capacity to expand functionality for managing data on animals in the wild. There are also some fields where data can be uploaded from *Excel* in order to facilitate capture of whole datasets without having to do single entries (e.g. uploading environmental measures such as water quality, temperature, or pH datasets for enclosures). Any data grid or report in the system can be downloaded to various formats including PDF, *Excel*, JPEG, and *Power Point* which offers the opportunity for manipulation of data for analysis and also for exchange of data between stakeholders.

Health and disease history

ZIMS for Medical (*ZIMS Release 2.0*) has added medical records functionality that integrates health information with animal inventory and husbandry records such that medical history is available within animal's specimen record. This first release includes

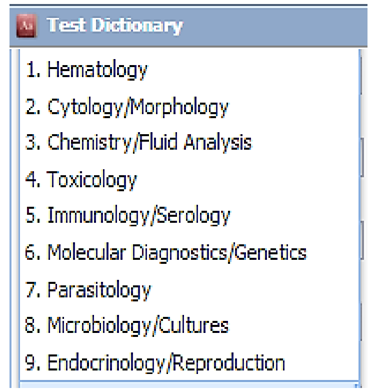


Figure 4.1. Diagnostic test categories in *ZIMS* (ISIS 2014).

modules for anesthesia, treatment and prescriptions, pharmacy inventory, samples, test results (Figure 4.1), physiological measurements, clinical notes, and diagnoses and procedures (Figure 4.2; Appendix XVIII). Future releases will add modules on sample shipping and storage, pathology records (necropsy/biopsy), diagnostic imaging (radiology and ultrasound), calendar functions (schedule sample collection, procedures, treatments), and research request functions (J. Andrew Teare, personal communication). The “*Medical*” component offers not only data entry modules but dictionaries for “tests”, “medical terms”, and “treatments” with the capabilities for the user to add new terms to the “Terms” and “Treatments” libraries as needed (the Tests library is edited on request by ISIS’ staff). There is overlap between the husbandry and medical records such that weight records are shared as well as “body condition scores” and “health status” which show up in the basic information screen for each specimen (Figure 4.3). “Clinical notes” has an interface that generates records that appear in the husbandry records as medical notes.

Medical data in *ZIMS* will be pooled to facilitate exchange of information in real time on treatment protocols, anesthesia libraries, physiological and morphometric normal values, disease prevalence and other health related information. An Institute of Museum and Library Services (IMLS) grant for $300,000 will enable ISIS to develop a *ZIMS* feature for reports that identify species-specific medical problems, commonly used anesthesia drugs and dosages and efficacy of various treatments using pooled medical data.

Over the last 40 years, 342,000 blood sample values for 2788 species have been collected for the ISIS Physiological Values database and Physiological Values Reference Intervals are available within *ZIMS* for 913 species (species with a minimum of 50 representative samples) (e.g., see Appendix XIX for Matschie's tree kangaroo (*Dendrolagus matschiei*) reference values; ISIS 2014). The Physiological Values database continues to grow as test results are entered, further refining the precision of the intervals. Collaborations to improve medical care will be facilitated by ready-access to a compilation of data from animals in captivity worldwide. Conservation management programs such as Species Survival Plans (SSP®s) in North American or Endangered Species Programs (EEPs) in Europe will be able to efficiently collect information on a particular medical problem for their species. *ZIMS* will be able to alert species coordinators when a certain disease trend occurs that causes concern, leading to early detection and treatment. This alert system will be possible for all of the species in *ZIMS*, effectively forming a bio-surveillance network to monitor the health of captive populations. There is great potential for capturing health data on monitored populations in the wild that will contribute to this bio-surveillance network.

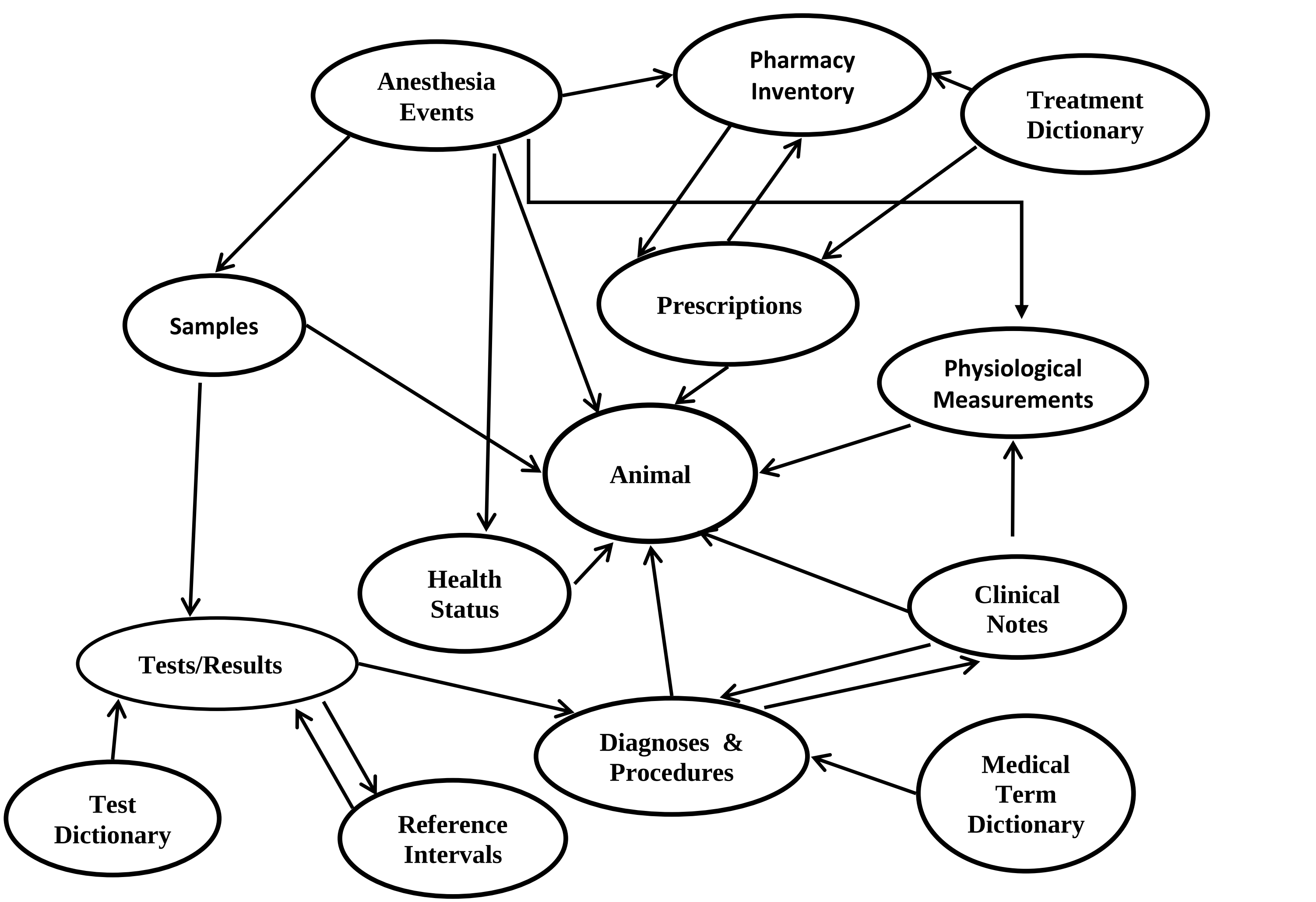


Figure 4.2.*ZIMS* Medical modules and relationships. The Animal Record is the intersection between husbandry and medical records. Courtesy of J. Andrew Teare/ISIS.

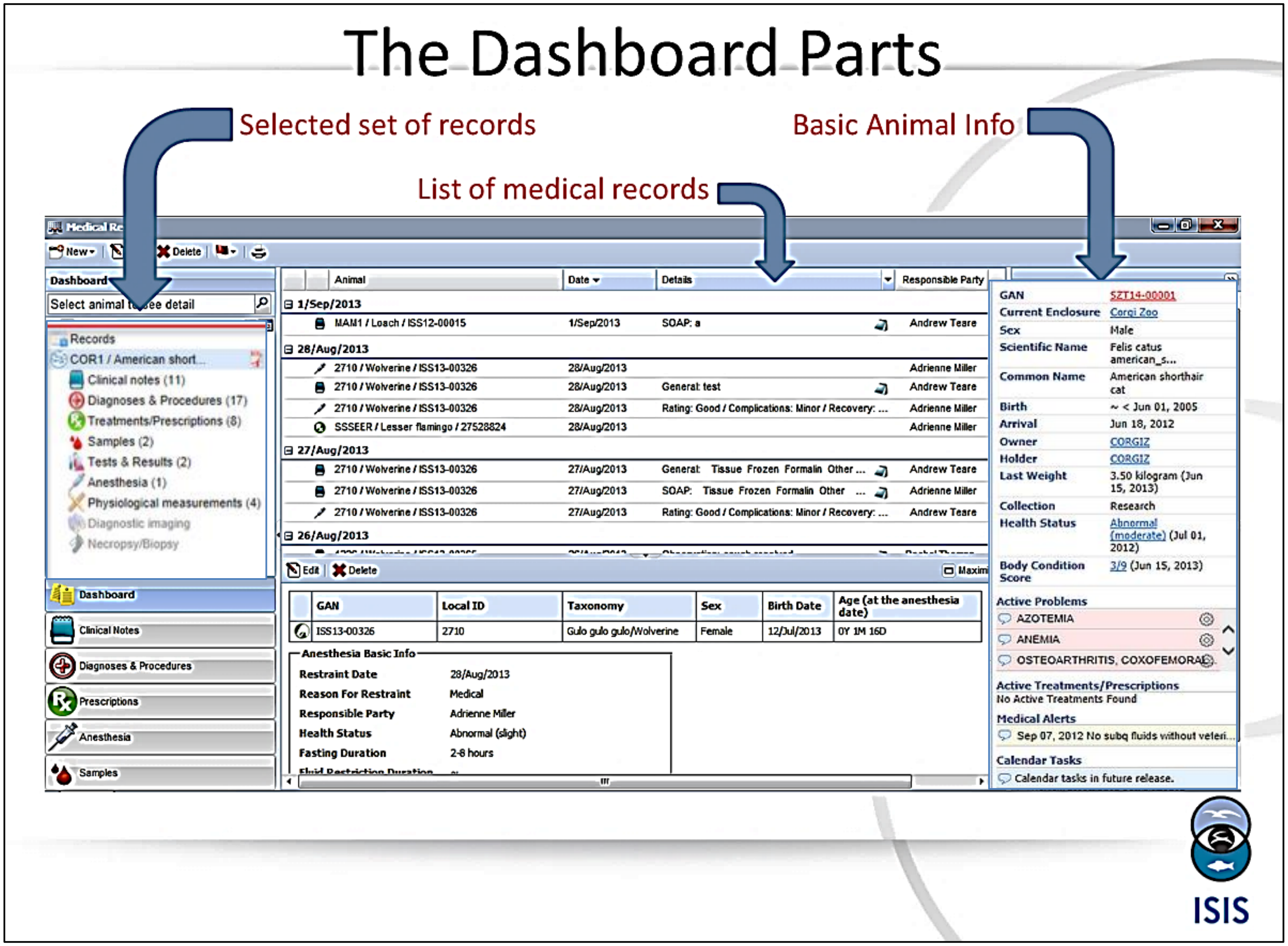
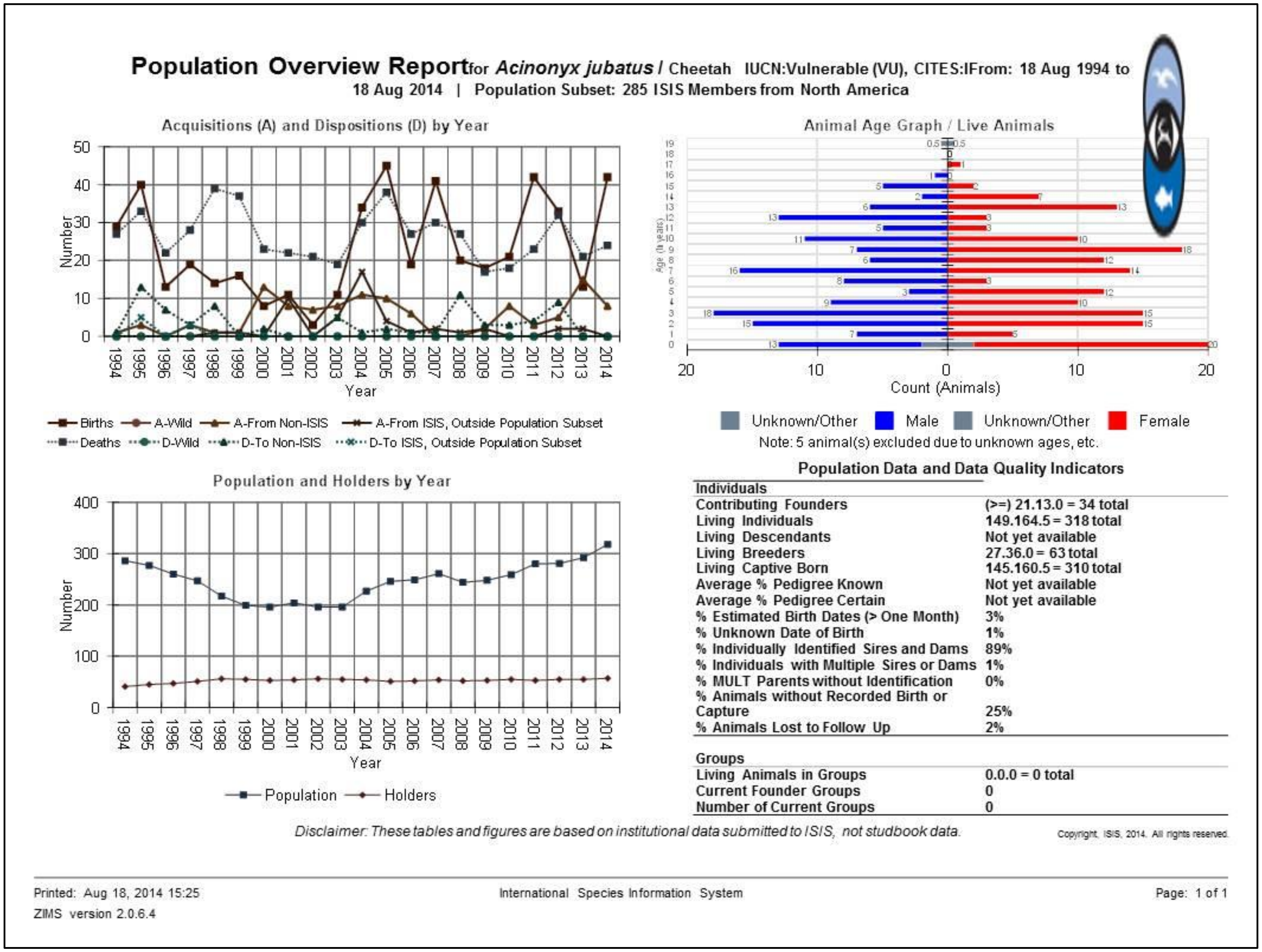


Figure 4.3. Dashboard for *ZIMS* Medical Records showing menus for selecting records on left, list of recent medical records in the middle and the basic information for the selected animal on the right. Courtesy of Adrienne Miller/ISIS.

Population management

Population management programs rely on the development of studbooks in order to make scientific-based plans for breeding recommendations and animal transfers. Parentage is extremely important to document for each animal since an animal with unknown parentage will be excluded from the breeding population in the breeding program. Breeding management for groups can be done on a less intensive scale by tracking group of origin and the splitting and merging of groups to form new breeding groups. *ZIMS* has a pedigree report for each animal in the system that documents the animal's pedigree as far back as the records go (ideally to the wild). Groups are tracked with a Group Explorer function that maps the origin and formation of new groups. Studbook keepers previously had to send questionnaires to participating institutions in order to update the studbook with births, deaths and transfers between institutions. *ZIMS* now offers a direct method of keeping studbook keepers up to date on their species' events through "Studbook News" which sends out a notification to the studbook keeper of any events that occur within that species in the global or regional population.

ZIMS compiles species data for each taxon in a Population Management Overview using key metrics for genetic and demographic parameters (Figure 4.4). The report includes acquisitions and dispositions by year, current age distribution, living population and number of holders and calculated metrics for demographic and genetic parameters. This is a report that can give a quick view of population parameters whereas more detailed analyses would be done for actual population management planning. *ZIMS Release 3*, now being developed, will contain the functionality currently captured in the current *SPARKS* and *PM2000/PMX* population management systems. Thus studbooks will be compiled directly from institutional records for ISIS members and manual entry will be limited to data on individuals from non-ISIS member institutions.



Population Data and Data Quality Indicators

Individuals	
Contributing Founders	(>=) 21.13.0 = 34 total
Living Individuals	149.164.5 = 318 total
Living Descendants	Not yet available
Living Breeders	27.36.0 = 63 total
Living Captive Born	145.160.5 = 310 total
Average % Pedigree Known	Not yet available
Average % Pedigree Certain	Not yet available
% Estimated Birth Dates (> One Month)	3%
% Unknown Date of Birth	1%
% Individually Identified Sires and Dams	89%
% Individuals with Multiple Sires or Dams	1%
% MULT Parents without Identification	0%
% Animals without Recorded Birth or Capture	25%
% Animals Lost to Follow Up	2%

Groups	
Living Animals in Groups	0.0.0 = 0 total
Current Founder Groups	0
Number of Current Groups	0

Disclaimer: These tables and figures are based on institutional data submitted to ISIS, not studbook data.

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ZIMS version 2.0.6.4

Figure 4.4. *ZIMS* Population Overview of *ex situ* cheetah (*Acinonyx jubatus*) population in the North American region (ISIS 2014).

Implications for integrating *in situ* and *ex situ* data management processes

Conservation programs are made up of a number of components that need to come together for a successful outcome. Core data needed for a conservation program will include parameters and methodologies for each stage of the programs for assessment at the population, meta-population, and eco-system levels (see Table 2.3). In the initial assessment phase, the extent of knowledge on life history, habitat requirements, threats and population status will impact the methodologies undertaken to mitigate population decline. Preliminary research is needed on the wild population with planning for action to answer *a priori* questions. *ZIMS* can maintain data on animals that are monitored such that all the data and events for each animal are in one place and can be compiled for an overview of the population. A conservation action plan can be designed that may include a conservation translocation involving transfer of wild –sourced animals or releasing animals from *ex situ* facilities (whether wild or captive-born) to the wild. For those programs with a number of *ex situ* partners (e.g., involved in collaborative breeding management programs), standardization of data management processes between those partners through use of *ZIMS* would be the first step to facilitate the breeding program. After release, a continuation of the animals' records in *ZIMS* will link their core data (age, parentage, rearing, sex, etc.), behavior, reproduction, and health data while in human care to post-release monitoring data as well as document pre-release, release and post-release methodologies to facilitate assessment on survival and persistence.

As monitoring health is important at all levels of a conservation program, maintaining medical records in one information system would be beneficial in a number of ways. For the individual animals, recording health information both while in a facility and after release to the wild will serve to understand disease processes and impact of medical history on survival and reproduction in the wild. Pooling medical records for *in situ* and *ex situ* populations either separately or together will elucidate health trends and act as a bio-surveillance system on population health. Ranges for physiological values for animals in the wild populations could be compared with those for *ex situ* populations to impact changes in husbandry and care protocols for those populations.

For a "one plan approach", *in situ* and *ex situ* populations together would constitute the managed meta-population, requiring careful genetic and demographic monitoring in order to assess and maintain sustainability. There are a number of programs that incorporate both *in situ* and *ex situ* populations in the species studbook (e.g. golden lion tamarin (*Leontopithecus rosalia*), Ruiz-Miranda 2010; red wolf (*Canis rufus*), Waddell 2014) to facilitate genetic management of both populations. The individual animal data for the studbook comes from institutional records for the *ex situ* population and from monitoring data for the *in situ* population. Thus, having all *in situ* and *ex situ* participants maintain their records in one information system would facilitate the development of the studbook for use in population management.

Finally, use of one web-based real time information management system would facilitate data sharing and link *in situ* and *ex situ* components of a conservation program to the benefit of both. Instead of having to compile data from various information systems, spreadsheets and databases to share, there would be immediate managed access that would increase efficiency of the data management communication processes. Linkages could be made to other information systems for those components of the programs that lie outside the functionality of *ZIMS*.

Objectives

The objective of this project was to align the data requirements for managing and assessing conservation programs for each program in the five categories of threatened species programs (as identified in Chapter 3) with the functionality of *ZIMS*. The results would illustrate how *ZIMS* could help provide the information management tools needed to enhance the connectivity of information on captive and wild/reintroduced populations and identify the areas for enhancement or linkage to existing systems.

Methods

For each conservation program outlined in Chapter 3, identified data requirements and data management tools were aligned with *ZIMS* functionality to illustrate how this information system could integrate *in situ* and *ex situ* data management processes. Data fields for representative programs were mapped to data fields available in *ZIMS* to identify the capacity of *ZIMS* to handle the data needs. Details and issues for data management for each program can be found in Chapter 3. Mock data screens with fictional data (using names of real scientists involved in the projects with their permission) were developed to show functionality of *ZIMS* relevant to the specific case studies.

Results

Category A Case Studies

Endangered species whose wild population became dangerously low and captive breeding or head-start program was implemented for purposes of release for reintroduction.

Program: American Burying Beetle Reintroduction in Missouri

Species: American burying beetle (*Nicrophorus americanus*)

The *ex situ* management of the American burying beetle (ABB) consists of an AZA Species Survival Program® that maintains two separate populations (an eastern and a western population) with census numbers kept in the American Burying Beetle North American Regional Studbook, compiled by St. Louis Zoo. Thus group records are kept in ISIS. All but one of the other institutions are ISIS members, but only St. Louis Zoo maintains individual records.

As the institution that leads the reintroduction program in Missouri, the St. Louis Zoo maintains individual records on their beetles in a separate *Access* database and *Excel* spreadsheets with breeding, genetic, demographic, and husbandry information. *ZIMS* has the required functionality to cover all the core data with the added advantage of tracking life stages, optimizing medical records and data on enclosures and environment. All of the fields in the ABB Breeding datasheet (see Appendix IX) currently kept in *Access* can be covered using *ZIMS* (Table 4.3). For individual information, each beetle can be accessioned with an assigned local ID with gender, acquisition and disposition dates, parentage, and location (brood bucket). Breeding information will be entered in the individual beetle's record such that all breeding events, partners, and outcomes will be in one specimen record. The use of keywords in a breeding management note (such as breeding pairs, retired date, successful/unsuccessful, do not breed, carrion type & weight, burial, parent removal date, number of larvae) will facilitate easy retrieval of the information in a report for documented breeding events. Use of the "enclosure log" will track introduction date for each pair in a particular bucket as well as removal dates for parents. *ZIMS* provides a specimen report that includes all the data for an individual or group, taxon reports that would compile the information for all individuals of a species, an enclosure report that includes environmental measures and all individuals that were in that enclosure, and a pedigree report that will track ancestors, siblings, and descendants. St. Louis Zoo currently maintains their American burying beetles as a group entity in *ZIMS* with census information on number of males and number of females. Individual beetles can be directly accessioned from this group record such that the background information is retained. These individual records will offer pedigree data that can be used for breeding management (the studbook could track individual pedigrees rather than census data on the *ex situ* populations), life stage data that can be linked to age-specific survivability, and document individuals' hatch dates, death dates, and disposition dates if they are released to the wild. In addition, the location of the release site and methodologies for the reintroduction can be documented. As the other institutions refine their data collection processes, individual animal records in a shared system would facilitate information exchange for the institutions within the SSP® and with the U.S. Fish and Wildlife Service (USFWS).

For the reintroduction program, the USFWS works with St. Louis Zoo to facilitate the monitoring processes that include release of an identified pair in a hole, with supportive measures by providing a carcass, and monitoring to check for reproduction and emerged new adults. Mark and recapture studies provide data on population densities and genetics. Thus, *ZIMS* could also be utilized for follow-up monitoring data. The release event would be entered in each beetle's record as a release into a wild collection and reproduction could also be tracked by individual. The release site could be considered as an "open range" enclosure (an option in *ZIMS*), with the location of the hole documented by GPS location. Supplemental feeding events could be maintained in the *ZIMS* "feeding log". Thus spatial and reproductive data as well as methodologies for each beetle can be managed in *ZIMS* and report functions offer the capability to compile information on the whole population for a set time range. Once the individually identified beetles die, their wild-hatched offspring can be monitored as part of the wild population in a group record in *ZIMS*. This group record would consist of census numbers as well as births and deaths and thus would monitor population size and growth. The group record could also contain any supportive measures (habitat restoration, supplemental provision of carcasses, etc.) for the wild population. The USFWS would be involved with entering monitoring data as the owner of the beetles. By utilizing *ZIMS* alone rather than *ZIMS* for census data and other databases for *ex situ* individual data, duplication of effort will be minimized and data can be more easily shared with the other institutions in the program as well as the USFWS.

The use of *ZIMS* will facilitate data collection for important parameters that will assist in tracking genetics for the *ex situ* breeding program, document husbandry methodology for management (environmental requirements, reproductive protocols, nutrition regimens), facilitate health assessments, track development and life stages, and release methodologies, and can be used for general census information for the wild population that would be indicative of population size and growth. The data could be used to learn about life history traits, improve management, facilitate the breeding management program, and assess the success in reaching the objectives for the recovery program.

Table 4.3 Data fields for *ex situ* data management for American burying beetle comparing current tools (*Access* and paper files) to fields covered in *ZIMS*. Br.mgnt note – breeding management note

Individual Information

Access	*ZIMS*
Individual ID	Global Animal Number
Location -institution	Physical Holder
Brood/Bucket	Enclosure – Bucket
Gender	Sex type
Date emerged	Birth/hatch date
Sire ID/Tag	Parentage – Sire ID/tag
Dam ID/Tag	Parentage – Dam ID/tag
Death date	Physical holder history
Retired date	Breeding management note

ZIMS advantage: specimen and taxon reports, enclosure report, Pedigree Explorer

Breeding Success

Access	*ZIMS*
Individual ID	GAN
Gender	Sex type
Bucket/Brood	Enclosure
Retired date	Br.mgnt note
Earliest time to breed	Alert
Successful/unsuccessful	Br.mgnt note
Breed to number	Br.mgnt note
Do not breed	Br.mgnt note
Weight	Weight

ZIMS advantage: specimen report, note retrieval report

Breeding Arena

Paper files & *Access*	*ZIMS*
<u>Set-up</u>	<u>Set-up</u>
Pair #	Br. Mgmnt -keyword
Male #	Male GAN
Female #	Female GAN
Date introduced	Br. mgmnt
Carrion type	Br. mgmnt -keyword
Carrion weight	Br. mgmnt -keyword
Date of burial	Br. Mgmnt -keyword
Burial – full or partial, not buried	Br. Mgmnt -keyword
Date to check larvae	Alert
Date parents removed	Br. Mgmnt -keyword
Initials	Responsible party

ZIMS advantage: Breeding management note template for ease of data entry, note retrieval report

Paper files & *Access*	*ZIMS*
<u>Larvae check</u>	<u>Larvae check</u>
Date to check	Alert
# of larvae	Br.mgmnt,
Date / initials	Hatch accession/ Responsible party
Date sire removed	Enclosure
Date dam removed	Enclosure
Remarks-observations	Observation
<u>Emergence</u>	<u>Emergence</u>
Pair#	Br. Mgmnt keyword
Bucket/Brood	Enclosure
Sire#/Dam#	Parentage
# emerged	Br. Mgmnt keyword

ZIMS advantage: Alerts, direct accessions for larvae, life stages documentation

Program: Takahē Recovery Programme

Species: Takahē (*Porphyrio hochstetteri*)

The Takahē Recovery Programme is a collaborative effort led by the Department of Conservation (DOC) who maintains the main takahē database for the program. Other databases are maintained by collaborating institutions such as Auckland Zoo (who maintains records in ISIS) and Massey University (who maintains a national mortality database for native fauna). The program involves collecting eggs (historically) or chicks from the wild for foster rearing in a DOC facility and managing a release program to six islands. The population is carefully managed as a meta-population with the use of a studbook that is maintained in *SPARKS* (*Single Population Animal Records Keeping Software*, managed by ISIS and used for population management planning).

