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Introduction to Reptile Conservation

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Reptiles are a very diverse group with a long evolutionary history dating back 300 million years to the Pennsylvanian subsystem of the Carboniferous period (Hedges & Poling, 1999; Sahney *et al*., 2010). Reptiles have adapted to a variety of habitats in environments ranging from temperate to hot and moist to arid. Compared with birds and mammals, reptiles often have very restricted distributions with specific microhabitat requirements; making them particularly vulnerable to anthropogenic environmental changes (Anderson, 1984; Anderson & Marcus, 1992). As such, reptiles are a group of conservation concern. Of the 10 038 described species listed in *The Reptile Database* (Uetz & Hošek, 2014), 44% (*c.* 4416 species) have been evaluated for the International Union for Conservation of Nature's (IUCN) *The IUCN Red List of Threatened Species* (IUCN, 2014). Furthermore, there are 964 reptile species listed in the IUCN Red List Extinct, Extinct in the Wild, Critically Endangered (CR), Endangered and Vulnerable (VU) categories, which is 9·6% of the species listed in *The Reptile Database*. Nearly the same amount [8·7% (811 reptile species)] is listed as Data Deficient (IUCN, 2014), making it obvious that there are still many gaps in our knowledge. Reptiles constitute a small proportion [11% (*c.* 435 species)] of the 3955 (in 2011) non-domestic terrestrial vertebrate species maintained by zoological facilities reporting to International Species Information System (Conde *et al*., 2013). Of the 964 threatened reptiles listed in the IUCN Red List, 178 species (18·4%) are actually kept by zoos and aquariums but, considering that relatively small total number, *c.* 40% of all reptile species maintained by zoological facilities are threatened (Conde *et al*., 2013).

While there are species-specific threats, there are several common factors that imperil all reptiles, including habitat alteration/destruction, pollution, over-collection and introduced species (Gibbons *et al*., 2000; Todd *et al*., 2010). Additionally, climate change is a recognized factor threatening reptile populations (Parmesan & Yohe, 2003; Stanton *et al*., 2015). For many taxa, temperature is important not only to the success of egg incubation but also for sex determination (Janzen, 1994); therefore, increasing global temperatures may have a detrimental impact on large numbers of reptile populations.

Despite the threats reptiles are facing globally, the number of known species is still increasing. In 2014, *The Reptile Database* contained more than 10 000 species, including 139 species described that same year (see http://www.reptile-database.org/db-info/news.html; Uetz & Hošek, 2014). Many species are newly described in scientific articles. Zoological facilities make a valuable contribution to this science by participating in, supporting and/or conducting biodiversity research. In Phong Nha-Ke Bang National Park in central Vietnam, 13 new reptile taxa were described between 2002 and 2010 (Ziegler, 2010). Thorough investigation of these poorly accessible areas resulted in the discovery of species that are new to the scientific world. Often, these are cryptic species

complexes that look alike and it is only by using new techniques, most often based on molecular investigations, that we are able to differentiate between the species (Hebert *et al*., 2003; Goldstein & DeSalle, 2010; Ziegler, 2015). Cryptic species complexes also occur in larger species, such as the VU African dwarf crocodile *Osteolaemus tetraspis* (IUCN, 2014; Schmidt *et al*., 2015). It is essential to carry out basic research in systematics and biodiversity, although the results may well have consequences for zoological facilities running conservation-breeding programmes, especially in relation to whether to manage such programmes by forming several taxonomically pure subpopulations or by continuing to include hybrids in the breeding programme.