There are many levels of data management and many partners for this program requiring effective communication and organization (see Figures 3.3 and 3.4 in Chapter 3). Data management processes could be effectively streamlined in a number of ways if the different institutions and government authority were working with a shared information management system. The DOC *Access* database contains many tables for different events and core data such that data for any individual bird may be held in a number of places, making it a challenge to develop a query to obtain a specimen record on one individual. Using *ZIMS*, an animal would be entered once into the system, and each additional event or transfer for that animal would be entered within that same record

(Table 4.4). All of the health assessment data (see health data fields for takahē in Appendix X) can be recorded in the medical component of *ZIMS* and would be connected to each bird's basic data information. As such, the medical history and basic core data for each bird will be accessible in its specimen record whether it is in a facility or being monitored after release to the wild. Compilation of medical data for the population will identify health and disease trends that can be addressed. Monitoring data, such as data from radio-telemetry tracking can be entered using custom templates developed to capture specific information, although this is less than ideal and points to the need for a future enhancement to handle monitoring data. *ZIMS* is structured such that records are entered in each individual or group's record. Data on nest activity would be entered by accessioning eggs or chicks in that particular nest and documenting the parents' location at the nest. There is no current capacity to document observations at a certain location (nest). The "enclosure log" could be set up to include GPS location of nests or feeding stations in open range areas as well as document which birds were present in that area. In terms of database structure, the DOC *Access* database contains numerous tables with specific fields (such as names of body parts for a measurement table – see Appendix X) that makes the view expansive when entering data. *ZIMS* offers a condensed view by utilizing drop down menus for standardized data fields and also contains term dictionaries or in many cases, mouse-over definitions of terms that promote standardized data entry practices. Standardization is very important, especially when a program includes a collaborative effort between a number of wildlife institutions and organizations.

Genetic management of the takahē population is extremely important especially since this small meta-population is spread between six different islands. Each individual is entered into the Takahē Studbook when initially discovered or captured for rearing, requiring data entry into the DOC database as well as transfer of that data to the studbook keeper. If the data are kept in *ZIMS*, the studbook keeper would have real time access to all the information on each individual as soon as the data are entered. This would increase the efficiency of data flow and save time through direct communication between the animal caretakers and studbook keeper.

The Takahē Recovery Program requires cooperation from a number of institutions to capture, organize, disseminate and use data to manage the conservation program for this endangered species. Use of *ZIMS* for data management processes for individual records, health data, and population management would link *in situ* and *ex situ* components. *ZIMS* does not have a functional module for monitoring data and as such, there would be a benefit to link current capacity to other programs maintaining the monitoring data. This would help streamline the use of the enormous amount of data required for effective conservation action.

Table 4.4 Individual information, measurements and health data fields for *ex situ* data management for takahē comparing fields using current tools (DOC *Access* database) to fields covered in ZIMS. See Appendix X for DOC fields.

Individual Information

Access	*ZIMS*
Individuals	Individuals
Band number	Identifier
Date banded	Identifier
Name	Identifier
Sex	Sex type
Natal year	Hatch date
Origin	Birth location
Nest site/territory	GPS location
Clutch/Egg#	Egg log
Dam/Sire ID	Parentage ID
Training Y/N	Training
Tussock, Winter	Training log
Hopper, Grass	Training log
Vaccinations	Vaccinations
Erysipelothrix	Medical treatment
vacc./date	Medical treatment
Erys. booster/date	Medical treatment

ZIMS advantage: drop down menus condense data within one individual record.

Measurements

Access	*ZIMS*
Bird name	Identifier
Current band/date	Identifier
Age of bird	Hatch date
Observer	Reported by
Weight	Weight
Culmen	Length
Nares	Length
Shield	Length
Left/right mid toe	Length
Left/right tarsus	Length
Bill depth	Length
Ldf sexing	Sex type note
Blood label	Sample
Stored location	Sample location
Storage method	Holding conditions
Notes	Notes

ZIMS advantage: Weights and lengths are entered by date and can be displayed in graph format.

Health

Access	*ZIMS*
Samples	Sample module
Sample ID	Sample ID
Band number	Bird identifier-Local ID
Date taken	Sample date
Collector name	Collected by
Site name	*Notes
Sample type	Sample type
Sample volume	Next *ZIMS* update
Storage medium	Next *ZIMS* update
Storage temperature	Next *ZIMS* update
Storage location	Next *ZIMS* update

ZIMS advantage: sample data is maintained in the medical module and linked to the individual

*No comparable *ZIMS* field.

Access	*ZIMS*
Sample results	Tests and Results
Sample results ID	
Sample results date	Results date
Sample ID	Sample ID
Ascarid	Diagnostic results
Campylobacter	Diagnostic results
Capillaria	Diagnostic results
CBC avian	Diagnostic results
Chlamydia	Diagnostic results
Erysipelothrix	Diagnostic results
Salmonella	Diagnostic results
Strongyle	Diagnostic results

ZIMS advantage: there are sample request and samples/tests/results reports for an individual's medical history.

Table 4.5 Data fields for *in situ* monitoring data for takahē comparing fields using current tools (DOC *Access* database) to fields covered in ZIMS. See Appendix X for list of DOC fields.

Monitoring

Data fields with no comparable *ZIMS* field

Location	Hardware
Sites:	Transmitters:
Site name	Entry number
Site type	Site name
Management regime	Transmitter channel
Pest status	Transmitter type
Current? Y/N	Transmitter status
Territories:	Date of status change
Territory name	Removal status
Site name	Harness size
Year trapping started	Date of expiry
Current? Y/N	Aerial
Easting/Northing	Transmitter weight
	Fine tune

Monitoring Observations

Access	*ZIMS*
Birds	Birds
Bird obs. ID	*Notes
Takahe year	* Notes
Band number	Identifier
Obs. method	*Notes
Site name	*Notes
Territory name	*Notes
Northing/Easting	Enclosure
Breeding year	Bird's record
Skyranger state	*Notes
Mate ID	Br. mngt nt
Bird weight	Weight
Monitoring event	*Notes
Status	*Notes

*No comparable *ZIMS* field.

Monitoring Observations

Access	*ZIMS*
Nests	Nests
Observation ID	‡Observations
Date	‡
Observer ID	Recorded by
Obs. Method	‡Observations
Site name	‡Notes
Territory name	‡Notes
Northing/Easting	Enclosure
Breeding year	Bird's record
Nest fate	Enclosure
Clutch	Egg log
Number of eggs	Accession eggs
Parent 1,2 ID	Parentage

‡These data would be documented in the bird's records with the nest data in the enclosure log.

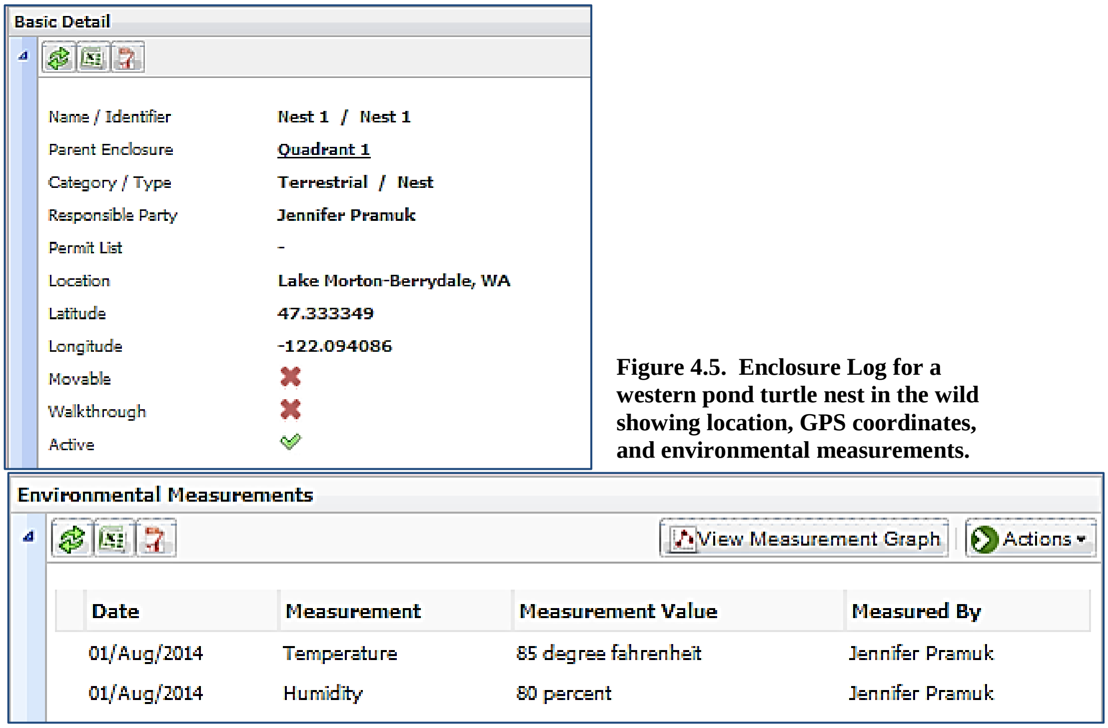
Access	*ZIMS*
Eggs/Chicks	Eggs/Chicks
Name	Identifier
Obs. ID	Observations
Nest obs. ID	Observations
Stage	Notes
Egg ID	Egg local ID
Egg Number	Egg number
Egg/chick status	Health note
Removed? Y/N	Disposition
Transferred in/out	Disposition
Chick band ID	Identifier
Foster parents ID	Accession info
Site transferred to	Disposition
Notes	Notes

ZIMS advantage: Eggs can be entered and when hatched, the entity changes to individual. All data is kept in one record.

Program: Western Pond Turtle Recovery Program

Species: Western pond turtle (*Actinemys marmorata*)

The western pond turtle program involves identifying nest locations through monitoring of females, collecting eggs or hatchlings for head-starting in zoological institutions and then returning them to the wild where they are intensively monitored. Although not ideal, the *ZIMS* "enclosure log" could document GPS location of the nests as well as maintain environmental data for each nest (e.g., temperature and humidity; Figure 4.5) and the individual animal that is found at that nest. The eggs or hatchlings that are collected from that nest thus can be linked to the female that was observed at the nest, and that information is documented in their specimen record. Eggs can be accessioned in *ZIMS* to document individual eggs within the nest (if monitored) or for eggs collected for incubation, hatching and rearing within an institution. Environmental measurements can be documented for incubation parameters (temperature, humidity, etc.) and incubation methodologies could be shared between participating institutions.


Basic Detail

Name / Identifier	Nest 1 / Nest 1
Parent Enclosure	Quadrant 1
Category / Type	Terrestrial / Nest
Responsible Party	Jennifer Pramuk
Permit List	-
Location	Lake Morton-Berrydale, WA
Latitude	47.333349
Longitude	-122.094086
Movable	✖
Walkthrough	✖
Active	✔

Environmental Measurements

View Measurement Graph
Actions

Date	Measurement	Measurement Value	Measured By
01/Aug/2014	Temperature	85 degree fahrenheit	Jennifer Pramuk
01/Aug/2014	Humidity	80 percent	Jennifer Pramuk

Figure 4.5. Enclosure Log for a western pond turtle nest in the wild showing location, GPS coordinates, and environmental measurements.

Two zoological institutions are involved in the head-starting program and both maintain individual records (core data, husbandry and medical records) in *ZIMS*.
The Local ID number for each turtle is cross-referenced in the Washington Department of Fish and Wildlife (WDFW) *Access* database which holds data on the turtles after their release. Although the data are linked in this way, all the data from the turtles' record while at the zoo (in *ZIMS*) is not passed on for entry in the WDFW database although the basic information is recorded (collection date, hatch date, sex, identifiers, capture and

release events, etc.). The data in the WDFW database mainly covers the information on each turtle after release (location, reproduction, mortality).

Turtles are monitored through radio-telemetry and recapture events. Currently, WDFW staff mark the location of the monitored turtles on a map as well as note the GPS coordinates. Although the terminology needs adjustment, the "enclosure log" in *ZIMS* could be a useful tool as water bodies can be identified in an open range area, and GPS coordinates will designate the exact location of the water body as well as the animals that are present. Any capture events can be documented with measurements, samples taken, and assessment of body condition noted in the animal's record. Recent health assessment studies have shown that as many as 30% of the released turtles develop shell rot disease as adults in certain release areas (Pramuck *et al*. 2013). Medical data on turtles in the wild are maintained by the WDFW separately from the medical data kept while the turtles are in the zoo. This makes it difficult to investigate methodologies for rearing and care in relation to the development of disease as adults in the wild. Having all the medical data in one place would improve efficiency and facilitate analysis.

One of the top priority goals that came out of the PHVA was for improvement in communication between *ex situ* and *in situ* personnel. This can be accomplished by closely linking the *ex situ* data (in *ZIMS*) with the *in situ* data (in the WDFW database) or through the use of a single system with access by all the partners in the program. Each participating organization and government authority would maintain the records for their portion of the program, and in using the same web-based system, communication would improve and the cumulative record for individual animals would document their whole history from the time they are collected as hatchlings, through the rearing phase in captivity and after release.

Category B Case Studies

Endangered species brought into captivity due to threat of extinction in the wild. At one time, listed as IUCN Extinct in the Wild. Reintroduction program well developed through captive breeding or head-starting with managed release and established monitoring program for assessment.

Program: Kakapo Recovery Programme

Species: Kakapo (*Strigops habroptilus*)

The small population of kakapo is intensively managed on predator-free islands by the Department of Conservation (DOC) in collaboration with the Auckland Zoo and Massey University. The DOC maintains an *Access* database on each component of the program from monitoring the birds in the wild for breeding and nesting (in burrows) activity, collection of eggs or chicks (with health issues) for incubation and rearing in a DOC facility, release with conspecifics of similar age (4-5 months old) using a soft release method, and continued monitoring after release to assess survival, growth and reproduction at maturity (see Appendix XI for data fields).

With such a small population, maintaining genetic diversity is critical and thus each bird is individually identified and parentage determined through monitoring in the wild or genetic analysis of biological samples. The DOC *Access* database holds core data for each individual in the population and in addition, parentage is recorded in *SPARKS* which will be used for meta-population management. *ZIMS* provides a platform for real-time access to reproductive events and pedigree documentation with a direct link to the studbook keeper for ease of direct communication with the animal caretakers. This direct link would facilitate efficient data flow for development of the studbook.

The DOC *Access* database contains extensive number of fields to capture data on the various components of the recovery program for kakapo. There are many aspects of *ZIMS* that would condense the data entry view and improve the efficiency for data entry and retrieval. *ZIMS* “enclosure logs” could be used to identify track and bowl locations as well as the individuals that are using them (males and females). The “enclosure logs” could also be used to identify and map (by GPS location) the burrows and the individual females that use them. Each individual egg could be accessioned in *ZIMS* with location (could be GPS location or burrow ID number), lay date, fertility status, expected hatch date and parentage as well as environmental measures within the burrows. When the eggs hatch, the entity within *ZIMS* will change from egg to individual animal and will retain the same Global Animal Number (GAN). The “enclosure logs” were not developed for structures or locations in the wild and although they may be used as a work-around, data standards reflecting the true nature of these locations need to be developed. That said, using the “enclosure” and accessioning eggs would assist in identifying kakapo that have bred (if breeding has been observed) and in assigning parentage for subsequent offspring that are produced. *ZIMS* offers the option for entering multiple sires and dams with the percentage of probable parentage for each individual if it is uncertain which would be useful for this species that exhibits a lek breeding system.

Comparison of data fields in the DOC A*ccess* database (see Appendix XI) to fields available in *ZIMS* shows that the individual information under All Birds and Health sections including origin, locations, measurements, band information, history, moults, health checks, chemistry, blood records, microbiology, samples, feathers, and sperm information can be maintained in *ZIMS.* For the Reproduction section, the track and bowl activity can be documented in *ZIMS* by entering the data in each bird's record. Mating information is covered and breeding history data could be determined by running a summary report for the individual bird. Nest details could be documented using the "enclosure" module, however, this is not ideal since the intent of the enclosure fields was for structures within an enclosure and thus the terminology would have to be standardized to reflect a structure in the wild. Although nest observations (behavioral observations) could be entered within each individual's record, there is no functionality in *ZIMS* to record observations for a structure. Hand-raising data, on the other hand, can be documented in *ZIMS.*

Monitoring of the birds is quite sophisticated with the use of Egg Timer transmitters for females and Checkmate transmitters for males. These monitoring devices will identify each bird and their activity such as breeding, incubating behavior or death. Since the birds are identified, these events could be documented in their individual records such that all the events for each bird are maintained in one place. For supplemental feeding, the snark (a part of the telemetry system) can program SMART (species monitoring, acceleration and radio-tracking) feeders to open for specific birds carrying transmitters and the food consumption for each individual could be documented in the individual's "feeding log" in *ZIMS (*feeding section in Appendix XI). Weights taken at the feeding station could be recorded in the "weights" section of the bird's record. Graphing functionality for weights will give a visual representation of weight gain or loss and with weight data and food consumption data both within one record, they can easily be compared to monitor the health of the animal. The other data fields for monitoring (Recovery section in Appendix XI) including hardware, triangulation data anchor traps, bearing, location, and weather do not have comparable fields in *ZIMS* although capture details could be documented in individual records.

Health checks are an important part of a routine monitoring program and involve capture for assessment of body condition and taking weights and biological samples. The medical component of *ZIMS* is structured to maintain medical records, samples and test results in one place for each individual bird which would be beneficial especially for maintaining the health records for the duration of the life of the bird as it is transferred from the wild, to a rearing facility (if captive-reared), and after release. Auckland Zoo staff works with the DOC to analyze samples, treat sick birds and perform necropsies (on all kakapo in the program). Records for birds at the zoo are maintained in *ZIMS* and sample results and necropsies for birds that were not physically at the zoo are maintained in documents with reports going to the DOC. It would be beneficial to maintain all of this information in one place as health and necropsy (available in a future *ZIMS for Medical* release) records can be pooled in *ZIMS* to identify disease trends in the population. This information would be available to all stakeholders that are part of the program, thus improving communication between the partners. In addition, compilation of health issues would be available for use in wildlife disease risk analysis as a global resource to other conservation practitioners.

The Kakapo Recovery Programme requires collaboration and efficient communication between many stakeholders. Auckland Zoo, as an active ISIS member, has already set protocols for animal records-keeping for kakapo using ISIS applications. Further participation by the DOC could help to streamline data management processes through the use of one information management system. *ZIMS* would be useful to standardize *ex situ* data between facilities, for maintenance of individual records of the whole population to track genetics and inform management for transfers, and to maintain health records on the whole population. *ZIMS* could then be used to link with monitoring data in the DOC *Access* database and the MU and DOC Huia Mortality Databases.

Program: Kihansi Spray Toad Reintroduction Program

Species: Kihansi spray toad (*Nectophrynoides asperiginis*)

The Kihansi spray toad was declared Extinct in the Wild after the population went through a rapid decline due to loss of its natural habitat in the Kihansi Gorge of Tanzania. The construction of a dam along the Kihansi River diverted the river away from the Gorge and completely altered the spray zone habitat that was critical for survival. In addition, an outbreak of chytridiomycosis was enough to send the population crashing. An assurance population was established at the Wildlife Conservation Society/Bronx Zoo and Toledo Zoo in the United States and both institutions developed a breeding program with the intent of returning the toads to the wild as habitat was restored. The toads could not be individually identified nor could they be transpondered or marked due to their small size. As ISIS members, both zoos maintained the toads in groups, documenting census numbers as well as births and deaths under a group record in *ZIMS.* At Toledo Zoo, the herpetology staff use *Excel* spreadsheets to maintain records on monthly inventory numbers, presence of parasites, husbandry data, and for research on environmental measures, nutrition, and population dynamics. Medical data are kept in *MedARKS*.

Breeding management for groups relies on different protocols than for individuals where pedigree data is known. With a known pedigree, inbreeding coefficients, founder representation, and mean kinship can be calculated and pairings can be made to ensure genetic diversity is maintained in the population (Princée 1995). Toledo Zoo tracks the groups in *ZIMS*, using a scheme for low-intensity genetic management by splitting and merging groups. Each group is maintained in a single vivarium that is documented in

Table 4.6 Monthly inventory data fields for *ex situ* data management for Kihansi spray toad reintroduction program comparing fields using current tools (Toledo Zoo *Excel* spreadsheets) and available fields in *ZIMS*. See Appendix XII for complete data field lists.

Monthly Inventory

Excel	***ZIMS***
<u>Group Info</u>	<u>Group Info</u>
Enclosure ID	Enclosure ID
Group count	Census count
#Males/#Females	#Males/#Females
# Unknown sex	#Unknown sex
Births	Births
Deaths	Deaths
Not reared	Young died
Departures	Dispositions
Male group ID	Male group ID
Female group ID	Female group ID
Unk group ID	Unk sex group ID
<u>Medical</u>	<u>Medical module</u>
Coccidia	Parasitology
Nematodes	Parasitology
Ciliates	Parasitology
Bacteria	Microbiology/cultures
Hookworms	Parasitology
Mites	Parasitology
Flagellates	Parasitology
Cage size	Enclosure

ZIMS advantage: the medical module can document parasites or bacteria for a group. The enclosure module can note environmental measures, cage dimensions, and substrates.

Inventory Analysis

Excel	***ZIMS***
Month Birth rate Death rate Transfer Not reared	Date Births, deaths, census numbers can be downloaded to Excel for analysis.

ZIMS. The enclosure module could also document enclosure dimensions, substrate types, construction, and environmental measures such as humidity, substrate pH, temperature, energy use, UV irradiance which are important to monitor for amphibian species. Toledo Zoo uses *Excel* spreadsheets to manage data for studies on impact of environmental measures, diet, and group management on health, growth, reproduction and mortality (Table 4.7).

Due to the high risk of the spread of chytrid infection for amphibians, the *ex situ* facilities maintain their Kihansi spray toad populations under bio-secure conditions. Health assessments are a top priority with routine testing for chytrid and other diseases during the time in the facility and as a pre-release protocol. Medical and necropsy data are stored under group numbers in *ZIMS* for the Toledo Zoo. Currently, the monthly inventory spreadsheet includes presence of parasites and bacteria (Table 4.6). A *ZIMS* group summary report for census numbers, births, deaths, transfers and medical data would preclude the need to do double data entry in *ZIMS* and *Excel* for the same information.

A soft release paradigm is used as the release mechanism to the wild. Small netted enclosures are set up within the spray zone (now artificially provided by misting systems). The toads are monitored within the enclosures for survival and reproduction with frequent health checks for evidence of chytridiomysosis, other diseases and presence of parasites. There are ecological parameters measured (see Table 4.8) to assess the habitat for the toads. Data are maintained in *Excel* spreadsheets. *ZIMS* would be very useful to track the animal data for the soft release (Table 4.8). Data on the released toads would be under a group number in *ZIMS*, which could track census numbers, sex ratios, dates and numbers of toads released, births and deaths. Health assessments for the group (including samples, tests, results) could be documented in the medical module as well as necropsy results. Data on enclosure location (GPS coordinates) , size, plant species, and environmental measures (air temperature, humidity) would be linked to the group data. *ZIMS* does not have the capacity to capture some environmental measures for the natural habitat. After release from the enclosures, *ZIMS* would be useful to maintain survey data on the released toads.

Using *ZIMS* for both *in situ* and *ex situ* populations would facilitate communication between conservation partners as they would have access to all the information on the whole population. Medical and physiological data from the *ex situ* population could be compared with the data from the *in situ* population. Management strategies and population censuses would be available to everyone. Sharing data will facilitate research collaborations for the overall conservation of this critically endangered species.

Table 4.7 Data fields for *ex situ* experiments for Kihansi spray toad reintroduction program comparing fields using current tools (Toledo Zoo *Excel* spreadsheets) and available fields in *ZIMS*. See Appendix XII for complete lists of data fields.

Experiments

Excel	*ZIMS*
<u>Reduced mist</u>	<u>Reduced mist</u>
Mist cyle variables	Enclosure variable
Cage ID	Enclosure ID
Group size	Census
Number of males	Number males
Number females	Number females
Unknowns	Unknowns
Male/Females group ID	Group Local ID
<u>UV effect on growth</u>	<u>UV effect</u>
UV or non-UV light	Enclosure UV
Enclosure ID	Parent Enclosure ID
Cage ID	Cage ID
Group size	Census
Number males	Number males
Number females	Number females
Unknowns	Unknowns
Male/Female Group ID	Group Local ID
Animal number	*Note Template
Mass	*Note Template
Snout vent length	*Note Template

*A note template can be set up to include weights and snout vent length measurements.

Excel	*ZIMS*
<u>Diet study</u>	<u>Diet study</u>
Number fruit flies	Feeding log
Cage ID	Enclosure ID
Date	Date
Group #	Local ID
Animal #	*Note template
Snout vent length	*Note template
Mass	*Note template
	*Note template
<u>Density study</u>	<u>Density study</u>
Cage ID	Enclosure ID
Start date	Date
Month	Date
Cage size	Enclosure size
Volume	Encl. volume
Area	Enclosure area
Original #indiv.	Census
Final #	Census
Deaths	Deaths
Density	Calculate
Animals /sq.in.	

*A note template can be set up to include weights and snout vent length measurements.

Table 4.8 Data fields for *in situ* monitoring for Kihansi spray toad reintroduction program comparing fields using current tools (*Excel* spreadsheets) and available fields in ZIMS.
See Appendix XII for complete list of data fields.

In Situ Monitoring

Excel	*ZIMS*
Ecological	Ecological
Air temperature	Enclosure temp
Humidity	Encl. humidity
Wind speed	*Notes
Precipitation	*Notes
Water quality-pH	Encl. water quality
Suspended solids	*Notes
Water flow-discharge	
Wetland vegetation	Encl. plant species
Wetland insect species	*Notes

*No comparable *ZIMS* field.

Excel	*ZIMS*
Kihansi spray toad	KST
Population size	Census
Sex ratios	Sex ratios
N reintroduced	N added
Date	Date
Soft release pen ID	Enclosure ID
Pen or release	
Location	GPS coordinates
Births	Birth addition
Disease	Medical
Death	Death subtraction
Necropsy	Medical

ZIMS advantage: can include all the information about the soft-release enclosure is in one place.

Program: Red Wolf Recovery Program

Species: Red Wolf (*Canis rufus*)

The Red Wolf Recovery Program depends on integration of *ex situ* breeding management with reintroduction and conservation translocation processes to conserve a population previously listed as Extinct in the Wild. In an analysis of the data fields currently used by *ex situ* institutions and the USFWS, those relating to individual histories, population management, medical data, reproduction and husbandry methodologies are available in *ZIMS* (Table 4.9). *ZIMS* falls short when considering monitoring data. Within the Red Wolf SSP®, all but five of the 44 institutions maintain their records in ISIS, which facilitates communication with the studbook keeper and species coordinator. There are a few institutions that continue to use paper records and these institutions should be encouraged by the SSP® to start with electronic records so that the information can more easily be shared. Ideally, all of the institutions would participate in ISIS using standardized records-keeping protocols such that data on any birth, death or transfer event would be readily available to the species coordinator. *ZIMS* facilitates sharing of data such that when an animal is transferred from one institution to another or released to the wild, the receiving institution or the USFWS can have access to the entire specimen record for that animal. Medical records management differs between the ISIS member institutions with only five institutions using *MedARKS* and the remainder (37 institutions) maintaining medical records in various formats including paper files. By using the medical component of *ZIMS*, medical histories for each animal would be readily available if they were transferred, and medical data could be added to the individual record after release to the wild (in the case of pups born in an institution and fostered to a wild litter). With the release of *ZIMS for Medical*, many more institutions will have access to the use of the medical component for their medical records.

The red wolves in the wild are extensively monitored as individuals for health, survival and reproduction. To track genetic diversity, all of the red wolves born in the wild are included in the studbook, and maintaining individual records of these individuals in *ZIMS* will facilitate ready access for birth and death events by the species coordinator. As introgression with coyotes is an issue, genetic monitoring is important as litters are produced in the wild. Although the “medical” module in *ZIMS* has a section to track samples, there are no specific data fields for results of genetic testing. Females are monitored to locate denning sites and when pups are born, they are given a health exam and blood is drawn to analyze for coyote introgression. Although not originally intended for this purpose, *ZIMS* “enclosure” module can be used to identify GPS location of dens as well as the individuals using the den. *ZIMS* medical component can contain the health data, document vaccinations given and track samples taken on each individual during capture events. *ZIMS* can handle individual information such as measurements and medical data that are collected during capture events however there currently is no module for specific monitoring data such as capture method, hardware (radio-collar transmitters), or radio-telemetry data (GPS coordinates). For the current data management system for animals in the wild, medical records, necropsy reports and media (x-rays) are kept separately in hard copy format and are difficult to access for analysis. Maintaining the medical records within the individual specimen record for animals both in the wild and those in zoological institutions will offer access to health information throughout the life of each animal as well as facilitate pooling of data for an overview of the health of the population.

The Red Wolf Recovery Program relies on integration of the *ex situ* breeding program (Red Wolf SSP®) with the *in situ* component through (historical) reintroduction and current cross fostering of pups born in SSP® institutions to supplement the wild population. Standardization of data management processes within the *ex situ* institutions will facilitate the breeding management program. In addition, use of *ZIMS* for the wild population will effectively integrate the data management processes that will eliminate the issue of multiple sources for medical and historical records, and fill in information gaps to facilitate analyses for assessment of the program.

Table 4.9 Event data fields for *in situ* data management for red wolf reintroduction program comparing fields using current tools (USFWS *Access* database) and available fields in *ZIMS*. See Appendix XIII for complete data field lists.

Monitoring Capture Event Process Table

Access	*ZIMS*
General Information	General Information
Species/Studbook #	Taxonomy/Studbook#
Sex	Sex type
Radio-collar serial #	*Notes
Radio-collar frequency	*Notes
Staff initials	Recorded by
Capture method	*Notes
Foot captured F/R,Fr/Rear	*Notes
Captive/free-ranging status	Holder history
Age (months)	Birth date
Weight	Weight
Drugs used Y/N	Anesthesia module
Body condition score	Medical module
Dentition wear	Medical module
Tooth pulled (identify)	*Notes
Fecal ? Y/N	Samples
Ectoparasites? Y/N	Samples
Surgery? Details in memo	Medical module
Sterile? Had surgery?	Medical module
Transponder #	Transponder identifier

*No comparable *ZIMS* field.

Access	*ZIMS*
Measurements	Measurements
Ear, tail, body	Lengths
Body+tail	Lengths
Front/hind foot	Lengths
Width + length	Lengths
Shoulder, neck	Lengths
Testicle w/l	Lengths
Vulva w/l	Lengths
Inguinal nipple w/l	Lengths
Medical	Medical module
Rabies vacc? Y/N	Immunizations
Ivermectin? Y/N	Treatment
Parasiticides?	Treatment
Flocillin?	Treatment
Amt. flocillin (ml)	Treatment
Heartworm results	Tests/results
Memo – comments	Clinical notes
Data entry (initials)	Recorded by
Proofed by (initials)	Reviewed by

ZIMS advantage: lifetime measurements and medical information in individual record.

Event Table

Access	*ZIMS*
Visits	Visits
Arrival	Acquisition
Birth	Birth
Birth location	Birth location
Release – Easting/Northing	Release to the wild – location
Release location - county	Notes
Capture by trapper	Rearing
Fostered to wild litter	Transponder
Transpondered in den	Life stage
Whelped	Contraception
Sterilized w/hormones	Transfer transaction
Shipped to other site/facility	Death disposition
Death –natural:health, intraspecific	Cause of death
Death - foul play	Death disposition
Legal take – trap, gunshot, handling, euthanized	Death disposition
Disappeared	Cause of death
	Disposition

Genetics samples
Samples can be documented in *ZIMS* Samples module but there are no specific fields to document genetic results. The taxonomy can be recorded in the individual's basic information record with designation of reason for taxonomy change.

Monitoring
Radio-telemetry fields for monitoring data such as GPS location and transmitters used are not available in *ZIMS*. Start and end dates, reasons for discontinuing, fate unknown, and comments can be documented in a note.

Category C Case Study
Endangered species that does not currently have a reintroduction program but future conservation efforts include such a program. Current *ex situ* programs contribute data to PHVA for the species and integrated plan is developed for overall conservation.

Program: Pantanal Tapir Program, Lowland Tapir Conservation Initiative

Species: Lowland Tapir (*Tapirus terrestris*)

The Pantanal Tapir Program involves research on the biology and ecology of lowland tapir in the Pantanal of Brazil to determine basic parameters on population sizes, distribution, land use, social behavior, reproduction, health, and genetic diversity of this threatened species. Close collaboration with *ex situ* tapir taxon advisory groups within the IUCN Tapir Specialist Group facilitated information exchange to provide input reproduction parameters from the *ex situ* population for analysis in the Lowland Tapir PHVA to make up for lack of information from wild populations. Basic research will provide life history information critical for future conservation planning and to facilitate reintroductions or translocations if needed in the future to restore reduced wild populations.

The research consists of monitoring individual tapirs within the landscape and depends on capture events to individually identify animals, perform health assessments, collect samples and radio-collar the animal for future monitoring. In addition, camera traps are placed around the study area to capture photos throughout the day and night. The data for the capture events are maintained in one large *Excel* spreadsheet containing capture, anesthesia, manipulation, health, and collected sample data as well as test results (over 200 fields – see Appendix XIV). Separate *Excel* spreadsheets contain data on measurements, capture summary and camera traps. To access a full record for one individual, data has to be extracted from the various *Excel* spreadsheets.

ZIMS will condense all the data for one individual into one specimen record. The "enclosure log" can be used to describe attributes (dimensions, materials used, GPS location, environmental measures) of the box traps as well as individual animals that are trapped for each capture event (Figure 4.6). An enclosure report for each box trap would list all the individuals that had been captured with the date of capture whereas the animal's specimen report would note the box trap and date for each capture event for that animal. Measurements can be documented in *ZIMS* core data section and health assessment data (body condition, anesthesia parameters, samples, hematology and biochemistry results, urine, feces and milk analyses, physiological values, parasite and infectious disease results) can be documented in the medical module. Each sample collected during a capture and manipulation can be documented in the animal's record (Figure 4.7) and results can be later entered in the Tests and Results section of the same medical record. Parentage can be documented through observation or camera trap photos of known individuals, or through genetic analysis of collected tissue or blood. Camera trap photo metadata and radio-tracking data can be cross-referenced to the individual's specimen record. Condensing all the data for one individual within a single specimen record will facilitate efficient data entry and analysis as well as provide data that can be pooled for population assessment.

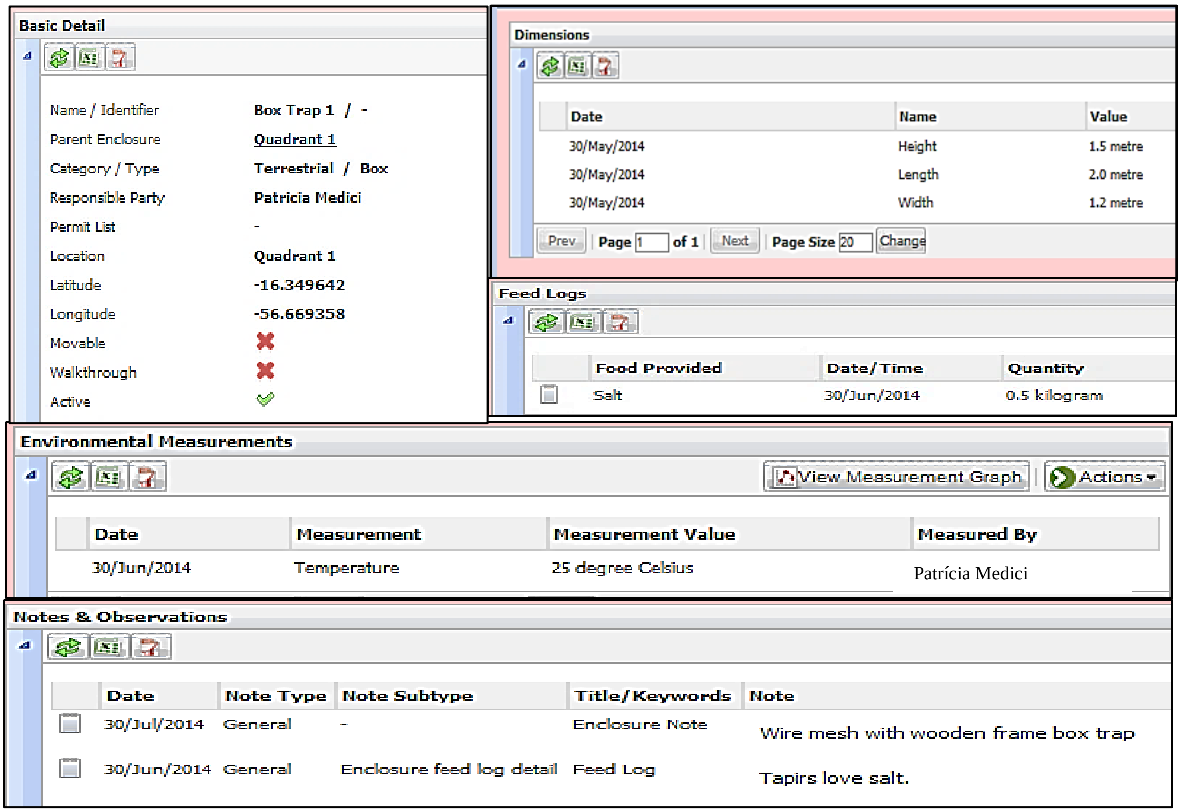
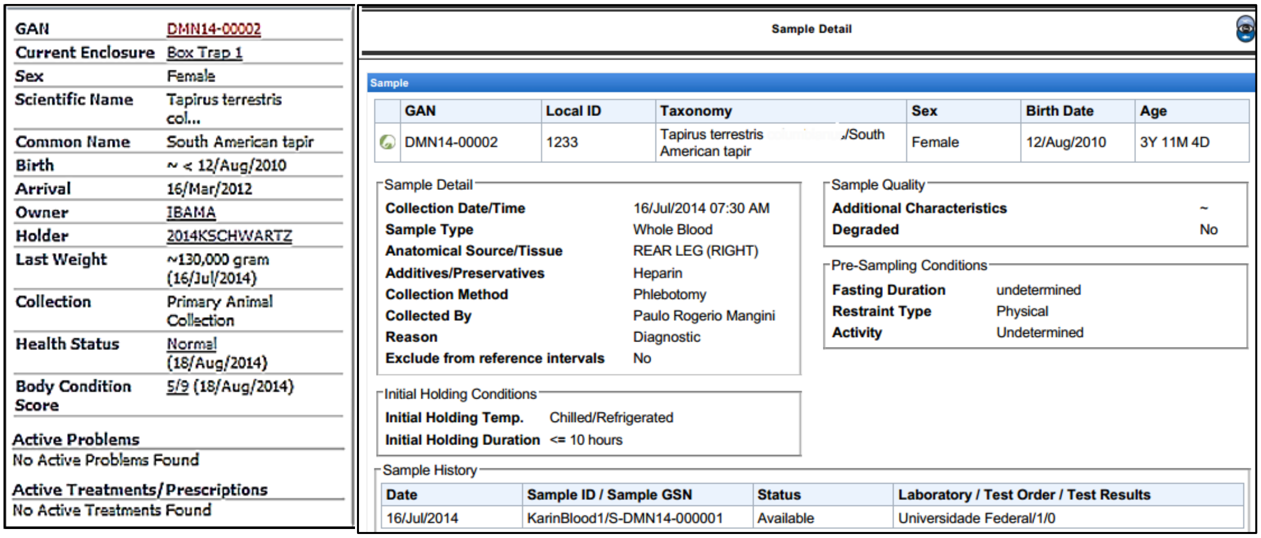


Figure 4.6 . *ZIMS* Enclosure Log to maintain data on box traps used for capturing tapirs. Data includes GPS location, dimensions, feed log, environmental measures (temperature) and notes/observations. ISIS 2014



GAN	DMN14-00002
Current Enclosure	Box Trap 1
Sex	Female
Scientific Name	Tapirus terrestris col...
Common Name	South American tapir
Birth	~ < 12/Aug/2010
Arrival	16/Mar/2012
Owner	IBAMA
Holder	2014KSCHWARTZ
Last Weight	~130,000 gram (16/Jul/2014)
Collection	Primary Animal Collection
Health Status	Normal (18/Aug/2014)
Body Condition Score	5/9 (18/Aug/2014)

Active Problems

No Active Problems Found

Active Treatments/Prescriptions

No Active Treatments Found

Sample Detail

Sample

GAN	Local ID	Taxonomy	Sex	Birth Date	Age
DMN14-00002	1233	Tapirus terrestris /South American tapir	Female	12/Aug/2010	3Y 11M 4D

Sample Detail

Collection Date/Time	16/Jul/2014 07:30 AM
Sample Type	Whole Blood
Anatomical Source/Tissue	REAR LEG (RIGHT)
Additives/Preservatives	Heparin
Collection Method	Phlebotomy
Collected By	Paulo Rogerio Mangini
Reason	Diagnostic
Exclude from reference intervals	No

Sample Quality

Additional Characteristics	~
Degraded	No

Pre-Sampling Conditions

Fasting Duration	undetermined
Restraint Type	Physical
Activity	Undetermined

Initial Holding Conditions

Initial Holding Temp.	Chilled/Refrigerated
Initial Holding Duration	<= 10 hours

Sample History

Date	Sample ID / Sample GSN	Status	Laboratory / Test Order / Test Results
16/Jul/2014	KarinBlood1/S-DMN14-000001	Available	Universidade Federal/1/0

Figure 4.7. Example of data entered in *ZIMS* Medical component for a whole blood sample collected during a capture and manipulation of 0.1 lowland tapir.

Category D Case Study

Endangered species that has a rescue/rehabilitation/release program but no current reintroduction program of captive animals to the wild.

Program: Cheetah Conservation Fund (CCF) Program

Species: Namibian Cheetah (*Acinonyx jubatus jubatus*)

The Cheetah Conservation Fund (CCF) Research and Education Centre is a rescue and rehabilitation organization for cheetahs injured or orphaned from surrounding areas, and also is a renowned research facility with a fully-equipped veterinary clinic as well as the only genetics laboratory at a conservation facility in Africa. Every cheetah that comes into the Centre receives a full medical exam that includes measurements, samples taken for genetic and health analysis and general health assessment. Every cheetah that can be returned to the wild goes through a recovery period and then through a soft release paradigm where it is monitored until able to survive back in the wild on its own. They are also monitored through radio-telemetry intensively after release to assess survival and reproduction.

There are three main areas for records-keeping at CCF (Figure 3.30): 1) *ex situ* – individual core data and husbandry/ medical records for cheetahs while at CCF;
2) research (samples - ectoparasites, endoparasites, hair, skeletal, cytology and blood slides, gastric biopsy, semen, scat) and results from analyses; 3) *in situ* - capture and release records, radio-tracking, camera trap data. The records were kept in *Excel* spreadsheets with one huge Master Database spreadsheet for capture data, feeding logs, health exams, measurements, blood analysis and sample data. There were separate spreadsheets for inventories of samples (see list above). Daily logs for events were kept in a spreadsheet, and records for individuals were copied and pasted into a spreadsheet for each cheetah. Although there were three main areas for records, the records for each individual animal spanned the three areas and there was no central place to find all the information on each animal. Previously, CCF was an ISIS member (from 1999-2009) and maintained medical records in *MedARKS*. Each animal was accessioned in *ARKS* (a requirement since *MedARKS* was linked to an animal through its accession number), but *ARKS* was not used for any of the animal data. A negative consequence of this was that the animals showed up in the ISIS database but accurate acquisition and disposition data were not entered. This caused the ISIS database to show incorrect numbers of cheetahs present at CCF subsequently falsely augmenting the global population numbers. Clinical

records at CCF in many cases were kept as hard copies and filed separately from the rest of the records.

Using *ZIMS* for collating all the data on each individual animal will centralize the records, improve the efficiency of data entry, and facilitate assessment. “Enclosure logs” can be used to document the location of the animal while at CCF, and the conditions of the soft release and final release processes. “Feeding logs” will track food consumption while at CCF as well as during food supplementation events after release. Data from medical exams and procedures will be contained in the medical component of each animal’s record. All of the samples taken and test results can be documented with reference to the individual animal and data can be pooled for an overview of the population. For each sample type (Figure 4.8), additional information on specific attributes for that type is available to fine-tune the record (e.g. entry for whole blood sample for a lowland tapir, see Figure 4.7). The radio-tracking and camera trap data can reference the individual animal’s record (which will span the time held at CCF and after release) in order to make assessments on survival and reproductive output after release to the wild.

CCF has now rejoined ISIS and is currently deploying *ZIMS* with the Medical component soon to follow. There will be some clean-up measures taken to restore the records for cheetahs previously accessioned in *ARKS* and corresponding medical files in *MedARKS*. As the International Cheetah Studbook Keeper, the CCF Director will now have direct access to global cheetah records and will be able to benefit from the population management functions of *ZIMS* .

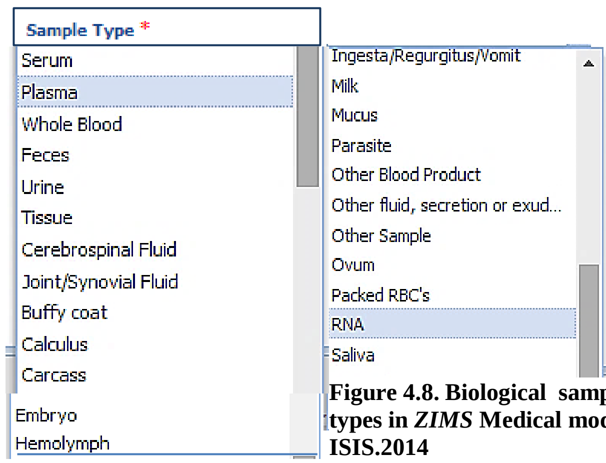


Figure 4.8. Biological sample types in *ZIMS* Medical module. ISIS.2014

Category E Case Studies

Endangered species with a research program for the wild populations but no current reintroductions from the captive population (if present). Data exchange is critical for understanding of the species, benefitting both wild and captive populations.

Program: Armenian Viper Research

Species: Armenian viper (*Montivipera raddei*)

Although there have been studies on reproduction and behavior of Armenian vipers in captivity (Ettling 1996), little was known about this venomous reptile in the wild. Thus, this research on this species was at the initial stages to gain information on basic biological and ecological life history traits. Vipers are hand-caught, individually identified (received PIT Tags or ventral scale clipping: Plummer and Ferner 2012), weighed and measured, with blood and tissue samples taken for genetic and health analyses. They are implanted with a radio-transmitter and then tracked to determine land use and monitor population dynamics.

Core and medical data could be maintained in individual records in *ZIMS* and linked to radio-telemetry data. Physiological values can be compiled for the monitored wild population and compared to the values from the *ex situ* population which may impact husbandry methods for maintaining this species in zoological institutions. Due to a health issue with low Vitamin D levels found in Armenian vipers in *ex situ* facilities, a study on Vitamin D levels in the wild population is being conducted so that comparisons could be made (see Armenian viper case study in Chapter 3). UV light levels and elevation are recorded to observe the relationship between these environmental parameters and Vitamin D levels in the blood. Attributes of the collection site including altitude can be recorded in *ZIMS* (Figure 4.10) and environmental measurements can be documented in the description of the capture area (Figure 4.9).

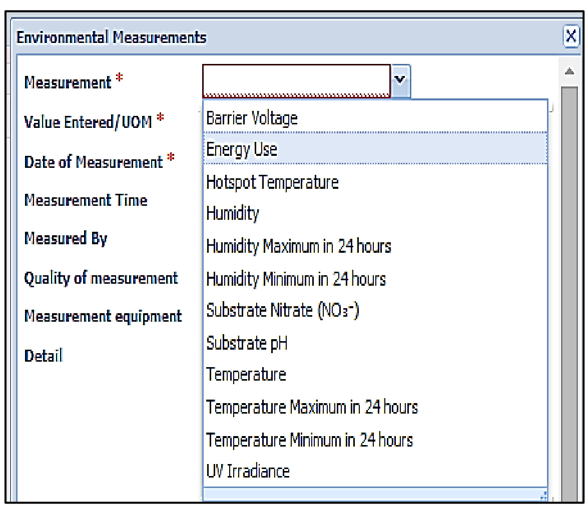


Figure 4.9. Menu of environmental measurement fields available for an enclosure or area.

Maintaining the records for a wild research population in *ZIMS* will facilitate data exchange between researchers and those caring for the animals within zoological institutions. Test results for genetic diversity and relatedness can be documented and along with medical and behavioral data, will facilitate an understanding of this species in the wild.

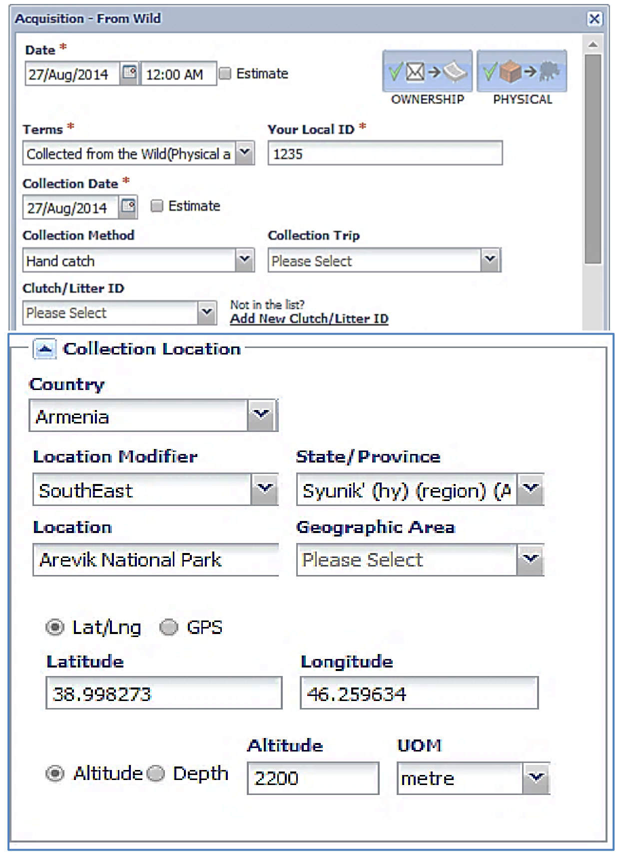


Figure 4.10. Accession data for an Armenian viper includes collection location, latitude/longitude coordinates and altitude. ISIS 2014

Program: Giant Armadillo Project

Species: Giant armadillo (*Priodontes maximus*)

Very little is known about the giant armadillo's life history and there are currently no individuals in ISIS member zoological institutions. The Giant Armadillo Project consists of research on basic life history parameters and population demographics through capture of individuals for health assessments and sample collection, and monitoring after release through radio-telemetry and camera trap photography. Large *Excel* spreadsheets are used for data capture with separate sheets for biometrics, containment and clinical evaluation, sample analysis and burrow measurements (see Appendix XVI) as well as spreadsheets for radio-telemetry and camera trap data.

Identification of individual giant armadillos is important to gain details on life history parameters and with the current data management system, data for one individual would have to come from a number of different spreadsheets. The *ZIMS* “enclosure logs” could be used to map the location of burrows, document attributes such as dimensions and environmental measurements as well as identify the individuals using the burrows (Figure 4.11). Reproduction, parentage and genetic test results would build a family tree showing relationships between individuals. The “medical” module could maintain the data on sample collection, health assessments, and test results within the animal’s record. Use of *ZIMS* would condense the data into one record for each individual, make data entry more efficient by reducing duplicate data entry, and facilitate analysis for the individual animal as well as for assessment at the population level.

e

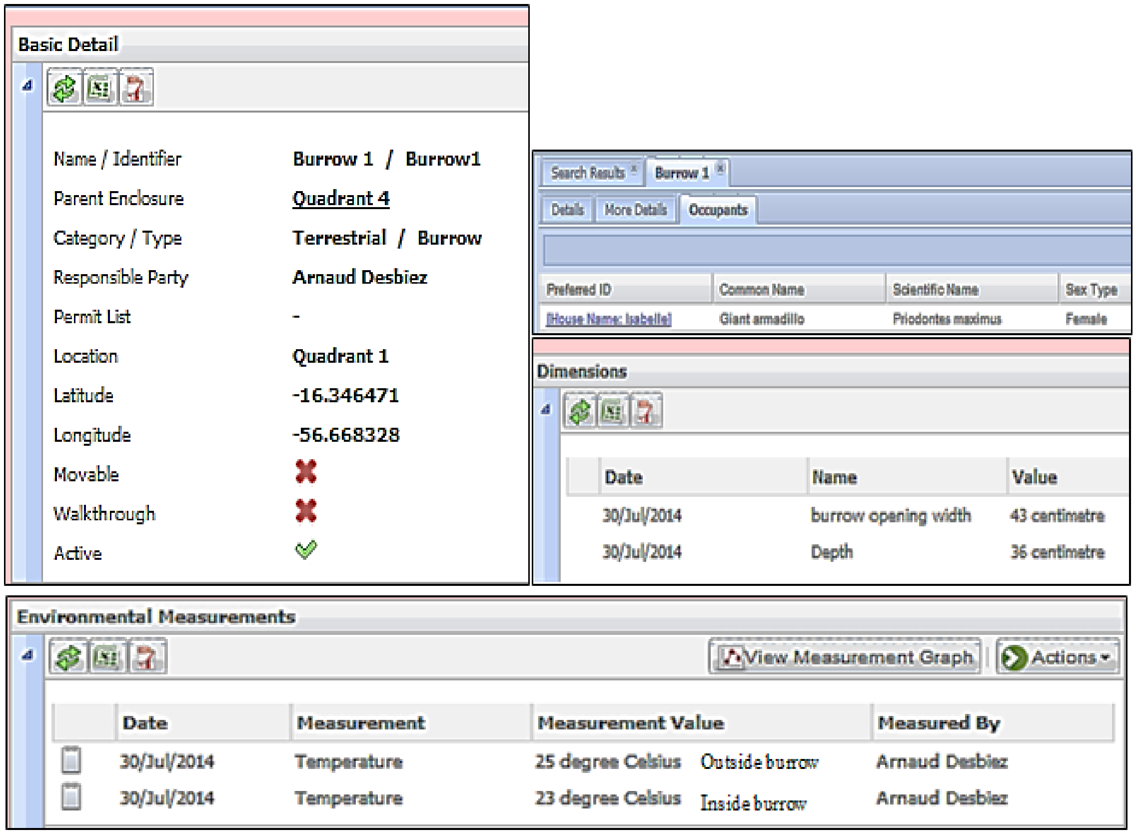


Figure 4.11 . Enclosure Log identifying a burrow's location, latitude/longitude coordinates, dimensions, environmental measurements and occupants (with hyperlink to the specimen record). ISIS 2014.