While new reptile species await discovery and description, many aspects of their biology and ecology remain the subject of future research. The success of conservation-breeding programmes for reptiles depends on the consideration of all aspects of their biology. For *ex situ* programmes, it is essential to consider the natural history of the species in order to optimize husbandry conditions and increase breeding results. The projects carried out by Cologne Zoo, Germany, in South East Asia are excellent examples of a holistic approach. They not only include basic research on biodiversity, with the description of newly discovered species, but also ecological studies of the animals in their natural habitat. Based on this knowledge, conclusions are drawn for the management of reptiles at Cologne Zoo and other zoological facilities, and the concurrent development of conservation projects in the range countries (Ziegler, 2015). Similarly, a decade has been dedicated to studying the spatial ecology, genetic diversity and natural history of rare vipers in Armenia: the Near Threatened Armenian viper *Montivipera raddei*, the CR Darevsky's viper *Pelias darevskii* and VU Armenian Steppe viper *Pelias eriwanensis* (IUCN, 2014; Ettling *et al*., 2015). Based on the results of this work, a conservation breeding centre for endemic reptiles and amphibians is being developed near Yerevan, Armenia, where these rare vipers can be bred and used to augment existing wild populations. The results of the field studies have also been used to expand and/or establish new protected areas for these snakes.

The *International Zoo Yearbook* has dedicated three previous volumes to reptiles. The first was published in 1969 (Volume 9, also including amphibians) and the second in 1979 (Volume 19), and these focused mainly on breeding reports and husbandry for many reptile species that rarely reproduced in zoos and aquariums at that time. Today, some of these species breed regularly in zoological facilities while others still remain difficult to propagate under artificial conditions. In 1989, a third volume (Volume 28) was dedicated to reptiles (although it also included amphibians). Again, the focus was primarily on collection management in zoological facilities with a special emphasis on breeding success in selected species. However, in Volume 28, there was an article on Operation Curieuse, a conservation programme for the Aldabra giant tortoise *Geochelone gigantea* in the Republic of Seychelles (Spratt, 1989). This conservation project took place within the range country without a counterpart programme in a zoo. When comparing the articles that appeared in the previous three volumes with those that appear here in Volume 49, it becomes readily apparent that the herpetological specialism has developed a variety of methods to link work in zoos and aquariums with conservation programmes being carried out in the field. These two approaches, regarded as distinct in the past, will be blurred in the future (Pritchard *et al*., 2012). More recently, the IUCN Species Survival Commission Conservation Breeding Specialist Group adopted the One Plan Approach, which promotes cooperation between *ex situ* (zoological) institutions and *in situ* (range-country) stakeholders in order to manage all populations of species using unified, integrated plans (Byers *et al*., 2013). The maintenance and breeding of rare reptiles are no longer a primary goal for zoological facilities. The ultimate goal is to support

the conservation of reptiles in their wild, natural habitats, and various means by which to achieve those goals are reported within Volume 49 of the *International Zoo Yearbook*.

The successful breeding of the CR Northern river terrapin *Batagur baska* at Vienna Zoo, Austria, is described alongside details of the Zoo's involvement in Project Batagur and breeding the species successfully within Bangladesh (IUCN, 2014; Weissenbacher *et al*., 2015). The Northern river terrapin is a large, aquatic freshwater turtle, while the Egyptian tortoise *Testudo kleinmanni* is one of the world's smallest, terrestrial tortoises, which is classified as CR as a result of habitat destruction and collection for the pet trade (IUCN, 2014; Zwartepoorte, 2015). A successful breeding programme for the Egyptian tortoise in Europe, including the contribution of private hobbyists, who commit time, money and effort, and have a great deal of knowledge and personal commitment, as well as the conservation measures in place to protect the species in Egypt are described (Zwartepoorte, 2015). One of the greatest challenges for all conservation programmes is space. For reptiles, cooperation between zoological facilities and private hobbyists could alleviate some of this problem; either by providing facilities for breeding groups (Zwartepoorte, 2015) or by housing non-breeding individuals so space can be released in zoos and aquariums for breeding-programme animals.