Discussion

The programs for threatened species represented in this study all exhibited basic components requiring data collection on species life history, population dynamics, genetic diversity, health, reproduction and population sustainability. These parameters follow the framework of essential biodiversity variables identified by the "Group on Earth Observation Biodiversity Observation Network" for measuring, reporting and management of biodiversity change (see section on Important Parameters for Managing and Monitoring Wild Populations, pp. 60-61; Pereira 2013). Programs for six of the species involved an *ex situ* component where individuals were maintained for a certain amount of time in zoological institutions (either born or head-started in a facility). Each program involved numerous *ex situ* and *in situ* partners and a common theme found within all six programs was the inability to efficiently compile data for analysis due to the multiple data management systems used among the partners. Three programs involved species for which basic life history and ecology parameters were unknown and data sharing on *ex situ* population parameters (of the same or related species) was important. Data management processes for these three programs consisted of numerous spreadsheets making compilation of data on individual animals difficult. For each program, use of *ZIMS* to integrate data management of *ex situ* (if present) and *in situ* populations would streamline data management processes to facilitate a "one plan approach" to species conservation.

Nine programs were based on data collected on individually identified animals and one was based on data for animals identified by a group. *ZIMS* is organized to gather all the information in individual specimen or group records as well as organize data for the institution (species inventories, enclosures, equipment inventories, staff roles, etc.). For population breeding management programs (American burying beetle, red wolf) or those wild populations that are managed using a studbook (kakapo, takahē, cheetah), parentage data can be maintained in *ZIMS* to facilitate development of the studbook. Maintaining records on the wild-born or hatched animals in *ZIMS* would facilitate incorporation of both *ex situ* and *in situ* populations into the studbook for meta-population management (e.g. red wolf). To facilitate communication between numerous partners involved in a breeding program, it is important that data management practices are standardized, which means that all partners should be using the same information system. This will also standardize husbandry and medical records-keeping processes.

All the programs except one involved monitoring individuals in the wild which required either attaching identifiers prior to release (for captive-bred or head-started animals) or capture for health assessments, tagging or transpondering and attaching radio-transmitters. Data on identifiers, collection of samples, health assessments and capture methodologies can all be maintained within an individual record in *ZIMS*. For those programs with an *ex situ* component, the data for animals recaptured in the wild would be added to their existing record, linking the information to the data on that animal while under human care. Integrating the data management processes in this way would offer the ability for both *ex situ* and *in situ* personnel to access the data to analyze results of pre- and post-release methodologies as well as track medical history for each animal. In addition, health data for a species could be pooled to characterize health and disease trends for comparison between *ex situ* and *in situ* populations.

ZIMS offers an “enclosure log” which was developed to document the enclosures within an institution as well as their attributes including location (GPS coordinates), dimensions, substrates, barriers, environmental measurements, feeding logs, plants, water bodies and the individual animals within the enclosures. The “enclosure log” could be used to document designated areas (with the selection of the term “open range”) in the wild that may or may not be actual enclosures. The enclosure log has the option to identify various structures within an “open range” such as nests or burrows, or capture areas such as box traps. Each capture event for an identified animal as well as the attributes and environmental measures for each area can be documented. Thus, a specimen report for an individual animal will show all the capture events, where it was captured, what samples and measurements were taken for each event, and results of the tests on that animal. Additionally, an enclosure report for a particular area, box trap or nest will show all the individuals that were captured or were present in that particular spot with a link to those individuals’ specimen records. Maintaining the records for these events in *ZIMS* would eliminate the need for data entry in an array of large spreadsheets, streamline the analyses processes, and offer real-time access to all partners facilitating effective communication.

Although the "enclosure log" can be manipulated for use for monitoring burrows or nests or documenting capture events in traps, this was not the original intent. The data standards for these fields refer to an *ex situ* environment where the different structures are found within an enclosed area of some type. To retain the integrity of the system, a new module would need to be developed for a "wild collection" that would contain data standards for documenting release areas and all the parameters for monitoring or capture events (location, methodologies, health assessment, samples collected, measurements, etc.). Some monitoring data (e.g. GPS coordinates for radio-telemetry, camera trap photos) may be beyond the purview of *ZIMS*, although there could be a link within an animal's record that would point toward these data.

Conclusions

Use of *ZIMS* for both *ex situ* and *in situ* data management would integrate the components of a conservation program for holistic action as identified in a "one plan approach". As a single, web-based information management system, *ZIMS* would facilitate genetic analysis for species that utilize a studbook to incorporate both *ex situ* and *in situ* populations into the planning process. For species whose basic life history and ecology parameters are not well known, a single web-based information management system would facilitate data sharing between wildlife researchers and *ex situ* partners to identify life history and health parameters needed for *Vortex* population analysis in a Population and Habitat Viability Assessment (PHVA) or in more complex analyses using *MetaModel Manager* for conservation planning (Pollack and Lacy 2013). Finally, use of

ZIMS for both *in situ* and *ex situ* data management processes would streamline data entry and facilitate communication between conservation partners.

As a global information management system, the ISIS central database offers the potential to pool data from across the world to contribute to an understanding of species biology, ecology, and conservation management. New knowledge is based on incremental gaining of understanding through analysis of past work and yet there has been criticism that the implementation of action after scientific advances have been made is slow due to inaccessibility to these findings (Fuller *et al*. 2014). Although ISIS is a membership organization and data are not freely available to the public, all partners within a conservation program would have access to the ISIS database as well as to the data from zoos and conservation partners worldwide. Using *ZIMS* for long-term monitoring of populations in the wild could assist in identifying population parameters necessary for evaluation of conservation status (population size, growth, range, effect of threats) and contribute to the IUCN Red List assessments. For species that are monitored using law enforcement programs such as *MIST* and *SMART*, *ZIMS* could serve as a repository for the basic information for each individual and link to the spatial information in the law enforcement programs. There is great potential to link with other global database systems that maintain biodiversity data such as the Species Information System (the Red List Assessment database), the Global Earth Observation System of Systems (GEO BON 2014), the Global Biodiversity Information Facility (GBIF 2014) and the Living Planet Index (Living Planet Index 2014).

The objective for this dissertation was to develop scientific-based recommendations for establishing a global database system to provide a direct link between information collected on animals under human care and on the wild population in order to enhance *in situ* conservation of these species. Data has been identified that is needed to manage and assess programs as well as data management tools currently in use by both *in situ* and *ex situ* partners. Integrative data process models for selected species recovery programs were developed and data needs for both *in situ* and *ex situ* components were aligned with the functionality of *ZIMS*. This is only the first step in building a framework for integrating *in situ* and *ex situ* data management processes for conservation programs. The case studies investigated here could be used as a starting point for a pilot study to implement the use of *ZIMS* for data management processes in holistic conservation programs. The next step forward would be to work with ISIS to identify how *ZIMS* could be used for *in situ* components of a conservation program.

As ISIS is a membership organization and there are licensing requirements for the use of *ZIMS* , the role for each participating organization in a conservation program would need to be clarified as far as the type of ISIS membership. Would a government authority such as the U.S. Fish and Wildlife have one membership for each individual program (such as red wolves or black-footed ferrets [*Mustela nigripes*], which are conducted in different areas of the U.S.) or would they have one umbrella membership under which all their programs would be managed? What type of membership would be available for those organizations that are doing basic wildlife research or are rescue/rehabilitation centers? The cost of ISIS membership is an economic issue that prevents some smaller institutions from participating, and thus some creative solutions need to be developed in order to get everyone on board. Currently, there are sponsorships by large institutions that partner with a small institution for a period of time, and also some commercial partners that provide sponsorships. The business aspects of ISIS membership and implications of business rules would need to be clarified by the ISIS Administration and Board of Directors.

ZIMS has current functionality that would cover many of the data management processes needed for individual or group records-keeping of animals in the wild. Data on individuals life history, reproduction, survival, mortality, and health as well as methodologies used in the implementation and monitoring levels of the program can be documented in *ZIMS*. However, data standards for *in situ* data that include monitoring and capture event parameters that are not covered by *ZIMS* would have to be developed by the stakeholders and ISIS working together. One example would be the use of the “enclosure logs” for identifying location and use of areas for monitoring traps, burrows, nests or bodies of water. While the basic functionality to capture location, physical and environmental measurements, and individual animals that are monitored in these areas is available, the terminology (“enclosures”) does not reflect the reality that these are not necessarily human-made enclosures that contain the animals. Data standards for *in situ* data that include monitoring and capture event parameters that are not covered by *ZIMS* would have to be developed by the stakeholders and ISIS working together. This could be done through a task force made up of representatives from ISIS, IUCN Species Survival Commission Specialist Groups (Reintroduction, Conservation Breeding and Taxon Specialist Groups), WAZA and related regional zoo organizations involved in *in situ* conservation to identify relevant terminology and develop data standards that would facilitate an integrated data management strategy for conservation programs.

ISIS released *ZIMS for Medical* in April 2014 and is currently working to bring all ISIS member institutions on board with this new issue. The target is for over 330 ISIS members using the medical component by the end of 2014 with the majority of the rest coming on board throughout 2015 (ISIS News 2014). The next major release will be *ZIMS R3* which will include Population Management functionality that was covered by *SPARKS* (the software for studbook development) as well as analyses capabilities to manage breeding programs. Thus, further adaptation of *ZIMS* to handle specific *in situ* population data would have to be deferred until after the release of *ZIMS R3* unless a funding source was identified to support the enhancements required by this *in situ* initiative (Nate Flesness and Josh Courteau, personal communication). As *ZIMS* could already be used in its current form to link data management processes for certain aspects of conservation programs (individual records, medical records, population management), ISIS would benefit by establishing a position for a manager to take this work forward and act as a coordinator for future work in establishing an *in situ* monitoring module.

Loss of biodiversity due to anthropogenic factors has threatened the sustainability of our natural world and natural resources. To facilitate the “one plan approach” to species conservation, the *in situ* and *ex situ* communities need to combine strategies for effective conservation action at all levels of a conservation program. Certain modules in *ZIMS* (individual animal core data, husbandry and medical) can now be used although fine-tuning the information system in the future with further adaptations and established data standards for integrated conservation programs will strengthen the effectiveness of the system. In order to improve management and assesment of conservation programs, all available tools should be utilized and collaborations strengthened to reach the targets set by the Convention on Biological Diversity for species conservation. Information exchange and standardization between *ex situ* and *in situ* data management practices via the ISIS *Zoological Information Management System* can link the components needed for effective management of species recovery programs

References

Byers, O., C. Lees, J. Wilcken, and C. Schwitzer. 2013. The One Plan Approach: the philosophy and implementation of CBSG's approach to integrated species conservation planning. WAZA Magazine 14: 2-5

Conde, D., N. Flesness, F. Colchero, O.R. Jones, and A. Scheuerlein. 2011. An emerging role of zoos to conserve biodiversity. Science 331(6023): 1390-1391

Ettling, J. 1996. Natural history, husbandry, and captive reproduction of mountain vipers (*Vipera bornmuelleri* and *Vipera wagneri*). pp. 139-144. In: P. D. Strimple (ed.). Advances in Herpetoculture, International Herpetological Symposium, Inc.

Fuller, R.A., J.R. Lee and J.E.M. Watson. 2014. Achieving open access to conservation science. Conservation Biology Early view: 1-8. DOI: 10.1111/cobi.12346

Global Biodiversity Information Facility (GBIF). http://www.gbif.org/ . Accessed 3.Sept.2014

Group on Earth Observations Biodiversity Observation Network (GEO BON). http://www.earthobservations.org/geobon.shtml Accessed 3.Sept.2014

Integrated Primate Biomaterials and Information Resource (IPBIR). 2014. https://catalog.coriell.org/0/Sections/Collections/IPBIR/?SsId=18. Accessed 31.Oct.2014

International Species Information System (ISIS).2014. zims.isis.org

International Species Information System (ISIS). http://www2.isis.org/news/Pages/ISIS-published.aspx. Accessed 20.July.2014

International Species Information System (ISIS) News. September 2014. http://www2.isis.org/news/Pages/ISISNews.aspx. Accessed 1.Sept.2014

Living Planet Index. http://www.livingplanetindex.org/data_portal. Accessed 3.Sept.2014

Miller, A. 2014. Organization of my institution. pp. 83-88. In: 2014 Institutional Records-Keeping Course. Association of Zoos and Aquariums. Silver Spring, MD

Müller, D.W.H., J.M. Gaillard, L. Bingaman Lackey, J.-M. Hatt, & M. Clauss. 2010 Comparing life expectancy of three deer species between captive and wild populations. European Journal of Wildlife Research 56(2): 205−208

Pereira, H.M., S. Ferrier, M. Walters, G.N. Geller, R.H.G. Jongman, R.J. Scholes, M.W. Bruford, N. Brummitt, S.H.M. Butchard, A.C. Cardoso. N.C. Coops, E. Dulloo, D.P. Fairh, J. Freyhof, R.D. Gregory, C. Heip, R. Höft, G. Hurtt, W. Jetz, D.S. Karp, M.A. McGeoch, D. Obura, Y. Onoda, N. Pettorelli, B. Reyers, R. Sayre, J.P.W. Scharlemann, S.N. Stuart, E. Turak, M. Walpole, M. Wegmann. 2013. Essential biodiversity variables. Science 339(6117): 277-278

Plummer, M.V. and J.W. Ferner. 2012. Chapter Nine: Marking reptiles. pp. 143-150. In: Foster, M. and R. McDiarmid (eds.). Reptile Biodiversity. University of California Press. Berkeley and Los Angeles

Pollak J.P. and R.C. Lacy. 2013. MetaModel Manager. Version 1.0. Brookfield, IL: Chicago Zoological Society

Pramuk, J., F. Koontz, M. Tirhi, S. Zeigler, K. Schwartz, and P. Miller (eds.).2013. Western Pond Turtle (*Actinemys marmorata*) Population and Habitat Viability Assessment: Workshop Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN

Princée, F.P.g. 1995. Overcoming the constraints of social structure and incomplete pedigree data through low-intensity genetic management. pp. 124-154. In: Ballou, J.D., M. Gilpin, and T.J. Foose (eds.), Population Management for Survival and Recovery. Analytical methods and strategies in small population conservation. Columbia University Press, New York

Ruiz-Miranda, C. R., B. B., Beck, D.G. Kleiman, A. Martins, J.M. Dietz, D.M. Rambaldi, M.C.M. Kierulff, P.P. Oliveira, and A.J. Baker. 2010. Re-introduction and translocation of golden lion tamarins, Atlantic Coastal Forest, Brazil: the creation of a metapopulation. pp. 225–230. In: Soorae, P. S. (Ed.). Global Re-introduction Perspectives. Additional case-studies from around the globe. IUCN/SSC Re-introduction Specialist Group (RSG), Abu Dhabi, UAE

Waddell, W. 2014. Red Wolf (*Canis rufus*) International Studbook. Point Defiance Zoo and Aquarium, Tacoma, WA

Weigl, R. 2005. Longevity of Mammals in Captivity: From the Living Collections of the World. E. Schweizerbart Science Publishers Stuttgart, Germany. pp. 214

Young, A.M., E.A. Hobson, L. Bingaman Lackey and T.F. Wright. 2012. Survival on the ark: life history trends in captive parrots. Animal Conservation 15(1): 28-43

APPENDIX I

Conservation Translocation Definitions

From IUCN/RSG Guidelines for Re-introductions and other Conservation Translocations (IUCN 2013)

Translocation is the overarching term for human-mediated movement of living organisms from one area with release in another. Translocations may move living organisms from the wild or from captive origins, may be accidental or intentional. Translocations can address a variety of motivations, including for reducing population size, for welfare, political, commercial or recreational interests, or for conservation objectives.

Conservation translocation is the intentional movement and release of a living organism where the primary objective is a conservation benefit: this will usually comprise of improving the conservation status of the focal species locally or globally, and/or restoring natural ecosystem functions or processes.

Population restoration is any conservation translocation to within indigenous range and may be one of two paradigms:

a. **Reinforcement** is the intentional movement and release of an organism into an existing population of conspecifics. Reinforcement is used to increase population size, increase genetic diversity, or increase demographic stability thus enhancing population viability. Example: East African Bongo Repatriation Program to return Bongo (*Boocercus eurycerus isaaci*) to the forests of Mt. Kenya (Estes 2006)

b. **Reintroduction** is the intentional movement and release of an organism into an area once part of its historical range, but from which it has been extirpated or become extinct. Example: Red Wolf Recovery Program to reintroduce red wolves (*Canis rufus*), previously extinct in the wild, back to the wilds of Alligator River Wildlife National Refuge in North Carolina (Hedrick *et al.* 2008)

Conservation introduction is the intentional movement and release of an organism outside its indigenous range. There are two types of conservation introductions:

a. **Assisted colonization** is the intentional movement and release of an organism outside its indigenous range to avoid extinction of populations of the focal species. This technique may be used if current or possible future threats in the current range will diminish the success of the conservation translocation compared to an alternative site. Example: Conservation translocations of the Seychelles white-eye (*Zosterops modestus*) to predator-free rehabilitated island of Fregate Island in the Seychelles archipelago (Rocamora and Henriette-Payet 2008)

b. **Ecological replacement** is the intentional movement and release of an organism outside its indigenous range to re-establish an ecological function in an area lost through extinction, and will often involve the most suitable existing sub-species, or a close relative of the extinct species within the same genus.

Example: Recommendation for conservation translocations of Aldabra tortoises (*Aldabrachelys gigantean)* and Madagascaran radiated tortoises (*Astrochelys radiate*) to replace extinct endemic giant *Cylindraspis* tortoises on the Mascarene Islands to restore ecological functions on the islands (Griffiths *et al.* 2010).

APPENDIX II

Core Data for Individual Specimen Records in ISIS

Individual	Reproduction/Breeding Management	Behavior	Husbandry
Taxonomy	Studbook ID	Social behavior	Enclosure requirements
Birth/Hatch Date	Introduction date	Aggression	Diet
Captive/Wild born	Copulation dates	Reproductive	Social grouping
Parentage	Egg lay/hatch or Parturition date	Parturition	Reproduction
Sex	Parturition behavior	Stereotypic	Incubation
Rearing	Number of eggs or neonates	Interspecific	Rearing
Birth Institution/Location	Survival of neonates	Predatory	Training
Collection location	Parental care	Feeding	Behavioral enrichment
Holding institution	Contraception	Health	Human interaction
Terms of acquisition	Enclosure/Environment	Morphometrics	Permits
Individual identifiers	Animals present	Development	CITES
Disposition date	Animal moves	Body condition	Marine Mammal Permit
Receiving institution	Location in institution	Immunizations	National Endangered Species
Death date	Measurements	Parasite checks	Exhibitor
Media - photos, video	Furniture	Illness	Collecting
	Life Suppport System	Injury	Transportation
	Water quality	Treatment	Injurious Species
	Temperature	Medications	
	Substrates	Media-x-rays, photos, ultrasound	
		Anesthesia	
		Necropsy	

APPENDIX III

Monitoring data

Survey		Health assessment	
Abundance	Presence-Absence	Medical condition	Measurements
Distance sampling transect data	Count-visual presence	Body condition	Weight
Mark-Recapture- Individual ID	Count-auditory presence	Injury	Size measurements
Detection probabilities	Count-nest or den presence	Disease	Temperature
Date	Count-presence of feces	Parasites	Blood pressure
Time	ID individuals by DNA analysis	Bacteria	
Weather	Date	Blood physiology	
Habitat	Time	Necropsy data	
	Location		

Monitoring			
Capture Events	Radio-tracking/GPS/VHS	Camera trap photos/videos	Genetic studies
Capture method	Location-GPS coordinates	Media - photo, video	DNA analysis - blood
Individual ID	Individual ID	Individual ID	Non-invasive DNA analysis - feces, hair
Date	Date	Date	ID taxonomy
Time	Time	Time	ID genetic diversity
Location	Social behavior	Location	ID individuals
Sex	Land use	Social relationships	ID parentage
Age	Weather	Reproduction (offspring)	
Development stage	Moon phase	Use of habitat by different species	
	Home range		
	Territory		

APPENDIX IV

References for Reintroduction Case Studies Database

Soorae, P.S. (ed.). 2008. Global re-introduction perspectives: re-introduction case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Invertebrates

***Acropora* and *Pocillopora* corals**
Encyclopedia of Life. http://eol.org/pages/23055/details. Accessed 6.Aug.2013

Field cricket (*Gryllus* sp.)
Texas A&M AgriLife Extension. https://insects.tamu.edu/fieldguide/aimg17.html. Accessed 6.Aug.2013.

Giant clam species (*Tridacna gigas, T. derasa, T. squamosal, T. maxima, T. crocea, T. tevoroa, Hippopus hippopus H. porcellanus*)
Ellis, S. Spawning and early larval rearing of giant clams (Bivalva: Tridacnidae). Center for Tropical and Subtropical Aquaculture. Publication Number 130. aqua.ucdavis.edu/DatabaseRoot/pdf/CTSA130.PDF. Accessed 6.Aug.2013

Karner blue butterfly (*Lycaeides melissa samuelis*)
Dirig, Robert. 1994. Historical notes of wild lupine and the Karner blue butterfly at the Albany Pine Bush, New York. In: Andow, David A.; Baker, Richard J.; Lane, Cynthia P., eds. Karner blue butterfly: a symbol of a vanishing landscape. Miscellaneous Publication 84-1994. St. Paul, MN: University of Minnesota, Minnesota Agricultural Experiment Station: 23–36

Swengel, A. B. 1995. Observations of spring larvae of Lycaeides melissa samuelis (Lepidoptera: Lycaenidae) in central Wisconsin. The Great Lakes Entomologist. 28(2): 155–170

Fish

Allis shad (*Alosa alosa*)

Acolas, M.L., M. L. Bégout Anras, V. Véron, H. Jourdan, M. R. Sabatié, and J. L. Baglinière. 2004. An assessment of the upstream migration and reproductive behaviour of allis shad (*Alosa alosa* L.) using acoustic tracking. Journal of Marine Science 61:1291 – 1304

Freyhof, J. & Kottelat, M. 2008. *Alosa alosa*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 6.Aug.2013

Kent Biodiversity Action Plan http://www.kentbap.org.uk/images/uploads/Allis_and_twaite_shad.pdf accessed 6.Aug.2013

Azraq killifish (*Aphanius sirhani*) : not much is known. Couldn't find references.

Burbot (*Lota lota)*

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Lota_lota/. Accessed 6.Aug.2013

Lake sturgeon (***Acipenser fulvescens***)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Acipenser_fulvescens/. Accessed 6.Aug.2013

Spanish toothcarp (*Aphanius iberus*)

Seriously Fish. http://www.seriouslyfish.com/species/aphanius-iberus/ Accessed 6.Aug.2013

Trout cod (*Maccullochella macquariensis*)

Australian Museum. http://www.australianmuseum.net.au/Trout-Cod-Maccullochella-macquariensis-Cuvier-1829/ Accessed 6.Aug.2013

EHow. http://www.ehow.com/facts_6897087_codfish-information.html. Accessed 6.Aug.2013

Amphibians

Mallorcan midwife toad (*Alytes muletensis*)
Arkive. http://www.arkive.org/mallorcan-midwife-toad/alytes-muletensis/ Accessed 8.Aug.2013

Encyclopedia of Life. http://eol.org/pages/1039071/details Accessed 8.Aug.2013

Puerto Rican crested toad (*Peltophryne lemur*)
AZA Puerto Rican Crested Toad Population Analysis & Breeding and Transfer Plan. 2011. https://ams.aza.org/iweb/upload/ToadPuertoRicanCrestedGreenSSP2011Final[1]-d6473697.pdf Accessed: 8.Aug.2013

Paine, F.L., J.D. Miller, G.Crawshaw, B. Johnson, R.Lacy, C.F.Smith and P. J. Tolson. 1989 Status of the Puerto Rican crested toad *Peltophryne lemur*. International Zoo Yearbook 28: 53-58

World Association of Zoos and Aquaria. http://www.waza.org/en/zoo/choose-a-species/amphibians/frogs-and-toads/peltophryne-lemur. Accessed 6.Aug.2013

Romer's tree frog (*Liuixalus romeri*)
Arkive. http://www.arkive.org/romers-treefrog/liuixalus-romeri// Accessed 6.Aug.2013

Reptiles

Chinese alligator (*Alligator sinensis*)
Crocodilians Natural History and Conservation. http://crocodilian.com/cnhc/csp_asin.htm. Accessed 8.Aug.2013

Xing, J. H. 2012 Chinese Alligator (*Alligator sinensis*) Recovery Plan. IUCN Crocodile Specialist Group. National Wildlife Research and Development Center, Chinese Academy of Forestry, Beijing, China

Xu, M., X-B. Wu, P. Yan and H. Zhu. 2009. Telomere length shortens with age in Chinese alligators *(Alligator sinensis).* J. Appl. Anim. Res., 36: 109–112.

IUCN Crocodile Specialist Group http://www.iucncsg.org/content_images/attachments/species_descriptions/Chinese%20Alligator.pdf Accessed 8.Aug.2013

Indian gharial (*Gavialis gangeticus*)

Crocodilians Natural History and Conservation. http://crocodilian.com/cnhc/csp_ggan.htm. Accessed 8.Aug.2013

International Reptile Conservation Foundation. http://www.ircf.org/programs/gharial/gharial-species-description/. Accessed 8.Aug.2013

Rao. R.J ., D. Basu, S. M. Hasan, B.B. Sharma, S. Molur, S. Walker (eds.).1995. Population and Habitat Viability Assessment (P.H.V.A.) Workshop Report for Gharial. Conservation Breeding Specialist Group. Apple Valley, MN

Mokohinau skink (*Cyclodina townsi*)

Chapple D.G., P.A.Ritchie, C.H. Daugherty.2009. Origin, diversification, and systematics of the New Zealand skink fauna (Reptilia: Scincidae). Molecular Phylogenetic Evolution **52** (2): 470–87

McGregor's skink (*Cyclodina macgregori*)

Arkive. http://www.arkive.org/mcgregors-skink/oligosoma-macgregori/ Accessed 8.Aug.2013

Orinoco crocodile (*Crocodylus intermedius*)

Seijas, A.E. and C. Chavez. 2000. Population status of the Orinoco crocodile (*Crocodylus intermedius*) in the Cojedes River system, Venezuela. Biol. Conserv. 94: 353-361.

Seijas, A .E., R. Antelo, J. B. Thorbjarnarson, M. C. Ardila Robayo.2012. Orinoco Crocodile (*Crocodylus intermedius*) Recovery Plan. IUCN Crocodile Specialist Group

Arteaga, A., I. Cañizales, G. Hernández, M. Cruz Lamas, A. De Luca, M. Muñoz, A. Ochoa, A. Seijas, J. Thorbjarnarson, A. Velasco, S. Ellis, U.S. Seal. 1997. Taller de Análisis de la Viabilidad Poblacional del Caimán del Orinoco (*Crocodylus intermedius*), Reporte del Taller. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN

Pacific gecko (*Hoplodactylus pacificus*)

Jones, R. E., T. Swain, L. J. Guillette, Jr. and K. T. Fitzgerald .1982. The comparative anatomy of lizard ovaries, with emphasis on the number of germinal beds. Journal of Herpetology 16(3): 240-252

Todd, A.C. 2005.The social mating system of *Hoplodactylus maculatus* .New Zealand Journal of Zoology 32(4): 251-262, DOI: 10.1080/03014223.2005.9518417

Todd, A.C. 2008.Using testis size to predict the mating systems of New Zealand geckos. New Zealand Journal of Zoology 35(2): 103-114, DOI: 10.1080/03014220809510107

Philippine crocodile (*Crocodylus mindorensis*)

van Weerd, M. 2009. Philippine Crocodile (*Crocodylus mindorensis*) Recovery Plan. IUCN Crocodile Specialist Group, Centre of Environmental Science, Leiden Universit.Utrecht, Netherlands

Swamp tortoise (*Pseudemydura umbrina*)

Burbidge A.A. and G. Kuchling.2004. Western Swamp Tortoise (*Pseudemydura umbrina*) Recovery Plan, 3rd Edition.January 2003 - December 2007. Department of Conservation and Land Management, Western Australian Threatened Species and Communities Unit. Wanneroo, Western Australia

Kuchling, G. and S.D. Bradshaw. 1993. Ovarian cycle and egg production of the western swamp tortoise *Pseudemydura umbrina* (Testudines: Chelidae) in the wild and in captivity. Journal of Zoology 229: 405–419. doi: 10.1111/j.1469-7998.1993.tb02645.x

Tuatara (*Sphenodon punctatus*)

Arkive. http://www.arkive.org/tuatara/sphenodon-punctatus/ Accessed 8.Aug.2013

Virgin Islands boa (*Epicrates monensis granti*)

Center for Biological Diversity. http://www.biologicaldiversity.org/species/reptiles/Virgin_Islands_tree_boa/natural_history.html. Accessed 8.August.2013

Tolson, P. and K. Schad. 2010. Population Analysis and Breeding and Transfer Plan: Virgin Islands Boa (*Epicrates monensis granti*). AZA Species Survival Plan® Program. Population Management Center. Lincoln Park Zoo

Birds

Akepa (*Loxops coccineus coccineus*)

Podzikowski, L. 2007. Loxops coccineus, Animal Diversity Web. Accessed 8.Aug.2013 at http://animaldiversity.ummz.umich.edu/accounts/Loxops_coccineus/

Aplomado falcon (*Falco femoralis septentrionalis*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Falconidae/. Accessed 10.Aug.2013

Jenny, J.P., W.Heinrich, A. B. Montoya, B. Mutch, C. Sandfort, and W. G. Hunt. 2004. Progress in restoring the Aplomado falcon to southern Texas. Wildlife Society Bulletin 32 (1): 276-285

Asian Houbara bustard (*Chlamydotis macqueenii*)

BirdLife International.2013. Species factsheet: *Chlamydotis undulata*. Downloaded from http://www.birdlife.org on 8.Aug.2013

Judas, J., O. Combreau, M. Lawrence., M. Saleh, F. Launay and G. Xingyi. 2006. Migration and range use of Asian Houbara Bustard *Chlamydotis macqueenii* breeding in the Gobi Desert, China, revealed by satellite tracking. Ibis, 148: 343–351. doi: 10.1111/j.1474-919X.2006.00546.x

Bearded vulture (*Gypaetus barbatus*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Gypaetus_barbatus/. Accessed 10.Aug.2013

Cheer pheasant (*Catreus wallichi*)

BirdLife International. 2014. Species factsheet: *Catreus wallichi*. Downloaded from http://www.birdlife.org/datazone/speciesfactsheet.php?id=266 on 10.Aug.2013

Beauty of Birds. http://www.beautyofbirds.com/cheerpheasants.html. Accessed 10.Aug.2013

Great spotted kiwi (*Apteryx haastii*)

Department of Conservation, Te Papa Atawbai, New Zealand http://web.archive.org/web/20071209184107/http://www.savethekiwi.org.nz/AboutTheBird/KiwiLifeCycle/

Golden eagle (*Aquila chrysaetos*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Aquila_chrysaetos/ Accessed 10.Aug.2013

Eagle Watch Weekend. http://www.eaglesatlakemonroe.com/Golden%20Eagle%20Biology.htm Accessed 10.Aug.2013

Hawaii creeper (*Oreomystis mana*)

BirdLife International .2013.Species factsheet: *Oreomystis mana*. Downloaded from http://www.birdlife.org Accessed 8.Aug.2013

Nene goose (*Branta sandvicensis*)

Black, J.M. 1995. The Nene *Branta sandvicensis.* Recovery Initiative: research against extinction. IBIS 137: S153-Sl60

Nene Net. http://0313a7b.netsolhost.com/notes/na_nene.html. Accessed 8.August.2013

North Island Robin (*Petroica longipes*)

Armstrong, D.P., J.G. Ewen, W.J. Dimond, T.G. Lovegrove, A. Bergstrom, B. Walter. 2000. Breeding biology of North Island robins (*Petroica australis longipes*) on Tiritiri Matangi Island, Hauraki Gulf, New Zealand. Notornis 47: 106-118

Department of Conservation, Te Papa Atawbai, New Zealand http://www.doc.govt.nz/conservation/native-animals/birds/birds-a-z/north-island-robin-toutouwai/facts/ Accessed 10.Aug.2013

Wittern, A. K., and Å. Berggren. 2007. Natal dispersal in the North Island robin (*Petroica longipes*): the importance of connectivity in fragmented habitats. *Avian Conservation and Ecology - Écologie et conservation des oiseaux* **2**(2): 2. URL: http://www.ace-eco.org/vol2/iss2/art2/

Red-necked ostrich (*Struthio camelus camelus*)

Roots, C. 2006. Flightless Birds. Westport, CT: Greenwood Press. p. 26. ISBN 0-313-33545-1

Islam, Z.M., K. Ismail and A. Boug. 2008. Re-introduction of the red-necked ostrich, *Struthio camelus camelus*, in Mahazat as-Sayad Protected Area in central Saudi Arabia. Zoology in the Middle East 44 (1): 31-40

Red-billed curassow (*Crax blumenbachii*)

BirdLife International .2013. Species factsheet: *Crax blumenbachii*. Downloaded from http://www.birdlife.org/datazone/speciesfactsheet.php?id=109 on 8.Aug.2013

Bernardo, C.S.2011.Red-billed Curassow (*Crax blumenbachii*).. T.S. Schulenberg, Ed. Ithaca: Cornell Lab of Ornithology, retrieved from Neotropical Birds Online: http://neotropical.birds.cornell.edu/portal/species/overview?p_p_spp=82631

Seychelles white-eye (*Zosterops modestus*)

BirdLife International.2013. Species factsheet: *Zosterops modestus*. Downloaded from http://www.birdlife.org on 8.Aug.2013

Southern ground hornbill (*Bucorvus leadbeateri*)

BirdLife International 2013Species factsheet: *Bucorvus leadbeateri*. Downloaded from http://www.birdlife.org on 8.Aug.2013

Human Aging Genomic Resources. http://genomics.senescence.info/species/entry.php?species=Bucorvus_leadbeateri. Accessed 8.Aug.2013

White-headed duck (*Oxiura leucocephala*)

BirdLife International .2014. Species factsheet: *Oxyura leucocephala*. Downloaded from http://www.birdlife.org/datazone/speciesfactsheet.php?id=359 . Accessed 8.Aug.2013

A.J. Green , A.D. Fox , B. Hughes & G.M. Hilton (1999) Time–activity budgets and site selection of White-headed Ducks Oxyura leucocephala at Burdur Lake, Turkey in late winter, Bird Study, 46:1, 62-73, DOI: 10.1080/00063659909461115

White-tailed sea eagle (*Haliaeetus albicilla*)

Golden Eagle Trust. http://www.goldeneagle.ie/index.php?option=com_k2&view=item&layout=item&id=613&Itemid=116. Accessed 10.Aug.2013

Mammals

Arabian oryx (*Oryx leucoryx*)

Conservation Breeding Specialist Group (SSC/IUCN). 2001. Conservation Assessment and Management Plan for the Arabian Leopard and Arabian Ungulates with Population and Habitat Viability Assessments for the Arabian Leopard, Arabian Oryx, and Tahr Reports. CBSG, Apple Valley, MN. USA

Black and white ruffed lemur (*Varecia variegate*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Varecia_variegata/ Accessed 12.Aug.2013

Chimpanzee (*Pan troglodytes*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Pan_troglodytes/ Accessed 14.Aug.2013

Gibbons in Indonesia

Kalaweit Gibbon Re-habilitation Project http://www.wildlifeextra.com/go/good/kalaweit-gibbons.html#cr

Campbell, C., N. Andayani, S. Cheyne, J. Pamungkas, B. Manullang, F. Usman, M. Wedana, and K. Traylor-Holzer (eds.). 2008. Indonesian Gibbon Conservation and Management Workshop Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN

Agile gibbon (*Hylobates agilis*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Hylobates_agilis/ 12.Aug.2013

Borneo Agile gibbon (*Hylobates albibarbis*)
Animal Diversity Web http://animaldiversity.ummz.umich.edu/accounts/Hylobates_agilis/ 12.Aug.2013

Borneo gibbon (*Hylobates muellen*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Hylobates_muelleri/ 12.Aug.2013

Javan gibbon (*Hylobates moloch*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Hylobates_moloch/ 12.Aug.2013

Kloss's gibbon (*Hylobates klossii*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Hylobates_klossii12/ 12.Aug.2013

Siamang (*Symphalangus syndactylus*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Symphalangus_syndactylus/ 12.Aug.2013

White-handed gibbon (*Hylobates lar*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Hylobates_lar/ 12.Aug.2013

Greater slow loris *(Nycticebus coucang*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Sciurus_vulgaris/ Accessed 10.Aug.2013

Grey wolf (*Canis lupus*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Canis_lupus/. Accessed 10.Aug.2013

Mona monkey (*Cercopithecus mona*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Cercopithecus_mona/ Accessed 14.Aug.2013

Red squirrel (*Sciurus vulgaris*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Sciurus_vulgaris/. Accessed 10.Aug.2013

Sand gazelle (Gazella subgutturosa)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Gazella_subgutturosa/ Accessed 10.Aug.2013

Conservation Breeding Specialist Group (SSC/IUCN). 2001. Conservation Assessment and Management Plan for the Arabian Leopard and Arabian Ungulates with Population and Habitat Viability Assessments for the Arabian Leopard, Arabian Oryx, and Tahr Reports. CBSG, Apple Valley, MN. USA

Mohammed, O.B., T.W. Wacher, I.A. Nader. and S.M. Mubarak. Captive breeding and reintroduction of Arabian mountain and sand gazelles in Saudi Arabia. King Khalid Wildlife Research Centre, National Commission for Wildlife Conservation and Development, Riyadh, Saudi Arabia. http://www.wmenews.com/Information/Other/Section1Mohammedpdfpp11-141.pdf Accessed 12.Aug.2013

Western lowland gorilla *(Gorilla gorilla gorilla)*
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Gorilla_gorilla/ Accessed 14.Aug.2013

Soorae, P.S. (ed.). 2010. Global re-introduction perspectives: additional case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

Invertebrates

Giant Gippsland worm (*Megascolides australis*)

Praagh, B. V. 1992. The biology and conservation of the giant Gippsland earthworm *Megascolides australis* .Soil Bid. Biochem. 24 (12): 1363-1367

Department of Sustainability and Environment. Victoria, Australia Gippsland Earthworm http://www.dse.vic.gov.au/__data/assets/pdf_file/0014/103217/077_Gippsland_Earthworm_1997a.pdf Accessed 16.Aug.2013

Leaf-vein slug (*Pseudaneitea maculata*)

Nature Watch New Zealand. http://naturewatch.org.nz/taxa/27555-Pseudaneitea-maculata. Accessed 16.Aug.2013

Banks Peninsula tree weta (*Hemideina ricta*)

Townsend, J.A., B. Brown, I.A.N. Stringer and M.A. Potter. 1997 Distribution, habitat and conservation status of *Hemideina* Ricta and *H. Femorata* on Banks Peninsula, New Zealand . New Zealand Journal of Ecology 21(1): 43-49

Jamieson, I.G. 2002. The relationship between male head size and harem size in the sexually dimorphic mountain stone weta ***Hemideina maori.*** Ecological Entomology 27 (1): 41–48

Flax snail slug (*Placostylus ambagiosus*)

Arkive. http://www.arkive.org/flax-snail/placostylus-ambagiosus/ Accessed 16.Aug.2013

Lord Howe Island phasmid (*Dryococelus ambagiosus*)

Natural History Museum, London http://www.nhm.ac.uk/nature-online/species-of-the-day/biodiversity/endangered-species/dryococelus-australis/index.html Accessed 16.Aug.2014

Pine hoverfly (*Blera fallax*)

Wild Travel Magazine http://www.wildlifeextra.com/go/news/pine-hoverfly.html#cr Accessed 16.Aug.2014

Miami blue butterfly (*Cyclargus thomasi*)

Daniels, J. C. 2005. Species Profile: Cyclargus thomasi bethunebakeri. In Shepherd, M. D., D. M. Vaughan, and S. H. Black (Eds). Red List of Pollinator Insects of North America. CD-ROM Version 1 (May 2005). Portland, OR: The Xerces Society for Invertebrate Conservation

Florida Fish and Wildlife Conservation Commission.2010. Miami Blue Butterfly Management Plan *Cyclargus thomasi bethunebakeri.* Tallahassee, FL

Southern damselfly (*Coenagrion mercurial*)

Thompson D.J., J.R. Rouquette and B.V. Purse.2003. Ecology of the Southern Damselfly. Conserving Natura 2000 Rivers Ecology Series No. 8. English Nature, Peterborough

San Francisco forktail damselfly (*Ischnura gemina*)

Robinson, J.V. and K.L. Novak. 1997. The relationship between mating system and penis morphology in ischnuran damselflies (*Odonata: Coenagrionidae*). Biological Journal of the Linnean Society 60 (2): 187–200

Fish

Adriatic sturgeon (*Acipenser naccarii*)

Fishbase.http://www.fishbase.org/Summary/speciesSummary.php?ID=2504&AT=Adriatic+sturgeon. Accessed 16.Aug.2013

Atlantic salmon (*Salmo salar*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Salmo_salar/. Accessed 16.Aug.2013

Landry, C., D. Garant, P. Duchesne, and L. Bernatchez. 2001. Good genes as heterozygosity: the major histocompatibility complex and mate choice in Atlantic salmon (*Salmo salar*). Proc. R. Soc. Lond. B 268:1279–1285

Bullhead (*Cottus perifretum*)

Freyhof, J. and M. Kottelat. 2008. *Cottus perifretum*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. www.iucnredlist.org. Accessed 21.September. 2013

Colorado pikeminnow (*Ptychocheilus lucius*)

Osmundson, D.B.2002 Population dynamics of Colorado pikeminnow in the upper Colorado River. Final Report. U.S. fish and Wildlife Service, Grand Junction, Colorado

Upper Colorado River Endangered Fish Recovery Program. http://www.coloradoriverrecovery.org/general-information/the-fish/colorado-pikeminnow.html. Accessed 16.Aug.2014

Tokyo bitterling (*Tanakia tanago*)

Kubota, H., K. Watanabe, N. Suguro, M. Tabe, K. Umezawa, S. Watanabe. 2010. Genetic population structure and management units of the endangered Tokyo bitterling, *Tanakia tanago*(Cyprinidae). Conservation Genetics 11(6): 2343-2355

Yarqon bleak *(Acanthobrama telavivensis)*

Elron, E., A. Gasith, M. Goren. 2006. Reproductive Strategy Of A Small Endemic Cyprinid, The Yarqon Bleak (***Acanthobrama telavivensis***), In A Mediterranean-Type Stream. Environmental Biology Of Fishes 77(2): 141-155

Amphibians

Booloorong frog (*Litoria booroolongensis*)

Amphibian Ark. http://www.amphibianark.org/litoria-booroolongensis/. Accessed 22.Sept.2013

Office of Environment and Heritage. NSW.2012. National Recovery Plan for Booroolong Frog (*Litoria booroolongensis*) Office of Environment and Heritage (NSW), Hurstville. North South Wales, Australia

Hamilton's frog (*Leiopelma hamiltoni*)

Amphibia Web. http://amphibiaweb.org/cgi-bin/amphib_query?table=amphib&special=one_record&where-genus=Leiopelma&where-species=hamiltoni

Bell, B. 1978. Observations on the Ecology and Reproduction of the New Zealand Leiopelmid Frogs. Herpetologica 34 (4): 340-354

Kihansi spray toad (*Nectophrynoides asperginis*)

Channing, A., K. S. Finlow-Bates, S. E. Haarklau, P. G. Hawkes.2006.The biology and recent history of the critically endangered Kihansi spray toad *Nectophrynoides asperginis* in Tanzania. Journal of East African Natural History 95(2): 117–138

Lee, S., K. Zippel, L. Ramos & J. Searle.2006. Captive-breeding programme for the Kihansi spray toad *Nectophrynoides asperginis* at the Wildlife Conservation Society, Bronx, New York. Int. Zoo Yb. 40: 241–253

Maud Island frog (*Leiopelma pakeka*)

Amphibia Web. http://amphibiaweb.org/cgi-bin/amphib_query?table=amphib&special=one_record&where-genus=Leiopelma&where-species=pakeka

Natterjack toad (*Bufo calamita*)

Di Minin, E. and R.A. Griffiths. 2011.Viability analysis of a threatened amphibian population: modelling the past, present and future. Ecography 34 (1): 162–169

Southern Corroboree frog (*Pseudophryne corroboree*)

Amphibia Web. http://amphibiaweb.org/cgi-bin/amphib_query?where-genus=Pseudophryne&where-species=corroboree&rel-genus=equals&rel-species=equals Accessed 21.September.2013

Corroboree Frog. http://corroboreefrog.com.au/corroboree-frog. Accessed 22.September.2013

Morgan, M.J., D. Hunter, R. Pietsch, W .Osborne and J. S. Keogh. 2008. Assessment of genetic diversity in the critically endangered Australian corroboree frogs, *Pseudophryne corroboree* and *Pseudophryne pengilleyi*, identifies four evolutionarily significant units for conservation. Molecular Ecology 17 (15): 3448–3463

Office of Environment and Heritage. NSW. 2012. National Recovery Plan for the Southern Corroboree Frog, *Pseudophryne corroboree*, and the Northern Corroboree Frog, *Pseudophryne pengilleyi*, Office of Environment and Heritage (NSW), Hurstville. New South Wales, Australia

Reptiles

Antiguan racer (*Alsophis antiguae*)

Arkive. http://www.arkive.org/antiguan-racer/alsophis-antiguae/. Accessed 25.Sept.2013

Daltry, J. 2008.Progress on the Reintroduction of Antiguan Racers to Green Island and York Island: Technical Report to the Mill Reef Club and Partners of the Antiguan Racer Conservation Project .http://www.eco-index.org/search/pdfs/1418report_8.pdf

Daltry, J. C., Q. Bloxam, G. Cooper, M. L. Day, J. Hartley, H. McRonnie, L. Kevel , and B. E. Smith.2001. Five years of conserving the `world's rarest snake', the Antiguan racer *Alsophis antiguae*. Oryx 35 (2): 119-127

Babcock's leopard tortoise (*Stigmochelys pardalis*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Psammobates_pardalis/
Accessed 25.Sept.2013

Global Species. http://globalspecies.org/ntaxa/1698755 Accessed 25.Sept.2013

Brother's Island tuatara (*Stigmochelys pardalis*)
Office of Environment and Heritage.
NSW.http://animaldiversity.ummz.umich.edu/accounts/Sphenodon_guntheri/
Accessed 25.Sept.2013

Cook Strait tuatara (*Sphenodon guntheri*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Sphenodon_punctatus/.
Accessed 25.Sept.2013

Duvaucel's gecko (*Hoplodactylus duvaucelii*)
The Reptile Database. http://reptile-database.reptarium.cz/species?genus=Hoplodactylus&species=duvaucelii
Accessed 27.Sept.2013

Shore skink (*Oligosoma smithi*)
Hare, K. M., C. H. Daugherty, and D. G. Chapple.2008. Comparative phylogeography of three skink species (*Oligosoma moco, O. smithi, O. suteri;* Reptilia: Scincidae) in northeastern New Zealand.Molecular Phylogenetics and Evolution 46 (1): 303-315

Siamese crocodile (*Crocodylus siamensis*)
Fauna and Flora International. http://www.fauna-flora.org/species/siamese-crocodile/
Accessed 27.Sept.2013

Woma python (*Aspidites ramsey*)
Global Species. http://globalspecies.org/ntaxa/1699167 Accessed 27.Sept.2013

Human Aging Genomic Resources.
http://genomics.senescence.info/species/entry.php?species=Hoplodactylus_duvaucelii
Accessed 27.Sept.2013

Pilbara Pythons. http://www.pilbarapythons.com/womapython.htm Accessed 25.Sept.2013

Birds

Black stork (*Ciconia nigra)*

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Ciconia_nigra/ Accessed 25.Sept.2013

Grifon – Birds of Prey Conservation Centre. http://www.supovi.hr/faq/faq-odgovori?lang=en. Accessed 25.Sept.2013

Corncrake (*Crex crex*)

Castlebar News. http://www.castlebar.ie/clubs/mayo-birdwatch/CorncrakeFactsSong.html. Accessed 25.Sept.2013

Crockford. N., R. Green, G. Rocamora, N. Schäffer, T. Stowe, G. Williams (eds.) 1996. Action Plan for the corncrake (*Crex crex*) in Europe, Birdlife International

Egyptian vulture (*Neophron percnopterus*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Neophron_percnopterus/ Accessed 25.Sept.2013

Grey partridge (*Perdix perdix*)

Arkive. http://www.arkive.org/grey-partridge/perdix-perdix/#src=portletV3api Accessed 3.Sept.2013

BirdLife International.2013. IUCN Red List for birds http://www.birdlife.org/datazone/speciesfactsheet.php?id=188 Accessed 3.Sept.2013

Griffon vulture (*Gyps fulvus*)

Stoynov E., H. Peshev 2011. Re-introduction of Griffon Vulture (*Gyps fulvus*) in Kresna Gorge of Struma River, Bulgaria, Annual Report 2010**,** Fund for Wild Flora and Fauna, Blagoevgrad

Helmeted honeyeater (*Lichenostomus melanops cassidix*)

Department of Sustainability and Environment. Victoria.http://www.dse.vic.gov.au/about-depi/media-releases/victorias-oldest-helmeted-honeyeater-lives-on Accessed 18.Sept.2013

Menkhorst, P. 2008 National Recovery Plan for the Helmeted Honeyeater Lichenostomus melanops cassidix. Department of Sustainability and Environment, Melbourne

Malherbe's parakeet (*Cyanoramphus mahlherbi*)
IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. www.iucnredlist.org. Accessed 25.Sept.2013

Ortiz-Catedral, L., J.C. Kearvell, M.E. Hauber, D.H. Brunton .2009. Breeding biology of the critically endangered Malherbe's parakeet on Maud Island, New Zealand, following the release of captive-bred individuals. Australian Journal of Zoology 57(6): 433-439

Noisy scrub-bird (*Atrichornis clamosus*)
Australian Government Department of the Environment http://www.environment.gov.au/biodiversity/threatened/publications/recovery/noisy-scrub-bird/introduction.html Accessed 17.Sept.2013

Danks, A., A. A. Burbidge, A. H. Burbidge and G.T. Smith.1996.Noisy Scrub-bird Recovery Plan. Department of Conservation and Land Management, Two Peoples Bay Nature Reserve, Albany, Western Australia

The Website of Everything. http://thewebsiteofeverything.com/animals/birds/Passeriformes/Atrichornithidae/Atrichornis-clamosus Accessed 17.Sept.2013

Red-fronted parakeet (*Cyanoramphus novaezelandiae*)
Arkive. http://www.arkive.org/red-fronted-parakeet/cyanoramphus-novaezelandiae/ Accessed 17.September.2013

BirdLife International 2012. *Cyanoramphus novaezelandiae*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. www.iucnredlist.org. Accessed on 17 September 2013

Talk Parrots. http://www.talkparrots.com/showthread.php?t=1375 Accessed 17.September.2013

Red kite (*Milvus milvus*)
BirdLife International .2014.Species factsheet: *Milvus milvus*. http://www.birdlife.org . Accessed 11.August.2014

Saker falcon (*Falco cherrug*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Falco_cherrug/. Accessed 17.Sept.2013

Socorro dove (*Zenaida graysoni*)
American Bird Conservancy. http://www.abcbirds.org/newsandreports/releases/081120.html Accessed 17.Sept.2013

Birdlife International. http://www.birdlife.org/datazone/speciesfactsheet.php?id=2555 Accessed 17.Sept.2013

Southern emu-wren (*Stipiturus malachurus*)
Australian Government Department of the Environment http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=26005#life_cycle Accessed 17.Sept.2013

Yellow-crowned kakariki (*Cyanoramphus auriceps*)
BirdLife International.2013.Species factsheet: *Cyanoramphus auriceps*. Accessed from http://www.birdlife.org on 17.September.2013

World Parrot Trust. http://www.parrots.org/index.php/encyclopedia/captivestatus/yellow_fronted_parakeet/ Accessed 17.Sept.2013

Western bristlebird (*Dasyornis longirostris*)
Australian Government Department of the Environment. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=515#life_cycle Accessed 17.Sept.2013

BirdLife International .2013 Species factsheet: *Dasyornis longirostris*. Downloaded from http://www.birdlife.org on 17.Sept.2013

Mammals

African wild dog (*Lycaon pictus*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Lycaon_pictus/. Accessed 20.Sept.2013

Mills, M.G.L., S. Ellis, R.Woodroffe, A.Maddock, P.Stander, A.Pole, G. Rasmussen, P.Fletcher, M. Bruford, D.Wildt, D. Macdonald and U. Seal (Eds.). 1998. Population and Habitat Viability Assessment African Wild Dog (*Lycaon pictus*) in Southern Africa. Final Workshop Report. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN

African elephant (*Loxodonta africana*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Loxodonta_africana/
Accessed 20.Sept.2013

Amur goral (*Naemorhedus caudatus*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Naemorhedus_caudatus/
Accessed 20.Sept.2013

Apennine chamois (*Rupicapra pyrenaica ornata*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Rupicapra_pyrenaica/
Accessed 20.Sept.2013

Asiatic black bear (*Ursus thibetanus*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Ursus_thibetanus/
Accessed 20.Sept.2013

Lee, H., D. Garshelis, U. S. Seal, and J. Shillcox (editors). CBSG. 2001. Asiatic Black Bears PHVA: Final Report. The Conservation Breeding Specialist Group, Apple Valley, MN, USA

Black rhinoceros (*Diceros bicornis minor*)
Animal Diversity Web
.http://animaldiversity.ummz.umich.edu/accounts/Diceros_bicornis/.
Accessed 20.Sept.2013

Bongo (*Tragelaphus eurycerus*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Tragelaphus_eurycerus/
Accessed 20.Sept.2013

Bornean orangutan(*Pongo pygmaeus*)
Animal Diversity
Web.http://animaldiversity.ummz.umich.edu/accounts/Pongo_pygmaeus/.
Accessed 20.Sept.2013

Singleton, I., S. Wich, S. Husson, S. Stephens, S. Utami Atmoko, M. Leighton, N. Rosen, K. Traylor-Holzer, R. Lacy and O. Byers (eds.). 2004. Orangutan Population and Habitat Viability Assessment: Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN

Chimpanzee (*Pan troglodytes*)
Animal Diversity Web http://animaldiversity.ummz.umich.edu/accounts/Pan_troglodytes/ Accessed 20.Sept.2013

Golden lion tamarin (*Leontopithecus rosalia*)
Kierulff, M. C. M., C. R. Ruiz-Miranda, P. Procópio De Oliveira, B. B. Beck, A. Martins, J. M. Dietz, D. M. Rambaldi & A. J. Baker.2012. The golden lion tamarin *Leontopithecus rosalia*: a conservation success story. International Zoo Yearbook 46**:** 36–45

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Leontopithecus_rosalia/ Accessed 20.Sept.2013

Hirola (*Beatragus hunter*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Beatragus_hunteri/ Accessed 20.Sept.2013