Another theme that runs through the Reptile Conservation section of Volume 49 is the fact that for field-conservation programmes to be successful, it is important to integrate local people who live within the range of the threatened species into the projects. For example, by delegating data-collection tasks to local Bedouins, and running training, education and awareness programmes for the Sweiriki people, the Egyptian tortoise recovery programme fully integrates the local community in its work (Zwartepoorte, 2015). However, involving the local community in conservation programmes can be challenging, especially when dealing with potentially dangerous and often misjudged species, such as crocodilians, which are hunted in many regions of the world. This can make it difficult to establish a conservation project in the range countries. The CR Philippine crocodile *Crocodylus mindorensis* is bred for release purposes in several locations in its natural range (IUCN, 2014; Manalo & Alcala, 2015), and successful breeding programmes exist both in North America and Europe. However, an intensive programme of public awareness, information campaigns, community empowerment and capacity building has been necessary to protect the Philippine crocodile from poaching or killing after human–wildlife conflicts in its natural range. Similar public-awareness campaigns and capacity-building measures have been used to involve local communities in the conservation of the VU Komodo dragon *Varanus komodoensis* in Flores (IUCN, 2014; Ariefiandy *et al*., 2015), the Aruba Island rattlesnake *Crotalus unicolor* [IUCN, 2014: Least Concern (LC)] (Odum & Reinert, 2015) and the VU Hungarian meadow viper *Vipera ursinii rakosiensis* (IUCN, 2014; Péchy *et al*., 2015).

The Aruba Island rattlesnake Species Survival Plan (Odum & Reinert, 2015) and West Indian iguana *Cyclura* spp reintroduction and recovery programmes (Grant & Hudson, 2015) are two examples of long-term (30+ years) reptile conservation commitments by zoos. Both programmes have benefited these threatened insular reptiles by using a combination of *ex situ* and *in situ* components. In addition to maintaining populations in zoos and aquariums, zoological facilities have also provided valuable contributions to the field-research effort in terms of funding and expertise that have ultimately made significant differences for the conservation of these species.

Over many decades, the CR Indian Gharial *Gavialis gangeticus* has been one of the most recognizable examples of a successful release project for reptiles (IUCN, 2014). In the mid-1970s, populations of the Gharial dropped dramatically to a few hundred animals. The Indian government established

Project Crocodile primarily for head-starting thousands of animals for augmentation of remaining wild populations (Stevenson, 2015). In the late 1970s, one of the last Gharials at a European zoo was sent from Frankfurt Zoo, Germany, back to India to support this conservation project. Another population crash occurred in the late 1990s, indicating that the effectiveness of this release programme needed to be improved dramatically in order to persist. An overview of the decades of conservation efforts for the Indian Gharial is provided and concludes with perspectives for the future (Stevenson, 2015). The VU Sunda gharial *Tomistoma schlegelii* also poses complex challenges for breeding in zoological facilities, while studying their ecology in the wild is difficult owing to their shy and secretive nature, and the inaccessibility of their natural habitat (IUCN, 2014). A healthy population of Sunda gharial was discovered a few years ago in Lake Mesangat in Kalimantan, Borneo. Field studies at this location were supported by the Tomistoma Task Force of the IUCN Crocodile Specialist Group, branded as a World Association of Zoos and Aquariums conservation project and financially supported by many zoos (Stuebing *et al*., 2015). The same site also served as the location for a study on the autecology of the CR Siamese crocodile *Crocodylus siamensis* carried out by Cologne Zoo (IUCN, 2014; Stuebing *et al*., 2015; Ziegler, 2015). This is only one of several crocodilian conservation projects supported by the work of zoos and aquariums, and between 2009 and 2014, US$1 183 370 was contributed by zoological facilities solely to crocodilian projects (Adams *et al*., in press).

Financial support for the Komodo Survival Program has been provided by the European Association of Zoos and Aquaria, and participants of the European Endangered Species Programme for the VU Komodo dragon contribute towards the Wae Wuul protection programme on the Indonesian Island of Flores (Ariefiandy & Purwandana, 2013; G. Garcia, pers. comm.). External funding, channelled through the Balai Besar Konservasi Sumber Daya Alam, has been used to rebuild a ranger post, train local rangers on how to monitor animals and conduct an awareness campaign for local people (Ariefiandy *et al*., 2015).