Lesser short-tailed bat (*Mystacina tuberculata*)
Te Ara. http://www.teara.govt.nz/en/bats/page-1 Accessed 20.Sept.2013

Arkive. http://www.arkive.org/lesser-short-tailed-bat/mystacina-tuberculata/ Accessed 20.Sept.2013

Pygmy hog (*Porcula salvania*)

Arkive. http://www.arkive.org/pygmy-hog/porcula-salvania/. Accessed 20.Sept.2013

Rock hyrax (*Procavia capensis*)
Arkive.http://www.arkive.org/rock-hyrax/procavia-capensis/Procavia. Accessed 21.Sept.2013

Roe deer (*Capreolus capreolus*)
Animal Diversity Web.http://animaldiversity.ummz.umich.edu/accounts/Capreolus_capreolus/ Accessed 21.Sept.2013

Sumatran orangutan (*Pongo abelli*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Pongo_abelii/ Accessed 21.Sept.2013

Tammar wallaby (*Macropus eugenii eugenii*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Macropus_eugenii/
Accessed 21.Sept.2013

Yellow-footed rock wallaby (*Petrogale xanthopus*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Petrogale_xanthopus/.
Accessed 21.Sept.2013

Woylie (*Bettongia penicillata)*
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Bettongia_penicillata/
Accessed 21.Sept.2013

Soorae, P.S. (ed.). 2011. Global re-introduction perspectives: more case studies from around the globe. IUCN/SSC Re-introduction Specialist Group, Abu Dhabi, UAE

<u>Invertebrates</u>

American burying beetle (*Nicrophorus americanus*)
Animal Diversity Web.
http://animaldiversity.ummz.umich.edu/accounts/Nicrophorus_americanus/.
Accessed

Large blue butterfly (*Phengaris arion*)
University of Copenhagen. http://www.zi.ku.dk/personal/drnash/atta/Pages/LargeBl.html.
Accessed 28.Sept.2013

Mottled grasshopper (***Myrmeleotetti maculatus***)
Willott, S. J. and Hassall, M. (1998), Life-history responses of British grasshoppers (Orthoptera: Acrididae) to temperature change. Functional Ecology, 12: 232–241. doi: 10.1046/j.1365-2435.1998.00180.x http://www.buzzle.com/articles/life-cycle-of-grasshoppers.html

Fish

Berg-Breede whitefish (*Barbus andrewi*)

Impson, D. & Swartz, E. 2007. *Barbus andrewi*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. http://www.iucnredlist.org/details/2560/0. Accessed 28.Sept.2013

Bullhead (*Cottus perifretum*)

Freyhof, J. and M. Kottelat. 2008. *Cottus perifretum*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. www.iucnredlist.org. Accessed 30.Sept.2013

Bull trout (*Salvelinus confluentus*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Salvelinus_confluentus/ Accessed 30.Sept.2013

Citico darter (*Etheostoma sitikuense*)

U.S. Fish and Wildlife Service.1993. Duskytail Darter Recovery Plan. Atlanta, GA pp. 25

Itasenpara bitterling (*Acheilognathu longipinnis*)

Kitamura, J., J.N. Negishi, M. Nishio, S. Sagawa, J. Akino. 2009. Host mussel utilization of the Itasenpara bitterling (*Acheilognathus longipinnis*) in the Moo River in Himi, Japan. Ichthyological Research 56 (3): 296-300

Akademie Věd České Republiky http://www.ivb.cz/fish/reichard_research.html. Accessed 30.Sept.2013

Kitamura, J. and M. Nishio. 2010. Reproductive ecology and life history of Itasenpara bitterling *Acheilognathus longipinnis* in a conservation pond in Himi, Toyama, Japan. Japanese Journal of Ichthyology 57(1): 35-42 2010

North Sea houting (*Coregonus oxyrinchus*)

Borcherding, J., M. Heynen, T. Jäger-Kleinicke, H. V. Winter, R. Eckmann. 2010. Reestablishment of the North Sea houting in the River Rhine: Reestablishment of houting in the Rhine. Fisheries Management and Ecology 17 (3): 291-293

Borcherding, J., A. Scharbert and R. Urbatzka .2006. Timing of downstream migration and food uptake of juvenile North Sea houting *stNoturus flavipinnisocked* in the Lower Rhine and the Lippe (Germany). Journal of Fish Biology 68: 1271–1286

The Sixth Extinction website.http://www.petermaas.nl/extinct/speciesinfo/houting.htm. Accessed 28.Sept.2013

Smoky madtom (*Noturus baileyi*)

Shute, J. R., P. L. Rakes and P.W. Shute.2005. Reintroduction of Four Imperiled Fishes in Abrams Creek, Tennessee. Southeastern Naturalist 4(1): 93-110

Striped bitterling (*Acheilognathu cyanostigma*)

Kitamura, J. 2006. Reproductive ecology of the striped bitterling *Acheilognathus cyanostigma* (Cyprinidae: Acheilognathinae). Ichthyological Research 53: 216-222

Smith C., A. Douglas, P. Jurajda.2002. Sexual conflict, sexual selection, and sperm competition in the spawning decisions of bitterling (*Rhodeus sericeus*). Behav Ecol Sociobiol 51:433–439

Tokyo bitterling (*Tanakia tanago*)

Kubota, H., K. Watanabe, N. Suguro, M. Tabe, K. Umezawa, S. Watanabe. 2010. Genetic population structure and management units of the endangered Tokyo bitterling, *Tanakia tanago*(Cyprinidae). Conservation Genetics 11(6): 2343-2355

Ushimotsugo minnow (*Pseudorasbora pumila*)

Konishi, M., H. Sakano, K. Igushi. 2009. Identifying conservation priority ponds of an endangered minnow, *Pseudorasbora pumila*, in the area invaded by*Pseudorasbora parva*. Ichthyological Research 56 (4): 346-353

Yellow madtom (*Noturus flavipinnis*)

Animal Diversity Web.http://animaldiversity.ummz.umich.edu/accounts/Noturus_flavipinnis/ Accessed 30.Sept.2013

Amphibians

Cape platanna (*Xenopus gilli*)

Measey, G.J. (ed.) 2011. Ensuring a future for South Africa's frogs: a strategy for conservation research. SANBI Biodiversity Series 19. South African National Biodiversity Institute, Pretoria

Amphibiaweb. http://amphibiaweb.org/cgi/amphib_query?where-genus=Xenopus&where-species=gilli. Accessed 29.Aug.2013

Chiricahua leopard frogs (*Lithobates chicahuensis*)

Amphibiaweb. http://www.amphibiaweb.org/cgi-bin/amphib_query?where-genus=Rana&where-species=chiricahuensis. Accessed 29.Aug.2013

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Lithobates_chiricahuensis/ Accessed 29.Aug.2013

Common midwife toad (*Altyes obstetricans*)

Amphibiaweb. http://amphibiaweb.org/cgi/amphib_query?where-genus=Alytes&where-species=obstetricans. Accessed 29.Aug.2013

AmphibiaWeb: Information on amphibian biology and conservation. [web application]. 2013. Berkeley, California: AmphibiaWeb. Available: http://amphibiaweb.org/. Accessed: 29.Aug.2013

Edge of Existence. http://www.edgeofexistence.org/amphibians/species_info.php?id=1374. Accessed 29.Aug.2013

Houston toad (*Anaxyrus houstonensis*)

Houston Toad Population & Habitat Viability Assessment Report. U.S. Seal (ed.). IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN. 1994: 1-145.

Iberian frog (*Rana iberica*)

Arkive.http://www.arkive.org/iberian-frog/rana-iberica/ Accessed 29.Aug.2013

Mountain yellow-legged frog (*Rana iberica*)

San Diego Zoo. http://library.sandiegozoo.org/factsheets/california_frog/frog.htm. Accessed 30.Sept.2013

Reptiles

African spurred tortoise (*Centrochelys sulcata*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Geochelone_sulcata/ Accessed 30.Sept.2013

Arnold's giant tortoise (*Dipsochelys dussumieri*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Dipsochelys_dussumieri/. Accessed 30.Sept.2013

Hawksbill sea turtle (*Eretmochelys imbricate*)

Phillips, K.P., T. H. Jorgensen, K. G. Jolliffe, S-M. Jolliffe, J. Henwood and D. S. Richardson.2013. Reconstructing paternal genotypes to infer patterns of sperm storage and sexual selection in the hawksbill turtle. Molecular ecology 22 (8): 2301–2312

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Eretmochelys_imbricata/ Accessed 30.Sept.2013

Sand lizard (*Lacerta agilis*)

New Forest National Park. http://www.new-forest-national-park.com/sand-lizard-fact-file.html Accessed 1.Oct.2013

Arkive. http://www.arkive.org/sand-lizard/lacerta-agilis/ Accessed 1.Oct.2013

Seychelles black mud turtle (*Pelusios subniger parietalis*)

Arkive. http://www.arkive.org/east-african-black-mud-turtle/pelusios-subniger/. Accessed 30.Sept.2013

Seychelles giant tortoise (*Pelusios subniger*)

Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Dipsochelys_dussumieri/ Accessed 30.Sept.2013

St. Croix ground lizard (*Ameiva polops*)

Division of Fish and Wildlife. U.S.V.I. Animal Fact Sheet #10. St. Croix Ground Lizard..*Ameiva polops.*http://noahsartcamp.com/images/St_Croix_Lizard.pdf. Accessed 30.Sept.2013

Turks and Caicos rock iguana (*Cyclura carinata*)

Arkive. http://www.arkive.org/bahamas-rock-iguana/cyclura-carinata/image-G19143 Accessed 1.Oct.2013

Yellow-bellied mud turtle (*Pelusios castanoides intergularis*)

Arkive. http://www.arkive.org/yellowbelly-mud-turtle/pelusios-castanoides/ Accessed 30.Sept.2013

Birds

Northern bald ibis (*Geronticus eremita*)
Arkive. http://www.arkive.org/northern-bald-ibis/geronticus-eremita/ Accessed 30.Aug.2013

Red-billed chough (*Pyrrhocorax pyrrhocorax*)
BirdLife International.2013. Species factsheet: *Pyrrhocorax pyrrhocorax*. http://www.birdlife.org Accessed 30.Aug.2013

British Trust for Ornithology. http://blx1.bto.org/birdfacts/results/bob15590.htm. Accessed 30.Aug.2013

Paradise Park website: Operation Chough http://www.paradisepark.org.uk/choughs/ochistory.html. Accessed 30.Aug.2013

White-winged guan (*Penelope albipennis*)
BirdLife International.2013. Species factsheet. *Penelope albipennis* http://www.birdlife.org/datazone/speciesfactsheet.php?id=81. Accessed 30.Aug.2013

Angulo, P.F. 2011. White-winged guan (*Penelope albipennis*). Neotropical Birds Online http://neotropical.birds.cornell.edu/portal/species/overview?p_p_spp=78631. Ithaca: Cornell Lab of Ornithology.

Ural owl (*Strix uralensis*)
The Website of Everything. http://thewebsiteofeverything.com/animals/birds/Strigiformes/Strigidae/Strix-uralensis. Accessed 30.Aug.2013

San Diego Zoo. http://animals.sandiegozoo.org/animals/owl. Accessed 30.Aug.2013

Mangrove finch (*Chamarhynchus heliobates*)
Arkive.http://www.arkive.org/mangrove-finch/camarhynchus-heliobates/#src=portletV3api Accessed 30.Aug.2013

Fessl, B., J.E. Rodríguez-Matamoros, G. Young, V. Carrión, H. Vargas, R. Young & Y. Matamoros (Eds.). 2010. Taller nternacional sobre manejo del Pinzón del Manglar (*Cactospiza heliobates*). 17-21 de Noviembre 2008. Puerto Villamil, Isabela, Galápagos, Ecuador. Conservation Breeding Specialist Group Mesoamerica

Mammals

Arabian oryx (*Oryx leucoryx)*
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Oryx_leucoryx/ Accessed 2.Sept.2013

Arabian sand gazelle (*Gazella subgutturosa*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Gazella_subgutturosa/ Accessed 2.Sept.2013

Black-footed ferret (*Mustela nigripes*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Mustela_nigripes/ Accessed 2.Sept.2013

Eurasian beaver (*Castor fiber*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Castor_fiber/ Accessed 2.Sept.2013

Mountain gazelle (*Gazella gazella*)
Animal Diversity Web.http://animaldiversity.ummz.umich.edu/accounts/Gazella_gazella/ Accessed 2.Sept.2013

Przewalski's horse (*Equus ferus*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Equus_caballus_przewalskii/ Accessed 2.Sept.2013

Arkive. http://www.arkive.org/przewalskis-horse/equus-ferus-przewalskii/. Accessed 2.Sept.2013

Scimitar-horned oryx (*Oryx dammah*)
Bemadjim, N. E., J. Newby, A. Desbiez, C. Lees, and P. Miller (Eds.). 2012. Technical workshop on the reintroduction of scimitar-horned oryx to the Ouadi Rimé-Ouadi Achim Game Reserve, Chad. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN

Zanzibar red colobus (*Procolobus kirkii*)
Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/Piliocolobus_kirkii/ Accessed 2.Sept.2013

APPENDIX V

Reintroduction Case Studies database fields

Category	Field	Description
Taxonomy and status	Common Name	
	Genus	
	Species	
	Subspecies	
	Family	
	Animal Group	Invertebrate, Fish, Amphibian, Reptile, Bird, Mammal
	IUCN Status	IUCN Red List status: Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in the Wild (EW), Extinct (EX), Not evaluated
	World Regions	IUCN Statutory Regions 1-8 (see IUCN World Regions section below)
	Reference Source	Global Re-introduction Perspectives version 2008, 2010 or 2011
Life History Traits	Life Span	Life span
	Trophic Level	Carnivore, herbivore, omnivore, frugivore, fungivore
	Social System	Solitary; pair; group; colony
	Mating System	Monogamy; polygamy; polygny; polygynandry; promiscuity; cooperative breeder; hermaphrodite
	Reproduction Type	Viviparous; oviparous; ovoviparous; asexual; asexual and oviparous
	Gestation	Length of gestation
	Parental Care	Dam; Sire; Both dam and sire; none
	Age at 1st Reproduction	Age at first reproduction
	Number per Litter/Clutch	Number of offspring per birth event/number of eggs per lay event
	Migratory	Change home range with change of season
	ActvtyType	Nocturnal, diurnal, crepuscular, cathemeral
	Symbiosis	Symbiotic with another species
World Regions[1]	1	Africa
	2	Meso and South America
	3	North America and the Caribbean
	4	South and East Asia
	5	West Asia
	6	Oceania
	7	East Europe, North and Central Asia
	8	West Europe
Program Management	Program Name	Species (official program name, if present) and location
	Date Range	Start of program to end (if applicable) or ongoing

Category	Field	Description
Program Management	Program Partners	Program partners-government agencies, NGOs, academia, *ex situ* facilities
	Captive or Wild	Release animals captive or wild born, or a combination
	Life Stage At Release	Life stage at release
	Number Released	Sex ratio for number of conspecifics released or overall numbers
	Related	Were released animals related? Individuals, family group, or related
	Hard/Soft Release	Hard - release directly to the wild; Soft - release in enclosed area to prepare for release to the wild.
	Supportive Measures	Supportive measures - feeding, health care, provision of nests/dens, eradication of predators, none
	TranslocationType	Translocation type - supplementation, translocation, reintroduction, conservation introduction
	Habitat Type	IUCN Red List habitat categories (see IUCN Habitat Types)
	MonitoringType	See Monitoring Type section below
	Recovery Plan	If yes, then most recent year
	CBSG PHVA	Conservation Breeding Specialist Group Population and Habitat Viability Assessment - if yes then most recent year
	Permits	International, Federal and Local permits required
	Protected Area	Yes/No - release site within a protected area?
	Human Interaction	Negative - hunting; conflict
	Program Success	Highly successful; successful; partially successful; failure; too soon to tell
	Difficulties	Major difficulties faced
	Lessons Learned	Lesson learned
IUCN Habitat Types[2]	1 Forest	Boreal, Subarctic, Sub Antarctic, Temperate, Subtropical/Tropical Dry, Subtropical/Tropical Moist Lowland, Subtropical/Tropical Swamp, Subtropical/Tropical Moist Montane, Subtropical/Tropical Mangrove Forest Vegetation Above High Tide Level,
	2 Savanna	Dry, Moist
	3 Shrubland	Subarctic, Subantarctic, Boreal, Temperate, Subtropical/Tropical Dry, Subtropical/Tropical Moist, Subtropical/Tropical High Altitude Shrubland
	4 Grassland	Tundra, Subarctic, Subantarctic, Temperate, Subtropical/Tropical Dry Lowland, Subtropical/Tropical Seasonally Wet/Flooded Lowland Grassland
	5 Wetlands (inland)	Rivers, Streams, Creeks [includes waterfalls]; Bogs, Marshes, Swamps, Fens, Peatlands [generally over 8 ha]; Freshwater Lakes [over 8 ha]; Freshwater Marshes/Pools [under 8 ha]; Freshwater Springs and Oases; Tundra and Alpine Wetlands; Geothermal Wetlands; Inland Deltas; Saline, Brackish or Alkaline Lakes; Saline, Brackish or Alkaline Lakes and Flats; Karst and Other Subterranean Inland Aquatic Systems
	6 Rocky Areas	Rocky Areas [e.g. inland cliffs, mountain peaks]
	7 Cave/Subterranean Habitats (non-aquatic)	Caves, Other Subterranean Habitats
	8 Desert	Hot , Temperate, Cold Desert
	9 Marine Neritic Submergent NearshoreContinental Shelf or Oceanic Island	Pelagic, Subtidal Rock and Rocky Reefs, Subtidal Loose Rock/Pebble/Gravel, Subtidal Sandy and Sandy-Mud, Macroalgal/Kelp/ Coral Reef, Outer Reef Channel, Back Slope
	10 Marine Oceanic	Epipelagic (0–200 m), Mesopelagic (200–1,000 m), Abyssopelagic (4,000–6,000 m)
	11 Marine Deep Ocean Floor (Benthic and Demersal)	Continental Slope/Bathyl Zone (200–4,000 m), Hard or Soft Substrate, Abyssal Plain (4000-6000 m)
	12 Marine Intertidal	Rocky Shoreline, Sandy Shoreline and/or Beaches, Sand Bars, Spits; Shingle and/or Pebble Shoreline and/or Beaches; Mud Shoreline and Intertidal Mud Flats, Salt Marshes (Emergent Grasses)

Category	Field	Description
IUCN Habitat Types	13 Marine Coastal/Supratidal	Sea Cliffs and Rocky Offshore Islands, Coastal Caves/Karst, Coastal Sand Dunes, Brackish/Saline Lagoons, Marine Lakes, Freshwater Lakes
	14 Artificial - Terrestrial	Arable Land, Pastureland, Plantations, Rural Gardens, Urban Areas
	15 Artificial - Aquatic	Water Storage Areas [over 8 ha]; Ponds [below 8 ha]; Aquaculture Ponds; Salt Exploitation Sites; Excavations; Wastewater Treatment Areas; Irrigated Land and Channels, Seasonally Flooded Agricultural Land, Canals and Drainage Channels, Karst and Other Subterranean Hydrological Systems [human-made], Marine Anthropogenic Structures, Marine/Brackish-culture Ponds,
	16 Introduced Vegetation	Introduced Vegetation
	17 Other	Other
	18 Unknown	Unknown
Monitoring Type	Individual ID	Individual identification method - tag, band, notching, photo, markings,
	Radio Track-VHS	Radio-tracking using VHS
	Radio Track-GPS	Radio-tracking using GPS
	Observation-Visual	Observation - Visual
	Aerial Survey	Aerial Survey
	Transect Sampling	Quadrat Sampling
	Camera Trap	Camera Trap - photos, videos
	Capture Recapture	Capture-Recapture (mist nets, traps) for abundance measures
	Visual Sign	Visual signs - nests, footprints, feces
	Non-Invasive Genetic	Non-invasive genetic techniques
	Observation-Auditory	Observation - by sound (calls, vocalizations)
	Survey	General survey for population numbers - unspecified method
	Health Assessment	Capture: weights, measurements, body condition, sample collection (blood, hair, orifice swabs, tissue, parasites, feces, urine, etc.)
	Marking-chemical	General marking (not for individual ID) - Alizarin red S, flurochrome (oxytetracycline)
	Marking-physical	General marking (not for individual ID) - notching, toe-clipping, dye,
	RadioTrack-transmitter	Radiotransmitter - internal, external
	Spotlight Survey	Spotlight surveys
	SamplingGenetics	Take samples for genetic analysis
	Data Loggers	Internal body data logger for internal temperature or environmental data loggers
Ex Situ Management	Ex Situ Facility	Zoo/Aquarium, Breeding Center, Rescue/Rehab (non-exhibition), Hatchery, Sanctuary
	ISIS Member	If ISIS member, then mnemonic for species coordinator or facilities. If not, no.
	ISIS Record	Yes/No - animal records kept in ISIS?
	Pre release Management	Yes/No - Were there special management protocols pre-release?
	Incubation	Yes/No - were eggs incubated?
	Rearing	Yes/No - Rearing protocols documented?
	Pre-release Training	Pre-release training (see Pre -release Training table)
Pre-release Training	None	
	Habitat Use	Locomotor skills, use of dens/nests, hiding places
	Feeding	Recognizing appropriate foods, foraging skills
	Predator Avoidance	Recognizing and avoiding predators
	Migration	Migration skills
	Physical Conditioning	Body conditioning for ability to move in the environment
	Social Structure	Appropriate social skills

1. IUCN's Statutory Regions are a list of States by Region as per article 16 and 17 of the Statutes and Regulation 36 of the IUCN Regulations
2. IUCN Habitat Classification Scheme: http://www.iucnredlist.org/technical-documents/classification-schemes/habitats-classification-scheme-ver3

APPENDIX VI

Breeding Management Programs for Captive-bred

Species in Conservation Translocation Programs

Common Name	Regional Zoo Association Program	Zoo/Aquarium	Other Institution	ISIS Member	On ISIS Institution List
INVERTEBRATES					
American burying beetle	AZA SSP®®	Roger Williams Park Zoo St. Louis Zoo		Yes	
field cricket		London Zoo		Yes	
8 species of giant clam			Hatchery	No	No
Karner blue butterfly		Toledo Zoo		Yes	
Lord Howe Island phasmid		London Zoo		Yes	
Miami blue butterfly			McGuire Center of Lepidoptera University of Florida	No	No
Pine hoverfly			Unknown facility in Scotland	No	No
FISH					
Adriatic sturgeon			Fish farm	No	No
allis shad			Fish farm	No	No
Azraq killifish			Hatchery, Wharjah Wildlife Centre	No	No
bull trout			Leaburg Fish Hatchery	No	No
bullhead			INBO fish culture center	No	No
burbot			Hatchery	No	No
Citico darter			Conservation Fisheries, Inc.	No	No
Colorado pikeminnow			Fish hatcheries	No	No
Formosan landlocked salmon			Fish hatchery	No	No
Itasenpara bitterling			Aquatic Life Conservation Research Center	No	No
Lake sturgeon		Tennessee Aquarium	FWS Hatcheries	Yes	No
North Sea houting			None	No	No
oily bitterling			Local fishery	No	No

Common Name	Regional Zoo Association Program	Zoo/Aquarium	Other Institution	ISIS Member	On ISIS Institution List
Smoky madtom			Conservation Fisheries, Inc.	No	No
Spanish toothcarp			El Palmar Fish Research Centre	No	No
striped bitterling			Lake Biwa Museum	No	Yes
Tokyo bitterling			Tochigi Prefectural Fisheries Experimental Station	No	No
trout cod			Hatchery	No	No
Ushimotsugo minnow			Gifu World Fresh Water Aquarium, Lake Biwa Museum	No	Yes
Yarqon bleak			Dept. of Zoology-Tel Aviv University	No	Yes
yellowfin madtom			Conservation Fisheries, Inc.	No	No
AMPHIBIANS					
Booroolong frog		Taronga Zoo		Yes	
common mid-wife toad			Natural Park of Peñalara Rearing Center	No	No
Iberian frog			Natural Park of Peñalara Rearing Center	No	No
Kihansi spray toad		Bronx Zoo, Toledo Zoo		Yes	
Mallorcan midwife toad		Durrell Wildlife Conservation Trust, London Zoo		Yes	
mountain yellow-legged frog		San Diego Zoo, Fresno Chaffee Zoo, Los Angeles Zoo		Yes	
natterjack toad			Unknown		
Puerto Rican crested toad	AZA SSP®®	21 zoos and aquariums (US, Canada, UK and Puerto Rico).		Yes	
Romer's tree frog		Melbourne Zoo, Frankfurt Zoo, Kadoorie Farm & Botanic Garden	Hong Kong U	Yes	No

Common Name	Regional Zoo Association Program	Zoo/Aquarium	Other Institution	ISIS Member	On ISIS Institution List
REPTILES					
Arnold's giant tortoise			NPTS headquarters	No	No
Brothers Island tuatara		Wellington Zoo Trust	Victoria University of Wellington, Nga Manu Nature Reserve	Yes	Yes
Chinese alligator			Anhui Research Center for Chinese Alligator Reproduction	No	Yes
Cook Strait tuatara	ZAA - ASMP	Wellington Zoo Trust	Victoria University of Wellington, Nga Manu Nature Reserve	Yes	Yes
sand lizard		Marwell Wildlife Park, Chester Zoo		Yes	
Seychelles black mud turtle			NPTS headquarters	No	No
Seychelles giant tortoise			NPTS headquarters	No	No
shore skink			Massey University Captive Reptile Breeding Facility	No	Yes
Siamese crocodile			Government Wildlife Rescue Centre	No	Yes
Virgin Islands boa	AZA SSP®	Toledo Zoo and 6 AZA zoos		Yes	
western swamp tortoise	ZAA ASMP	Perth Zoo		Yes	
woma python		Adelaide Zoo		Yes	
yellow-bellied mud turtle			NPTS headquarters	No	No
BIRDS					
Aplomado falcon			World Center for Birds of Prey	No	Yes
Asian houbara bustard			National Wildlife Research Center and National Avian Research Center	No	Yes
bearded vulture	EAZA EEP	35 EAZA facilities		Yes	
black stork			Naturund Tierpark Goldau, Monticello Breeding Center	No	Yes
cheer pheasant			Islamabad incubation/release facilities	No	No
corncrake		Whipsnade Wild Animal Park		Yes	
grey partridge			Local game farms	No	No
helmeted honeyeater	ZAA ASMP	Healesville Sanctuary, Taronga Zoo		Yes	

Common Name	Regional Zoo Association Program	Zoo/Aquarium	Other Institution	ISIS Member	On ISIS Institution List
Malherb's parakeet			Isaac Wildlife Trust	No	No
nēnē			Breeding centers in Hawaii	No	No
red kite			Semi-secluded aviaries	No	No
red-billed chough		Paradise Park Wildlife Sanctuary		Yes	
red-billed curassow			Crax Brasil	No	Yes
red-necked ostrich			Mahazat as-Sayd pre-release enclosure	No	Yes
Saker falcon			Not named		
Socorro dove	EAZA EEP	EEP, Paignton Zoo, Edinburgh Zoo, Albuquerque Biological Park		Yes	
Ural owl		Unnamed zoos		Yes	
white-headed duck			Fülöpháza Breeding Center	No	No
white-winged guan			Breeding center	No	No
MAMMALS					
African wild dog			DeWildt Cheetah and Wildlife Center, Cango Wildlife Ranch	Yes	
Apennine chamois			Unnamed		
Arabian oryx		Al Ain	Sir Bani Yas Island Collection, private collections	Yes	Yes
Arabian oryx			Hai-Bar Yotvata Nature Reserve	No	Yes
Arabian oryx			Private Royal collection	No	No
Arabian oryx			Captive breeding facility within Reserve	No	No
Arabian oryx			King Khalid Wildlife Research Center	Yes	
Arabian sand gazelle			King Khalid Wildlife Research Center, Al Sudairy Gazelle Research Center	Yes	Yes
Arabian sand gazelle			King Khalid Wildlife Research Center	Yes	
Arabian sand gazelle			King Khalid Wildlife Research Center	Yes	
black and white ruffed lemur	AZA SSP®®	15 AZA institutions		Yes	
black-footed ferret	AZA SSP®	Cheyenne Mt Zoo, Louisville Zoo, SCBI, Phoenix, Toronto	National BFF Conservation Center	Yes	Yes

Common Name	Regional Zoo Association Program	Zoo/Aquarium	Other Institution	ISIS Member	On ISIS Institution List
eastern bongo	EAZA EEP AZA SSP®	SSP®-41 institutions EEP-45 institutions		Yes	
Eurasian beaver		Unknown			
golden lion tamarin	AZA SSP® and EAZA EEP	AZA - 70 institutions EEP - 52 institutions		Yes	
mountain gazelle			King Khalid Wildlife Research Centre	Yes	
mountain gazelle			King Khalid Wildlife Research Centre	Yes	
Przewalski's horse	EEP institutions	52 institutions		Yes	
pygmy hog			Pygmy Hog Breeding Centre	No	Yes
red squirrel	The Wales Mountain Zoo			Yes	
roe deer			Ajloun Nature Reserve breeding facility	No	No
sand gazelle			King Khalid Wildlife Research Centre		
scimitar-horned oryx	AZA SSP® EAZA EEP	SSP®-24 institutions EEP-61 institutions		Yes	
tammar wallaby	ZAA ASMP	ASMP - 9 institutions		Yes	
western lowland gorilla	EAZA EEP	Howletts and Port Lympne Wild Animal Parks		Yes	
yellow-footed wallaby	ZAA ASMP	ASMP - 6 institutions		Yes	

APPENDIX VII

Survey for integration of *in situ* and *ex situ* data management
identifying data collection and monitoring systems for species conservation programs

Project Name Project Start Date
Researchers and affiliations Collaborators
Species (common and scientific name) Animal group
IUCN world region Geographic range Habitat
Conservation status (IUCN Red List, ESA, CITES, MMPA)
Background Information – document resources for all information
Population size Home range size Trophic level
Life history parameters:

- Breeding system
- Mean and maximum litter (brood) size
- Precocial or altricial young
- Parental care
- Age of first reproduction (females)
- Age of first reproduction (males)
- Longevity
- Generation time

Threats

What are the objectives of the program or study (project description required)?
Does the project have an *ex situ* component? What institutions are involved? Are animals captive born?
If wild born, were the animals ever maintained under human care (for rescue/rehab/release or headstarting)?
If so, what institution(s) is(are) involved? ISIS member?
What was the duration that animals were maintained?

Data Management

How much time is dedicated to data management - data collection, data entry, data analysis?
How were the animal records maintained while under human care?
How were monitoring data maintained?

Individual animal records
Database or records-keeping method used
ID number (accession number) or other ID?

ID method
Physical Identifier
Visual marking (photograph, camera trap photo or observation)
Tag/Band/Transponder   Radio-collar   Ear notching   Toe clipping
Logical Identifier
Name   Studbook Number   Local ID Number
Footprint Identification Technique
Genetic techniques (DNA analysis, feces)   Other

Age   Measurements – Weights and lengths   Location
Parentage   Reproduction   Health status   Death

Human/wildlife conflict
Are records maintained in individual specimen or group records?

Release Protocols – how are protocols documented?
Pre-release management – special management protocols for animals born in captivity or head-started and slated for release
Hard or soft release
Parameters of release (age; individual, family group or group; season or time of year; time of day; weather conditions; phase of the moon)
Special conditions for release – supplementation, supportive measures
Have protocols changed over the course of the program? How can the changes be tracked?

Monitoring
For each technique used, what are the data collection requirements (how are the data collected, specifically what data are collected, what type of database is used {paper, spreadsheet, records-keeping system}, what type of file format is used and how is the data analyzed {programs used with required format, type of analyses done}).

What monitoring techniques are used in research studies on:

Spatial Ecology:
Establishing presence, abundance and density.
Distance sampling   Camera traps
Transect surveys   Mark and recapture
Aerial surveys   Non-invasive genetic techniques (feces, hair)
Cue count surveys (audio)   Radio-telemetry
Trapping Line surveys   GIS

Home range/territory
Radiotracking: VHS and/or GPS   Camera traps   Non-invasive genetic techniques

Population Dynamics:
Monitoring methods for data on:

- Social Organization – camera traps, observation
- Reproduction
- Genetic variability
  - Non-invasive genetic techniques (DNA analysis from hair, feces)
  - DNA analysis from blood
- Growth and development   Dispersal   Migration

How many individual animals are being monitored? By what method?
What is the area of the study site being monitored?
What is the density of the population being monitored (calculated, estimated or observed)? How is the density calculated?

Health:
Capture and immobilization procedures
Health assessment:
Collection, processing and analysis of samples for health studies (hematology, blood chemistry, serology, bacterial cultures, parasites, urine, saliva, feces, tissues)

- Measurements   Weight   Body condition   Injury
  - Disease

Population Management

Is an IUCN/SSC Specialist Group involved in the program for this species?
Has a Population Habitat and Viability Assessment been done? What year? Who was involved?
Is there a Conservation Action Plan (government, IUCN/SSC Specialist Group)? What year?
Is the population under any type of management (demographic and/or genetic)? If so, how is the analysis done (databases and programs used)?
What types of population management actions occur?
Is the population maintained as part of a meta-population? If so, how are records on each population integrated for meta-population management?
Are there separate databases used to maintain the different monitoring data?

APPENDIX VIII

Conservation Translocation Cycle Parameters for Field Research Case Studies

		Category A			Category B		
Conservation Translocation Cycle	Parameter	American Burying Beetle	Takahe	Western Pond Turtle	Kakapo	Red Wolf	Kihansi Spray Toad
Life History	Animal Group	Invertebrate	Bird	Reptile	Bird	Mammal	Amphibian
	Lifespan	1 year (season)	14-20 years	50-70 years	40-60 years	10 years	3 years (captive)
	Habitat	Grasslands, open understory oak and hickory forests	Alpine grassland	Water bodies with slow moving waters, deep pools	Temperate forest	Wetland and forest	Waterfall spray zone
	Trophic Level	Carnivore	Herbivore	Hervibore/carnivore	Herbivore	Carnivore	Carnivore
	Social System	Pairs	Family groups	Groups	Dam and offspring Males solitary	Pairs and offspring	Solitary
	Mating System	Monogamous	Monogamous	Polygynous	Lek	Monogamous	Polygynous
	Repro Type	Oviporous	Oviporous	Oviparous	Oviparous	Viviparous	Ovoviviparous
	Age 1st Reprod	1 year		Male - 5-9 years Females - 7-10 years	Male - 5 years Female - 9-11 years	2-3 years	1 year
	Number offspring/event	12-18 eggs	1-3 eggs	2-13 eggs	1-4 eggs	2-8 pups	5-13 offspring
	Parental Care	Dam and Sire	Dam and Sire	None	Dam	Dam and Sire	None
	Activity Type	Diurnal	Diurnal	Diurnal	Nocturnal	Diurnal	Diurnal
Status	IUCN Red List	Critically Endangered	Endangered	Vulnerable	Critically Endangered	Critically Endangered	Extinct in the Wild
	Threats	Habitat loss	Invasive predator, competition	Habitat loss, invasive predators	Habitat loss, invasive predators	Habitat loss Extermination by humans Coyote introgression	Habitat loss, toxins, chytrid fungus
	PHVA	2005	Planned for future	2013	Planned for future	1999	2008
Design	Recovery Plan	USFWS ABB Recovery Plan 1991	Takahe Recovery Plan 2007-2012	Western Pond Turtle Washington State Recovery Plan 1999	Kakapo Recovery Plan 2006 – 2016	Recovery/Species Survival Plan 1990 Adaptive Management Plan 2013	Kihansi Spray Toad Re-introduction Guidelines 2010
Implementation	*Ex situ* data	ISIS, Access database	At Auckland Zoo - ISIS Other facilities - Access	ISIS Excel Spreadsheets	At Auckland Zoo - ISIS Other facilities - Access	ISIS, Excel, paper forms	ISIS, Excel
	Breeding Management	AZA SSP®	No captive breeding	No captive breeding	No captive breeding	AZA SSP®	Two AZA zoos
	ISIS Studbook	SPARKS	SPARKS	None	SPARKS	SPARKS	None
	Pre-release training	None	Foster reared by conspecifics	None	Raised with conspecifics	Limited human contact	None
	Release type	Hard	Hard	Hard	Soft	Soft	Soft
	Supportive measures	Food supplementation	Food supplementation	Nest site protection Predator control	Food supplementation	Food supplementation	Spray system, habitat restoration
	Health/mortality data	Access database	MedARKS by Auckland Zoo Access and Huia Morality Databases	MedARKS at WPZ Access and Word	MedARKS by Auckland Zoo Access and Huia Morality Databases	MedARKS for 7/44 zoos, Excel, Word, paper docs	MedARKS, Word
Monitoring	Methods	Capture, surveys	Visual surveys, radio-telemetry health checks	Capture, radio-telemetry health checks	Visual survey, video camera trap, Egg Timer and Checkmate transmitters, health check	Radio-telemetry visual survey camera trap, health checks	Visual survey, capture, health checks, sample collection
	Data management	Excel	Access	Access	Access	Access	Gov. ecological monitoring database (EMD)
	Heath/Mortality data	Word docs	Access and Huia Database	Access, Word, paper docs	Access and Huia Database	Excel, Word, paper docs	Gov. EMD

APPENDIX VIII (continued)

Conservation Translocation Cycle Parameters for Field Research Case Studies

		Category C	Category D	Category E	
Conservation Translocation Cycle	Parameter	Lowland Tapir	Cheetah	Armenian Viper	Giant Armadillo
Life History	Animal Group	Mammal	Mammal	Reptile	Mammal
	Lifespan	≤30 years	10-12 years	10 years (captivity)	12-15 years
	Habitat	Tropical lowland rainforest and floodplains	Open or lightly forested grassland, dense bush country, dry forest, montane moorlands, swamps	Rocky mountain habitat	Tropical/subtropical rainforest, savanna, floodplains, arid/semi-arid woodlands
	Trophic Level	Herbivore	Carnivore	Carnivore	Carnivore (Insectivore)
	Social System	Solitary or Dam and offspring	Females - Solitary or with cubs Males - coalitions	Groups in winter	Solitary
	Mating System	Polygynous	Polygynous	Polygynous	Monogamous/polygynous (?)
	Repro Type	Viviparous	Viviparous	Oviviparous	Viviparous
	Age 1st Reprod	2 years	Females - 13-16 months Males - 2-3 years	3 years	9-12 months
	Parental Care	Dam	Dam	None	Dam
	Activity Type	Crepuscular	Diurnal	Diurnal/crepuscular	Nocturnal
Status	IUCN Red List	Vulnerable	Vulnerable	Near Threatened	Vulnerable
	Threats	Habitat loss, agriculture/cattle ranching, overhunting, roadkill	Habitat loss, human persecution, predation by other carnivores	Habitat loss and fragmentation, human persecution	Hunting, habitat loss
	PHVA	2007	2002	None	None
Design	Recovery Plan	Lowland Tapir Conservation Workshop 2007	Conservation Action Plan for Cheetah and Wildlife in Namibia - 2013	None	None
Implementation	*Ex situ* data	N/A	ISIS, Excel, Word	N/A	N/A
	Breeding Management	N/A	N/A	N/A	N/A
	ISIS Studbook	N/A	International Studbook in SPARKS	N/A	N/A
	Pre-release training	N/A	Predatory behavior	N/A	N/A
	Release type	N/A	Soft	N/A	N/A
	Supportive measures	N/A	Food supplementation	N/A	N/A
	Health/mortality data	N/A	MedARKS (prior to 2009) Excel, Word	N/A	N/A
Monitoring	Methods	Capture, health checks, samples for analysis, radio-telemetry camera traps	Radio-telemetry, non-invasive genetic techniques (fecal analysis), camera traps, capture/health assessment	Surgical radio-transmitter implantion, radio-telemetry, capture/health assessment, genetic analysis, environmental measurement	Capture, health assessment, sample collection, radio-telemetry, genetic analysis, camera traps
	Data management	Excel	Excel, Word	Excel	Excel
	Heath/Mortality data	Excel, Word	Excel, MedARKS (prior to 2009)	Excel	Excel

APPENDIX IX

American Burying Beetle (*Nicrophorus americanus*)

Breeding	
Individual Information	Breeding Success
Individual number	Individual number
Location (St. Louis Zoo)	Gender
Brood/Bucket	Bucket/Brood
Gender	Retired from Bucket date
Date Emerged	Earliest time to breed
Sire ID/Tag	Successful/Unsuccessful/ Emerged
Dam ID/Tag	Breed to number
Deceased/Date of death	Do not breed
Retired/Retired date	Weight
Notes	

Breeding Arena	
Set Up	Larvae check
Pair #	Date to check for larvae
Sire #	Number of larvae at check
Dam #	Date checked/Initials
Date introduced	Date father removed
Carrion type	Date mother removed
Weight of carrion (g)	Remarks-observations
Date of burial	Emergence
Burial - Fully covered Partial burial *Not buried	Pairing # Bucket/Brood Sire #/Dam #
Date to check larvae	Date of first emergence
*Not buried in 3 days Date parents removed	Number of beetles emerged (separate entry for each date)
Initials	Remarks-observations

Bird Data				Location	Hardware
All Birds	Measurements	Health		Sites	Transmitters
Band number	Bird Name	Samples	Sample results	Site name	Entry number
Band combo	Current_Band	Sample ID	Sample results ID	Site type	Band number
Bird name	Date	Band number	Sample results date	Management regime	Site name
Sex	Age_of_bird	Date taken	Sample ID	Pest status	Transmitter channel
Natal year	Observer	Collector name ID	Ascarid	Current? Yes/No	Transmitter type
Origin	Weight	Site name	Campylobacter	Territories	Transmitter status
Nest site	Culmen	Sample type	Capillaria	Territory name	Date of status change
Nest territory	Nares	Sample volume	CBC avian	Site name	Removal status
Clutch	Shield	Storage medium	Chlamydia	Year trapping started	Harness size
Egg #	Left_mid_toe	Storage temperature	Coccidia	Current? Yes/No	Date of Expiry
Dam ID	Right_mid_toe	Storage location	Erysipelothrix	Easting	Aerial
Sire ID	Left_tarsus	Sample storage	Salmonella	Northing	TX Weight
Date banded	Right_tarsus	Name Type	Strongyle		Fine tune
Tussock trained Yes/No	Bill_depth	Storage location	Observations		
Winter trained Yes/No	Ldf_sexing	Storage address	Nests	Birds	Eggs/Chicks
Pellet trained Yes/No	Blood_label	Phone	Nest observation ID	Bird observation ID	Name
Hopper trained Yes/No	Stored_location	Email	Observation date	Takahe Year (Calculated)	Egg/chick observation ID
Grass trained Yes/No	Storage_method	Deads	Observer ID	Band number	Nest observation ID
Erysipelothrix vaccination Yes/No	Notes	Current band	Observation method	Site name	Stage
Date of vaccination		Name	Site name	Territory name	Egg ID
Erysipelothrix booster Yes/No		Territory	Territory name	Easting/Northing	Egg number
Date of booster		Condition	Northing	Observation method	Egg/chick status
		Complete/incomplete	Easting	Observation date	Removed? Yes/No
		Date	Breeding year	Observer ID	Transferred Out? Yes/No
		Comments	Nest fate	Skyranger state	Transferred In? Yes/No
		Final_storage_location	Clutch	Mate ID	Chick band ID
			Number of eggs	Bird weight	Foster parent 1 ID
			Parent 1 ID	Notes	Foster parent 2 ID
			Parent 2 ID	Mate #2	Site transferred to
				Monitoring event	Notes

APPENDIX X

Takahē (*Porphyrio hochstetteri*)

New Zealand

Appendix XI

DOC *Access* Database Fields for Kakapo

All Birds			Health		
Bird Name	shell weight	Measurements	Health checks	Blood records	Samples
Studbook No.	Shell thickness	Bird Name	Recovery Id	Blood Record ID	Name
Sex	actual fresh weight	Exposed Culmen	Eyes	Recovery ID	Sample Type
Mother	FW co efficient x10-4	Tarsus Width Unsquashed	Ears	Collection date/time	Catalogue Number
Father	width/length	Tarsus Width Squashed	Cere and nostrils	Date processed in lab	Analysis Results
definite father Yes/No	viable	Tarsus Depth Unsquashed	Bill	Case Number	Recovery ID
Date Laid	dead embryo	Tarsus Depth Squashed	Cloaca	Haematology	Feathers
Date Hatched	first day at/very close to nest	Tarsus Length	Legs	Sample status	Feather Type
Fledged Yes/No	est age when 1st found	Tail Length	Feet and toes	Hct (l/l)	Feather Count
Demise Date/Time	days on nest	Leg	Transmitter	HB (g/l)	Catalogue Number
Comments	inter clutch laying interval	Longest Toe	Band	WBC (x109/l)	Recovery ID
Bird ID	Incubation Period	Wing Length	Microchip	Band heterophils (x109/l)	New Record
Alive Yes/No	dates mated	Long Toe Claw	New Record	Heterophils (x109/l)	Feather ID
New Record	last date mated	Boom Sac Yes/No	Chemistry assays	Lymphocytes (x109/l)	Sperm Header
Current Island	mating to nesting: days	Brood Patch Yes/No	Chemistry Assay ID	Monocytes (x109/l)	Recovery ID
Plumage colour	mating to laying	In Moult Yes/No	Chemistry Header ID	Eosinophils (x109/l)	Collection method
Leg colour	mated with	RecoveryID	Chemistry Assay	Basophils (x109/l)	Sample Number
Expected weight	nesting to laying	New Record	Value	Myelocytes (x109/l)	Papilla swelling 1-3
Target weight	Results	Gape	Chemistry header	Fibrinogen (g/l)	Simulation 1-3
lay year	lay island	Culmen Only	Recovery Id	Red cell morphology	Stress 1-3
clutch	Transmitter group	Femur	Chemistry Header ID	Metarubricytes	Sperm Measures
clutch order	Nest mother	Sternum-shoulder	Time of centrifuge	Polychromasia	Name
date first found	Discovery date	Average chick weights	Chemistry Method	Anisocytosis	Sperm Header ID
Length	Ages	average female chick weights	Plasma or serum	Hypochromasia	Sperm Measure
Width	Bird name	Average male chick weights	Chemistry Comments		Sperm Value
Weight	Sex	age	Microbiology Header	Microbiology Tests	Sperm Measure ID
Band Change	Year	Weights	Name	Microbiology Header ID	New Record
New Band Number	Status	Weight	Recovery ID	Microbiology test	Named Locations
Leg	Bird History	N	Microbiology Header ID	Microbiology Value	Island

Recovery ID	Bird Event	Sd Dev	Date processed	New Record	LocationType
New Record	Bird ID	Method	Case Number	Microbiology Test ID	Easting
Microchip	Location General	Recovery ID	Swab Site	Comments	Northing
Moults		New Record			Location Name
Primaries	Under Wing Coverts	Event Date	Kakapo (continued)		Mapping Method
Secondaries	Upper Tail Coverts	History id			Comments
Tertials	Upper Parts	food type			New Record
BastardWing	Head	feeding regime			Bird ID
Primary Coverts	Under Tail Coverts				Activity Status Yes/No
Greater Coverts	Under Parts				First Date
Lesser/MedianCoverts Byte 1	Recovery ID				GPS count

Reproduction					
Track and bowl activity	Mating Info	Nest Details	Nest observations		Handraise data
T and B	Female Bird	Nest Type	Nest obs ID	Heat pad time	Amount fed
Date	Male Bird	Chamber Height	Bird ID	chick 1 ID	percent solids
Track activity	Date/Time	Chamber Diameter	Location name	chick 2 ID	Number of feeds
Sticks	Comments	Entrance Height	Notes	breathing rate 1	recovery ID
Grubbing	New Record	Entrance Diameter	Date/Time	breathing rate 2	new record
T and B rec ID	Mating info ID	Site Description	New Record	mum back 1	Temperature
New Record	Breeding history	Location Name	Number of eggs	chick first feed 1	Relative Humidity
Observer	Bird ID	Chamber length	Number of chicks	mum back 2	Brooder type
tape used	Year	Entrance Rise	Total time off	chick first feed 2	Medication
Skraaking	Island	Chamber Rise	Max time off	mum back 3	% Dietary Fibre
Chinging Yes/No	1st clutch	Nests	First time off	chick first feed 3	Largest meal
Booming Yes/No	2nd clutch	Year	Number of times off	mum back 4	Hand Rearing Formula
time recorded	Total fledged	Female	Scratches	chick first feed 4	Drug Text 255
Mating sign	fertile_1	Male	Rolls	heatpad 1 Yes/No	Concentration value
Comments	fertile_2	Island	Start observation time	heatpad 2 Yes/No	Dose rate
Fighting sign	fledge_1	Clutch size	Finish observation time	heatpad 3 Yes/No	Route
TB/hopper	fledge_2	Fertile	Lay date	heatpad 4 Yes/No	Times per day
	Raised	Hatched & certainty	Hatch date	Time on nest during daylight	Day number
	Raised own	Fledged & certainty	chick 1 & 2 time fed	Time on nest during night	Course length

	Breeding year Yes/No	Independent & certainty	chick 1 & 2 number feeds	Active day minutes	Concentration units
Kakapo (continued)		Offspring 1, 2, 3	unknown chick time fed	Active night minutes	
		Nest ID		Percentage of day active	
Feeding	Recovery		Hardware	Temperature logger data	Triangulation data
Name Type	Island	Entry Date	Egg timer	Bird ID	Recovery ID
Feed ID	Date	Entry Time	Recovery ID	Transmitter channel	Name 1-5
Location	Time	Nesting	Activity X days ago	Date and Time	X1-5 , Y1-5
Date out	Bird Cert	Booming	Mean activity	Weight	Bearing 1-5
Date in	Location	Supportive feeding	Hair trigger	Radio Frequency ID	Intersection 1-10
Bird 1, 2, 3	Easting	First arrive time	Battery life	Transmitter change	Anchor_traps
Kates pellets in or out	Northing	Last depart time	Pulse rate	New Tx channel	Name
Little pellets in or out	Map Method	Duration	Days since change	Tx Life Expectancy	ID
Kahikatea in or out	RecoveryType	Number of visits	Duration of previous	Tx mortality	Altitude & depth
Walnuts in or out	Location Description	Bearing and Dist Recs	Checkmate	Tx Rigging	Temperature
Almonds in or out	Observer	Location Code	Recovery ID	Beats/min	Chick import
Corn in or out	Obs Quality	Recovery ID	1-4 female	Recovery ID	Bird ID
Apple in or out	Activity	New Record	1-4 time	Removed Y/N	Island
Kumera in or out	Comments	Easting	1-4 duration	Old harness left & right length	Recovery type
Food Consumed	Recovery ID	Northing	Battery	New harness length	Recovery ID
Comments	Bird ID	Bearing	Pulse rate	Frequency	Date
Observer Details	Location	Capture Details	Bird ID	Hours on & off	Time
Observer	Island	Capture Method	Weather		
Contact address	Location Type	Response, Struggled, Calm	Temperature, Rain		
Phone – work	Easting and Northing	Shivered , Panting Y/N	Cloud, Wind		
Phone – home	Location Name	Head down, Eyes closed Y/N	Recovery ID		
Notes	Mapping method	Recovery ID		Kakapo (continued)	

APPENDIX XII

Kihansi Spray Toad (*Nectophrynoides aspirginis*)

Toledo Zoo data fields

Monthly Inventory	
Group Information	Medical
Enclosure ID	Coccidia
Group count	Nematodes
# Males	Ciliates
# Females	Bacteria
# Unknown sex	Hookworms
Births	Mites
Deaths	Flagellates
Not Reared	Cage size
Departures	
Male/Female/Unk group ID #	
Female group ID#	
Unk group ID #	

Inventory Analysis	
Month	N
Birth Rate	Transfer
Death Rate	Not Reared

Experiments			
Reduced mist cycle	UV test - effect on growth	Fruit flies diet study	Density effect on mortality
Mist cycle variables (10 min/2 hrs)	UV or Non-UV light	Number of fruit flies fed	Cage ID
Cage ID	Enclosure ID	Cage ID	Dates started
Group size	Cage ID	Date	Month
Number of males	Group size	Animal number	Cage size
Number of females	Number of males	Group number	Volume
Unknowns	Number of females	Snout Vent Length	Area
Male group ID	Unknowns	Mass	Original number individuals
Female group ID	Male group ID		Final number of individuals
	Female group ID		Deaths
	Animal number		Density Animals/sq. in.
	Mass		
	Snout Vent Length		

In Situ Monitoring	
Ecological	Kihansi spray toads
Air temperature	Population size
Humidity	Sex ratios
Wind speed	N reintroduced/date
Precipitation	Soft release pen ID
Water quality - pH, suspended solids	Pen or release location
Water flow - discharge	Births
Wetland vegetation	Disease
Wetland insect species	Death/necropxy

APPENDIX XIII

Process Table				
General Information		**Measurements (cm)**		**Medical**
ID# (species + Studbk #)	Drugs used? Y/N	Ear	Hind paw length	Rabies vaccine? Y/N
Sex	Body condition score	Tail	Hind paw width	Ivermectin? Y/N
Radio collar frequency	Dentition - no, slight, moderate, heavy wear	Body	Testicle length	Additional parasiticides?
Radio collar serial #	Tooth pulled (identify)	Total body (tail +body)	Testicle width	Flocillin?
Initials of staff	Fecal taken? Y/N	Hind foot	Vulva length	Amt flocillin (ml)
Capture method (leg trap, box, pen trap, darted, snatch pole, by hand, etc.)	Ectoparasites? Y/N	Shoulder	Vulva width	Heartworm test results
Foot captured (L/R, Fr/Rear)	Surgery? Details in Memo	Neck	Inguinal nipple length	Memo - any comments
Captive or free-ranging status	Sterile? Had surgery?	Front paw length	Inguinal nipple width	Initials of data entry person
Age (months)	Transponder #	Front paw width		Initials of person proofing
Weight				

Red Wolf (*Canis rufus*)
United States

APPENDIX XIII (continued)

Event Table			
Genetic samples	**Visits**		**Monitoring**
ID# (species + Studbk #)	Arrival event (+/-)	Event Date	Start Date-radiotelemetry
Sex	Birth event (+/-)	Death (+/-) Status (F or C)	End Date-radiotelemetry
Previous canid# if changed	Birth location (N Carolina, captivity, island, Smokeys)	Site location , county	Reason -died, removed, captured, lost contact w/collar, removed due to landowner request
Sire ID	Release event (+/-)	Easting/Northing	Non-resident start date
Dam ID	Capture by private trapper	Release Date	Non-resident end date
Genetics - # loci Genetic results: wolf, coyote, RedWolfBackCross, CoyBC, F1, F2	Fostered to wild litter (+/-)	Release Location	# pups whelped
Ambiguous results	Transpondered in den (+/-)	County where released	Fate unknown (lost contact w/radio collar)
Wolf p-value from genetic results	Sterilized w/hormones intact (+/-)	Release Easting/Northing UTM	Comments
Coyote/RWBC p-value	Sterilized w/o hormones intact (+/-)	Cause of death unk, vehicle, legal, take, natural, foul play	
F1/F2 hybrid p-value	Shipped to another site/captive facility	Legal take-trap, gunshot, handling, euthanized	
# coyote specific alleles	Natural - health, intraspecific	Whelped (+/-)	
% of red wolf	Foul play - gunshot, poison, other	Disappeared (+/-)	