Zoological facilities not only focus their attention on exotic reptile species but also, in some instances, to threatened species living in their own region. Research projects and conservation-management measures can be carried out within the grounds of a zoo. An example can be found at Prague Zoo in the Czech Republic, where a colony of the LC European Green lizard *Lacerta viridis* is regularly monitored (IUCN, 2014; Rehák, 2015). Habitat-modification and preservation measures have been used to ensure the species persists in this region. Similarly, a conservation programme for the Hungarian meadow viper is an example of a local project involving several collaborating entities (Péchy *et al*., 2015). The *ex situ* programme was initiated in 2004 with 16 adult vipers (collected between 2004 and 2008). By 2013, the number of vipers bred had reached *c.* 1700 individuals. The first release of 30 adult vipers occurred in 2010 and by 2013, 240 vipers had been released at three different sites (Péchy *et al*., 2015). Post-release monitoring indicated that breeding was taking place and 18 of the released females observed were gravid. Public education was a strong component of these successful conservation programmes (Péchy *et al*., 2015; Rehák, 2015).

In Volumes 19 and 28 of the *International Zoo Yearbook*, there were articles on the status of the CR Western Australian swamp tortoise *Pseudemydura umbrina* in captivity (IUCN, 2014). In the late 1970s, the situation was already serious with numbers of individuals in the wild ranging between 30 and 90 specimens. Perth Zoo, Australia, had 21 animals that bred and produced very low numbers of offspring (Spence *et al*., 1979). The situation became increasingly severe in the early 1980s with only 15–25 animals remaining in the wild and 17 animals at Perth Zoo, none of which had bred since 1980 (Kuchling & DeJose, 1989). Immediate action was required, including propagation and release programmes. Although still

classified as CR, the conservation measures taken during the late 1980s proved to be successful and the population recovered. One of the key elements to this success was the use of ultrasound scanning of adult females, which marked the first time that this technique had been used as a management tool to assess the reproductive status of a turtle (Kuchling, 1989). Since then, ultrasound has been used in various other chelonian species. This technique has not only enhanced our knowledge about the natural history of the Western swamp tortoise by revealing some little-studied or unknown traits but also contributed actively to the conservation of highly threatened species (Kuchling, 2015).

One of the most famous articles in the long history of the *International Zoo Yearbook* is certainly 'How to exhibit a bullfrog: a bedtime story for zoo men', written by William G. Conway (Conway, 1973) and well known to every zoo biologist. A crocodile museum that meets many of the criteria described in Conway's (1973) article was constructed in the 1990s at Zoológico Regional Miguel Álvarez del Toro in Tuxtla Gutierrez, Mexico. Luis Sigler, who was the responsible curator at that time, describes the development of the exhibit in detail (Sigler, 2015). This sort of paper follows a long tradition of the *International Zoo Yearbook* to publish articles describing developments in the education of visitors, including an article on exhibiting reptiles by Gans (1979) in Volume 19 and an investigation into improving visitor appreciation of reptiles using an innovative new 'behind-the-scenes' exhibit design at Dallas Zoo, TX, USA, in Volume 28 (Murphy & Mitchell, 1989).

Zoological facilities can make valuable contributions to the scientific understanding and conservation of reptiles. As many species have cryptic behaviour, zoos and aquariums have the unique opportunity to observe, record and publish information about the natural history and biology of reptiles. For example, zoos maintaining Komodo dragons have recently documented that the species can reproduce parthenogenetically (Watts *et al*., 2006). Many zoos and aquariums have solid reptile husbandry experience and associated breeding programmes, which are essential to maintaining assurance colonies that can be used for augmentation and reintroduction programmes in due course. This volume of the *International Zoo Yearbook* demonstrates with a few examples, albeit representing many others, that a number of conservation programmes have benefited not only from reptiles bred in zoological institutions but also from collective zoo knowledge, financial contributions, expertise, efforts and the commitment of staff.

We are confident that the contents of this volume clearly demonstrate the evolution of herpetology programmes in zoological institutions, with the movement away from large collections of occasionally breeding reptiles towards linked partnerships for the conservation of species in their natural habitats worldwide. Volume 49 of the *International Zoo Yearbook* provides examples of the links between zoological facilities and field-conservation programmes, lending support to the One Plan Approach (Byers *et al*., 2013). The world's zoos and aquariums are visited by more than 700 million people each year (http://www.waza.org), providing the perfect platform to educate visitors not only about the problems reptiles are facing in a rapidly changing world but also about the projects and programmes that have been developed to counter these threats.

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