APPENDIX XIV

Lowland Tapir Data Fields

Capture, Anesthesia, Manipulation, Health

General Information	Chemical/Physical Restraint		Body Condition	Hematologic Parameters	
ID	Capture method	Processing time	General state	Collect blood Y/N (why?)	Myelocytes
Name	Activity when found	Maximum heart rate (BPM)	Appearance: skin/hair	Volume (ml)	Metamyelocytes
Capture date	Veterinarian	Type of respiratory frequency	Scars, Wounds	Erythrogram	Band neutrophils
Manipulation #	Team (names)	Maximum respiratory frequency (MPM)	Dental abscesses	Red blood cells	Segmented neutrophils
Biome	Objective for anesthesia	Minimum respiratory frequency (MPM)	Eyes	Hemoglobin	Lymphocytes
Sub-region Pantanal	Time of capture	Maximum/Maximum SPO_2 (%)	Fractures	Hematocrit (%)	Reactive lymphocytes
Study area/Specific location	Anesthetic protocol	Drooling/salivation	Dental conditions	Average RBC volume	Atypical lymphocytes
UTM Coordinates	Mode of application	Muscular relaxation	Genitalia	MCH (pg)	Monocytes
Habitat at shooting time/when found	Volume (IM) in ml	Maximum Temperature (^oC)	Pregnant	MCHC %	Eosinophils, basophils
Sex	Atropine?	Minimum Temperature (^oC)	Lactating	MCV	Platelet count

Age class estimate	Supplemental dose	Reversal drug/dosage (ml)	Identifiers	Erythrocyte Morphology	Platelet
Weight estimate (kg)	Mode of application	Reversal effect/recovery	VHF , GPS	White blood cells	Hair Y/N
Back length (cm) Height (cm)	Time of capture/Time until unconscious (min)	Anesthetic Review	Microchip	Leucocytes, neutrophils, promyelocytes	Genetics - Tissue Y (where?)/N

APPENDIX XIV - Lowland Tapir Data Fields

Corporal Measurements						
General Information			Measurements			
Date	Capture method	Location	neck perimeter	total length (back)	back groin perimeter	front height
Individual	Estimated weight (kg)	GPS coordinates	tail-neck length	total length (side)	front groin perimeter	ear length
Age class	LTCI Program		head length	front leg length	belly perimeter	distance eyes
Sex	Study Area		head width	back leg length	back height	

Camera Traps	
Team	Date
Study Area	Time
Camera	Month
Near Box Trap?	Moon Phase
Tapir ID	Temperature

Capture Rounds – Capture days, capture traps, working dogs

APPENDIX XIV

Radio-tracking		
Bearings	Direct Sightings	Activity Patterns
Year	Date/Time	Date
Position X,Y	Team	Time
Date	X, Y	Activity

Lowland Tapir Data Fields
Sample Analyses

Round number, date range, number of methods, darting, box

Capture Summary	
Year	Direct Sightings
Study Area	Photos/Videos Camera-Traps
Tapir Name	Collar fell off
Captures/ Recaptures	Death
Locations TelVHF/GPS	TOTAL

APPENDIX XIV

Lowland Tapir

Biochemistry		Swabs (Bacteria)	Feces	Urine		Milk	Infectious Diseases	
Na, K, Ca	Total Cholesterol	Mouth	Collected Y/N	Collected Y/N	Urobilinogen	Milk aspects	Equine	Various
Inorg Phos	Cholesterol (HDL)	Nose	Fecal parasites	Color	Squamous cell	Dry material	Encephelo-myelitis	Lepto-spirosis
Urea	Cholesterol (LDL)	Eye	Laboratory used	Density	Leucocytes	Total fat	Infectious Anemia	Brucellosis
Creatinine	Cholesterol (VLDL)	Ear	**Ectoparasites**	pH	Erythrocytes	Ash	Bovine	Trypano-somes
Bilirubin	Triglycerides	Anus	Ectoparasite	Proteins	Red blood cells	Protein	Blue Tongue	Leishmani-asis
Total Protein	Amylase	Vagina	Sci.name Female/male	Glucose	Hyaline cylinders	Carbohydrates	Bovine Leukosis	Porcine
Albumin	Magnesium	Prepuce	Laboratory used	Ketone bodies	Cylinders	Calories	Vesicular Stomatitis	Aujezky Disease
Globulins	Iron	Urethra		Bile pigments	Crystals	Laboratory used	Bovine Viral Diarrhea	Porcine Parvovirus
Alb/Glob	Zinc	Injuries		Hemoglobin	Bacteria	Minerals	Fibromuscular Disease	
Glucose Chloride	Copper Cholinesterase	Laboratory used		Bilirubin Nitrites	Mucous filaments	N, P, K, Ca, Mg, S, Na B, Cu, Fe. Mn, Mo, Zn		

APPENDIX XV

Cheetah Conservation Fund Data Fields

Daily Cheetah Log

Transponder number:	None
Studbook Number:	8798
General info:	Found on the side of the road by a farmer - skin and bones

DATE	DIET	FEEDING METHOD	RUN	MOVED	MEDS / SYMPTOMS	Heat Cycle	BEHAVIOUR	**GENERAL**
7-Feb-09	Donkey	chopped meat	No	Arrived at CCF	Took bloods	-	Scared but quiet	Picked up by Laurie and Jenny from a farm, brought to CCF in a very poor condition - malnourished and extremely thin.

APPENDIX XV
Cheetah Data Fields
CCF Master Cheetah Database

Animal Data	Capture Data	Age	Health Exam	Identification	Teeth (cm)	Measurements		Blood analysis		Antibody levels
File #	Farmer	Age used	Physical Status	Name	Upper	Skull (cm)	Forelegs left / right (cm)	Na mmol/L	PCV %	Feline panleukopenia virus
Animal #	Farm	Cumulative age	Wounds	Tag #	Left	Length	Total	K mmol/L	MCV fl	Feline herpes virus
Animal #-visit	Farm #	Age Original	Coat	Tattoo #	Right	Width	Shoulder -elbo	Ca mmol/L	MCHC %	Feline corona virus
Exam no.	Region #	Age used	Hair Loss	Transponder	Lower	Body (cm)	Elbow-heel	Inorg Phos	Leuc. *10^9/L	Others
Date of exam	Date of capture original	Age group formula	Claws	Collar Freq.	Left	Length	Hind legs left/right (cm)	Urea	Platelets * 1000	Anesthesia
Reason for exam	Date of capture used	Low End Range	Pads	Sample Data	Right	Girth	Total	Creatinine	Neutr. %	Drug
Fate	Days Cptv. Original	Low end range formula	Cheetah flies, lice, ticks	Blood	Upper Pre-molars	Neck girth	Hip - knee	Bilirubin	Band %	Anesthesia comments
Date of Release	=Days Cptv used+P4	Mid Range	Date of vaccine	Skin	Left #	Chest girth	Knee - heel	Total Protein	Lymph %	Comments - other conditions
Necropsy	Day capt formula	Mid range formula	Vaccination	Fecal	Right #	Abdomen girth	Front feet left/right (cm)	Albumin	Mono. %	Final fate
Necropsy date	Copied formula	Diet	Cat's temperature *(F)*		Left *1,2,3*	Body length	Length	Globulins	Eosin. % Baso. %	Necropsy Y/N
Date of death	First cptr?	Food given	Gross necropsy report		Right *1,2,3*	Tail length	Width	Amylase	Erythro. *10^12/l	More comments
Sex	Re-caught?	Amt given (kg)	Histopathology report		Perforated yes =y, no = n	Overall body + tail length		Glucose	Neutr. *10^9/L	Tissue measurement
Weight (kg)	Re-exam?	Last fed *hours ago*	Linda's assession no.		Missing? *1=yes*	Testicles		Chloride	Band *10^9/L	Left/Right kidney (cm)
	Captr-cage?	Meat type	Comments		Broken? *1=yes*	Lft length/width		AST	Lymph. *10^9/L	Length
	# Oth anmls cght	CA supplement			Crowded? *1=yes*	Rt ength/width		GGT, CK	Mono. *10^9/L	Width
	# Other animals in wild	Total Diet			Tartar? *1=yes* Yellow? 1=yes			Hem. g/dl	Eosin. *10^9/L Baso. *10^9/L	Blood smear

Ectoparasite Inventory
Date
AJU number (cheetah)
No of jars/cat
Box number

Cheetah Skeletal Bones
AJU number
Sex
Skull Y/N
Radio Collar #
Ear Tag #
Blood Freezer Bag #
Tissues: Box #
Tissues: Bag #
Blood Slides: Box #
Age at Death (mo)
Date of Death
Necropsy
Premolar
Cause of Death
Animal History
Farm where killed
Farmer
Region
Captures
Date of 1st, 2nd,…capture
Additional notes
One spreadsheet / cheetah

Endoparasite Inventory
AJU number (cheetah)
Date
Species (host)
Bag #
Comments (type of parasite)

Cytology and Blood Slide Inventory
Box #
Slide #
AJU #
Name
Sex
Date
Comments (type of sample)
One spreadsheet/Box

Gastric Biopsy Samples Tank#
AJU #
Sample type
Cane name
Bucket #

Scat Database
AJU #
Date collected
Location (where found)
Comments
Have we found them? Y/N
Location of the sample (CCF)

Hair Inventory
Date
ID number (cheetah)
No of envelopes/cat
Box number

Semen Collection	
Date	Total sperm volume
Species	Raw concentration
AJU #	Total sperm
Institution	Total motile sperm
Clinicians	Motility
Fraction I Volume (ul)	Status
Fraction I Motility (*%)	pH
Fraction I Status	# of straws frozen
Fraction I pH	Concentration frozen
Fraction I opacity/color	Volume of straws
Squares counted	Cane label (GRB #)
Sperm count	

CCF Biosamples Database

Appendix XV (continued)

Appendix XV (continued)

Cheetah Conservation Fund Necropsy Database

Necropsy Database				
Accession	Present (Y/N, NA or *Text)			
Type	Central hemorrhage	Splenic Lymphoid Depletion	Myelolipma liver	FIP
SSP Path Evaluated Y/N	Amyloid liver	Adrenal Cortical Hyperplasia	Other neoplasia	FIP Titer
Studbook	Telanangiectasia	Lung Foam Cell Foci	Vacuolar Neuropathy	FHV1
AJU #	*Other Liver Diagnosis 1	Pneumonia	Leukoencephalopathy	Parvovirus
ISIS	*Other Liver Diagnosis 2	Pleuritis	Myelopathy	Other virus
Name	Membranous GN	Parasitic Pneumon ia	Endometrial hyperplasia	Sarco
Origin	*Glomerulosclerosis Grade	Myocarditis	Cystic Wolffian duct remant	*Other Parasite 1
Zoo/Site	Amyloid kid	Cardiac fibrosis	Testis degeneration	*Other Parasite 2
Africa Y/N	Papillary necrosis	Vascular disease	Spermatogenic Arrest	Bacteria
Age	Oxalate Nephrosis	Enteritis	Other Repro Diagnosis 1	Cryptococcus
Sex	*Other Renal Disease 1	Colitis	Skin Diagnosis	*Other fungus
Days Captive	*Other Renal Disease 2	Pancreatitis	*Other Diagnosis 1	
Weight	Oral ulc	Pancreatic Duct Ectasia	*Other Diagnosis 2	
Fertility	Gastritis	Pancreatic necrosis	*Other Diagnosis 3	
History	Helicobacter	Pancreatic Atrophy	*Other Diagnosis 4	
Gross Necropsy Findings	Gastric Mycoplasma	Pancreatic nodular hyperplasia	*Other Diagnosis 5	
Cause of Death	Gastric Atrophy	Myelolipoma spleen	Infectious Disease	

Appendix XV (continued)

CCF Cheetah Release						
Release group number	Track age	Stand	Weight	Drink	Direction	Pacing the fenceline
Cheetah	Fresh Kill	Run	Chase Distance (m)	Drinking Location	Wind	Distance from fence in m.
Waypoints	Vegetation	Climb	Time spent eating in minutes	Drinking location (GPS)	Weather conditions	Lay on road
Day of freedom	Activity	Rest spot	Who Killed	Water provided or found on own	Temperature	Escape
Time	Food Provided	GPS Distance (m) from last fix	Vegetation type where hunted	Play Tree	Vocalization	Distance from Cheetah (m)
Day	Species fed	Movement direction	Successful kill	Area Marked	Vocalising Notes	Aggression
Month	Amount (kgs)	Wind direction	Parts eaten?	Tree Species	Laying on each other	Aggression Notes
Year	Feeding Notes	Hunt	Drink	Marking Type	Laying apart (m)	Observer(s) Initials
Y-coordinates	Walk	Species hunted	Drinking Location	Rest Area	Grooming	General Notes
X-coordinates	Lie, not alert	Other Species	Drinking location (GPS)	Chirp, m.apart	Grooming Notes	
Encounter	Lie, alert	Age	Water provided or found on own	Who calls who	Pacing the fenceline	
Scat Fresh	Sit	Gender	Play Tree	Approachability (m)	Distance from fence (m)	

APPENDIX XV - CCF FEEDING AND RADIO-TRACKING DATABASES

Individual #
Name
Sex
Arrival
Departure

Feeding Log		
Date	Run	Pen #
Time of day	Anesthesia	Pen Classification
Meat	Anesthesia Drug	In/Out
Kg	Why Anesthetized	Neighbor Change
Organ Meat	To Vet for Treatment	New Neighbor
Cheetah Supplement	Deworm	ID
Calcium supplement	Sick	Neighbor Group Size (total in complex)
FeliVit	Injured	Group Change In
Protein	Medicines	Group Change Out
Predator Supp.	Pen Change	Group Size
Ate	Complex #	

Radio-tracking			
Animal code	Game Comments	PLENGTH	Age in months at 1st collaring
New Fixes	Livestock	movement per day	Age in Days
ID number	Livestock Comments	Season1	Age in months
Date	Homestead	Season2	# cats
Latitude	Homestead Comments	Date	Bush code
Longitude	Visual	days_btwn_fix	Animal Num
Regflt	Visual Comments	ID number	General Comments

APPENDIX XVI

Giant Armadillo Data Fields

Biometrics	
Head Circumference	Body length s / a (dorsal) tail
head length	Total length (dorsal)
Distance between the eyes	Total length of the tail
Length of ears	Carapace length
Width of ears	Carapace width
Neck Circumference	Length anterior leg
Chest circumference	Length hindpaw
Circumference of the abdomen	Length of jaws
Body length s / a (ventral) tail	Length of the penis / clitoris
Total length (ventral)	Girth

Containment & Clinical Evaluation	
Date	Transmitter: implant, external VHF, GPS/VHF
Location	Drug / Concentration mg/kg
Geographical position	Dose (ml)
Species	Method
Sex: Male or Female	Time
Age: Adult - Sub-adult - cub	Respiration rate
Weight - dose estimate	Heart rate
Real dose	Oxygen saturation
Body condition: Emaciated, thin, good, obese	Capillary refill time
Apparent health: Good, moderate, poor, risk of death	Muscle relaxed (no, mild, incomplete complete)
Capture technique: trap, manual	Respiratory type (costal, abdominal, costoabdominal, surface, deep).

Sample Analysis	
Species	Erythrocytes
Name	Hematocrit
Transponder	Hemoglobin
Animal ID (name, #)	MCHC
Day (capture)	MCV%
Gender	Total protein
Kind of sample	Leukocyte
Sample location	Morphology
Sent to	Metamyelocytes
Date sent	Eosinophils
Who sent the sample?	Basophils
Results	Lymphocytes
Comments	Monocytes
	Hemoparasites

Burrow Measurements	
Date	Type of excavation
Location (GPS)	New/old
Height	Temperature (outside)
Width	Temperature (inside)
Depth	Use by other species (identify)
Orientation of hole	Slope

APPENDIX XVII
ZIMS Data Fields

Institution Organization	Individual Record	Reproduction/Breeding Management	Behavior
Institution Statistics	Taxonomy	Studbook ID	Social behavior
Animal Census	Birth/Hatch Date	Introduction date	Aggression
Number of species	Captive/Wild born	Copulation dates	Reproductive
Staff Statistics	Parentage	Egg log	Parturition
Birth count/last 12 months	Sex/Rearing	Egg lay or Parturition date	Stereotypic
Number of animals available/wanted	Acquisition/Disposition Terms	Parturition behavior	Interspecific
Staff Organization	Birth Institution	Number of eggs or neonates	Predatory
Teams/Departments	Collection location	Survival of neonates	Feeding
Staff Roles (access)	Holding institution	Parental care	Husbandry
Institution Collections	Individual identifiers	Contraception	Enclosure requirements
Main collection	Transponder inventory	Enclosure/Environment	Diet/Feeding log
Education collection	Life stages	Animals present	Social grouping
Rescue/Rehabilitation	Receiving institution	Animal moves	Reproduction
Research/Wild	Death date	Location in institution (GPS)	Incubation
Quarantine/Confiscation	Media - photos, video, audio files	Measurements	Rearing
Permits	Group Record	Substrates/Furniture	Training Log
CITES	Census	Life Suppport System	Behavioral enrichment
Marine Mammal Permit	Sex ratio	Water quality	Human interaction
National Endangered Species	Parentage	Temperature	Medical Modules
Exhibitor	Splits and merges	Health	Anesthesia records
Collecting	Animal/Enclosure Alerts	Morphometrics	Treatments/Prescriptions
Reports	Maintenance - routine	Body condition	Pharmacy Inventory
Specimen Report	Maintenance - issues	Immunizations	Samples
Taxon Report	Reproductive due dates	Parasite checks	Tests and Results
Inventory Report	Prescription duration	Illness/Injury	Physiological measurements
Population Overview Report Physiological Values Report	Medical procedures Treatments	Media-x-rays, photos, ultrasound	Clinical notes Diagnoses and procedures
Enclosure Report	Husbandry alerts	Necropsy Medical terms dictionary	Reports - medical history, anesthesia summaries, test results/ unresolved medical issues

APPENDIX XVIII

***ZIMS for Medical* Release includes the following features:**
From http://www2.isis.org/support/*ZIMS* /Pages/*ZIMS* %20Release%20Notes.aspx#2.0

Health status
A log of the changes in health status of an animal over time
Body Condition Score
A log of the changes in the standardized body condition score of an animal over time
Anesthesia
A record of the drugs given, the effects produced, and the outcome of an anesthesia event with linkages to samples collected and physiological measurements made during the event
Treatment and Prescriptions
Standardized orders for medical care; linked to dispensing and administration records
Pharmacy Inventory
This module gives users the ability to track the pharmaceuticals used at your institution; especially useful for controlled drug compliance.
Samples
A record of the samples collected and the subsamples produced with linkages to tests performed on that sample
Tests & Results
The tests performed on a sample and the outcome/result of that test
Physiological measurements
The heart rate, respiratory rate, body temperature and similar measurements routinely collected during an anesthesia event or while an animal is awake; values can be graphed to show changes over time
Clinical notes
The free-text portion of the medical record of an animal; supports the SOAP format
Diagnoses & Procedures
The standardized list of clinical signs, clinical findings, major procedures, medical conditions, diseases and issues experienced by an animal during its lifetime
Incomplete Accessions
Staff can be given the ability to do an incomplete accession to get an animal in the system when medical records, notes, or other information needs to be captured and the animal has not yet been fully accessioned. Users will have the ability to match these incomplete accessions up with fully accessioned animals so that the information can be moved to the permanent animal record.

Infrastructure

Providing support in the integrated *ZIMS* platform for the management of medical records

Dashboard

The initial view of recent medical records; can be grouped and sorted by date or by animal and filtered by record type

Search panels

Allows filtered search of medical records to produce a customized view of the medical records

Medical term dictionary

Global and local lists of medical terms used to build standardized diagnoses; supports alternative languages and crowd-sourced translation

Treatment item dictionary

Global and local lists of drugs and other treatment items used to build standardized prescriptions; supports alternative languages and crowd-sourced translation

Test dictionary

Global list of tests that can be performed on samples; supports alternative languages and crowd-sourced translation

Note templates, Favorite Samples, Test Panels and Measurement Panels

A variety of tools to make medical data entry simpler, faster and more consistent

Reports

Complete Medical History

Anesthesia Summary Report

Samples/Tests/Results

Unresolved Medical Issues

APPENDIX XIX

ISIS Physiological Reference Intervals for Captive Wildlife - 2013
edited by J. Andrew Teare, DVM (Teare 2013)

Matschie's Tree Kangaroo (*Dendrolagus matschiei*)
Samples contributed by 33 institutions.

- **No selection by gender.**
- **All ages combined**
- **Animal was classified as healthy at the time of sample collection**
- **Sample was not deteriorated**

Physiological Reference Intervals for Dendrolagus matschiei

Test	Units	Reference Interval	Mean	Median	Low Sample[a]	High Sample[b]	Sample Size[c]	Animals[d]
White Blood Cell Count	*10^9 cells/L	1.91 - 8.71	4.35	3.90	0.70	11.80	342	107
Red Blood Cell Count	*10^12 cells/L	4.17 - 7.40	5.70	5.71	3.20	8.12	299	95
Hemoglobin	g/L	112 - 197	155	155	102	219	311	97
Hematocrit	L/L	0.325 - 0.578	0.449	0.451	0.260	0.660	384	112
MCV	fL	68.4 - 92.1	79.1	79.0	63.2	98.4	294	93
MCH	pg	23.2 - 32.1	27.2	27.1	21.5	34.7	296	94
MCHC	g/L	307 - 380	344	343	286	409	306	95
Segmented Neutrophils	*10^9 cells/L	0.61 - 4.40	1.92	1.72	0.02	5.49	340	107
Neutrophilic Band Cells	*10^9 cells/L	0.01 - 0.04	0.02	0.01	0.00	0.05	328	106
Lymphocytes	*10^9 cells/L	0.43 - 4.96	1.94	1.61	0.02	6.24	340	107
Monocytes	*10^6 cells/L	31 - 497	173	142	16	615	304	102
Eosinophils	*10^6 cells/L	30 - 594	182	139	6	720	300	99
Basophils	*10^6 cells/L	0 - 105	55	49	14	160	111	59
Platelet Count	*10^12 cells/L	0.000 - 0.358	0.166	0.148	0.011	0.505	101	47
Nucleated Red Blood Cells	/100 WBC	0 - 9	3	2	0	17	90	61

Matschie's Tree Kangaroo (*Dendrolagus matschiei*)

Test	Units	Reference Interval	Mean	Median	Low Sample[a]	High Sample[b]	Sample Size[c]	Animals[d]
Glucose	mmol/L	2.62 - 10.07	5.23	4.82	0.72	11.39	375	108
Blood Urea Nitrogen	mmol/L	5.0 - 12.7	8.6	8.5	3.6	13.9	374	110
Creatinine	µmol/L	53 - 154	97	97	27	186	368	110
BUN/Cr ratio		11.3 - 40.4	23.1	22.0	3.0	53.8	366	109
Uric Acid	µmol/L	0 - 74	32	26	0	107	78	36
Calcium	mmol/L	1.87 - 2.57	2.19	2.17	1.55	2.93	367	109
Phosphorus	mmol/L	0.90 - 3.44	1.99	2.01	0.45	4.62	350	107
Ca/Phos ratio		0.7 - 3.1	1.6	1.4	0.6	3.9	343	107
Sodium	mmol/L	132 - 149	140	139	123	156	332	101
Potassium	mmol/L	3.2 - 6.3	4.6	4.5	2.3	7.3	330	101
Na/K ratio		20.7 - 42.3	31.1	30.7	11.4	45.9	331	101
Chloride	mmol/L	93 - 110	102	102	85	113	313	98
Total Protein	g/L	53 - 84	67	66	47	95	351	108
Albumin	g/L	35 - 59	45	45	23	64	349	110
Globulin	g/L	6 - 40	21	22	2	50	336	104
Alkaline Phosphatase	U/L	215 - 1707	636	493	106	1940	324	103
Lactate Dehydrogenase	U/L	175 - 1032	411	321	162	1142	124	53
Aspartate Aminotransferase	U/L	13 - 107	44	36	5	128	323	103
Alanine Aminotransferase	U/L	0 - 20	7	5	0	25	301	101
Creatine Kinase	U/L	18 - 571	155	109	3	653	219	79
Gamma-glutamyltransferase	U/L	16 - 173	62	49	8	203	265	87
Amylase	U/L	3 - 49	18	15	0	61	137	66
Lipase	U/L	0 - 38	15	12	0	72	60	32
Total Bilirubin	µmol/L	0.0 - 8.3	2.5	1.7	0.0	15.4	297	97
Direct Bilirubin	µmol/L	0.0 - 3.4	0.7	0.3	0.0	5.1	78	36
Indirect Bilirubin	µmol/L	0.0 - 3.7	1.4	1.3	0.0	5.1	61	28
Cholesterol	mmol/L	2.02 - 6.65	3.86	3.68	0.31	8.44	321	101
Triglyceride	mmol/L	0.20 - 1.48	0.61	0.53	0.04	1.75	132	51
Bicarbonate	mmol/L	11.0 - 31.6	21.3	21.3	10.0	33.0	50	20
Magnesium	mmol/L	0.213 - 1.356	0.775	0.785	0.251	1.603	49	26
Carbon Dioxide	mmol/L	9.5 - 32.1	21.6	21.8	8.0	37.0	126	50
Test	Units	Reference Interval	Mean	Median	Low Sample[a]	High Sample[b]	Sample Size[c]	Animals[d]
Body Temperature	C	33.7 - 38.6	36.3	36.4	33.4	39.8	144	65

[a] Lowest sample value used to calculate the reference interval. [b] Highest sample value used to calculate interval.

[c] Number of samples used to calculate the reference interval. [d] Number of different contributing individuals.

BIOGRAPHY

Karin R. Schwartz was born in Wisconsin and grew up in St. Louis, MO. Karin earned a Bachelor's Degree in Biology from the University of Missouri, Columbia in 1978, and a Masters of Science Degree in Animal Behavior with a specialty in olfactory communication from the University of Missouri, St. Louis in 1986. During her course work for her undergraduate degree, she worked as a zookeeper at the St. Louis Zoo. This led to a 17 year career as Registrar at the Milwaukee County Zoo. She then spent 3 years as Biological Database Manager in the Conservation Science Department at Brookfield Zoo before leaving the zoo community to concentrate on finishing her Ph.D.

Karin was an active member of the Zoo Registrar Association and served as Chair of the Training Committee from 1995 through 2008. She initiated and led the development of the Association of Zoos and Aquariums (AZA) Institutional Records-Keeping (IRK) Course in 1998 and continues to serve as a Co-administrator. The IRK course is a core course in the Masters Degree program in Zoo Leadership through George Mason University. She was on the Steering Committee for the Association of Zoos and Aquariums (AZA) Institutional Data Management Advisory Group and currently serves as Registrar Advisor to the Cheetah Species Survival Program (SSP), Tree Kangaroo SSP, Monotreme and Marsupial Taxon Advisory Group (TAG) and Tapir TAG. Karin has served on the International Species Information System Scientific and Technology Advisory Committee (ISIS STAC) and chaired the ISIS STAC Animal Data Standards Subcommittee. This led to involvement in Conservation Breeding Specialist Group (CBSG) meetings in Australia, Austria, Costa Rica, Taiwan, Hungary, Germany, and Czech Republic. Other international experience includes presentation of records training sessions in Ecuador, Argentina, India, and South Korea. She has participated in global conservation efforts as an active member of the IUCN/Species Survival Commission (SSC) Tapir Specialist Group as well as the IUCN/SSC Reintroduction Specialist Group. She earned her Doctoral Degree at the Department of Environmental Science and Policy at George Mason University in the fall semester of 2014.