Captive Breeding and Reintroduction of Amphibians as a Conservation Tool

by

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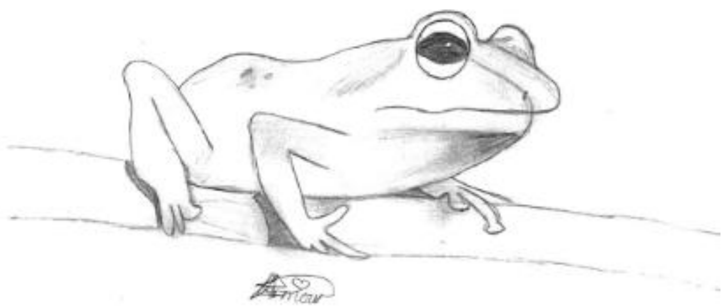

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Abstract

Recent figures show that over 30% of the world's amphibian species are considered to be threatened with extinction. As the current escalation in extinctions continue the number of species going into captive breeding programmes is likely to increase. The Amphibian Conservation Action Plan (ACAP) states that captive assurance colonies are the only hope for species at immediate risk of extinction. This study reviewed current amphibian captive breeding and reintroduction programmes to identify increases in programmes and changes in terms of threats, geographical regions and species status since the publication of the ACAP in 2007. A 30% increase in conservation breeding programmes has been observed since the ACAP. A significant increase was seen in species within programmes in Latin America with more than 60% of the programmes identified being from South America, Central America and the Caribbean. The numbers of Least Concern species in captive programmes have declined since the ACAP, while Critically Endangered species increased by 20%. Habitat loss remained the largest threat to species within these programmes. These factors indicate that the ex situ recommendations made within the ACAP are beginning to influence the types of conservation methods being used to combat amphibian declines. Sixty-two amphibian reintroduction programmes were assessed against ten reintroduction criteria in order to understand how compliant they are with current guidelines. All species in programmes were of conservation importance locally, regionally or globally, so complied with the criterion relating to threats. However, fewer programmes met the criteria relating to the establishment of viable populations and adequate resources. Reintroduction programmes of longer duration and higher success were shown to meet reintroduction criteria more completely indicating that a programme needs to run for around 15 years or more in order to show a high level of success. Key measures to help ensure ex situ conservation is carried out for the right reasons and to the highest standard are identified. These include implementing conservation management through evidence-based theory and undertaking reintroductions in line with published criteria and recommendations.

Keywords: translocation, amphibian decline, frog, toad, ex situ conservation, captive assurance, guidelines.

Acknowledgments

Firstly, I would like to thank my supervisor Richard Griffiths for his patience, support and sense of humour throughout my MSc.

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Biodiversity Crisis

Climate change and habitat loss are having a significant impact upon the world's species and ecosystems (Pounds et al. 2006; Bellard et al. 2012). Based upon the IUCN Red List almost one-fifth of existing vertebrates are classified as threatened (Hoffmann et al. 2010). Although threats are affecting a range of species, amphibians are likely to be the only major group currently at risk on a global scale (Wake & Vredenburg 2008). With recent figures showing that over 30% of the world's amphibian species are threatened with extinction (Bishop et al. 2012).

As habitats and species become more threatened the need for conservation intervention increases (Ewen et al. 2012). Conservation management options extend to a wide variety of measures and techniques including habitat management and protection, supplementary feeding, creation of nature reserves and more intensive methods such as captive breeding and reintroduction (Rahbeck 1993; Caughley 1994; Conde et al. 2013). As the current escalation in extinctions continue the number of species going into captive breeding programmes is likely to increase (Conde et al. 2013). Captive breeding and reintroduction for conservation is a reasonably new concept but one that has been increasing as a conservation management tool over the past few decades (Ewen et al. 2012; Seddon et al. 2014).

Captive breeding and reintroduction

The first known captive breeding and reintroduction project with conservation as a goal was that of the American bison *Bison bison* implemented by the Bronx Zoo in 1907 (Seddon et al. 2007). Other successful pioneering projects include the translocation of the North Island Saddleback *Philesturnus rufusater* in New Zealand in 1964 (Parker 2008) and the captive breeding and reintroduction of the Arabian Oryx *Oryx leucoryx* in

Oman in 1982 (Stanley Price, 1989). In 1988, following the emergent use of reintroduction, a Reintroduction Specialist Group (RSG) was formed by the IUCN in order to facilitate the planning and monitoring of reintroduction projects. This group also helped to develop the first IUCN reintroduction guidelines which were published in 1998 (Ewen et al. 2012).

The first review of species reintroduction was undertaken by Griffith et al. (1989). This was concerned primarily with mammalian and avian translocations and identified good quality habitat and the ability to identify and control limiting factors as key aspects for generating reintroduction success. Additional studies have shown that reintroductions were more likely to succeed when the source population was derived from wild stock rather than captive bred (Fischer & Lindenmayer 2000). Long term research, monitoring and data recording are also considered crucial for identifying successes and reasons for failure (Griffith et al. 1989; Sarrazin & Barbault 1996; Fischer & Lindenmayer 2000; Dodd 2005; Seddon et al. 2007).

The first explicit discussions of amphibian reintroductions were published in a series of papers in Herpetologica in 1991. Dodd and Seigel (1991) deemed amphibian reintroductions to be largely unsuccessful and questioned the effectiveness and theory underpinning reintroduction. They emphasised that understanding causes of decline, biological constraints, population genetics, social structure and disease transmissions along with the implementation of long term monitoring can increase reintroduction success. Further publications such as that by Bloxam and Tonge (1995) discussed the suitability of amphibians as candidates for captive breeding and reintroduction programmes. They suggest that due to their high fecundity and limited behavioural problems amphibians make good candidates for captive breeding but that there are risks involved with the release of captive stock in relation to genetics and the spread of pathogens. Additional reviews by Seigel and Dodd (Seigel & Dodd 2002) and Dodd (2005) question the advocacy of reintroduction (in reference to Marsh & Trenham 2001) along with reliability of the determinants of reintroduction success. Later reviews include those by Griffiths and Pavajeau (2008) and Germano and Bishop (2009), describe an increase in the success of amphibian reintroductions along with the need for further improvement in research and practice.

Definitions

The IUCN definition of reintroduction is: 'the intentional movement and release of an organism inside its indigenous range from which it has disappeared' (2013, p3). The IUCN 2013 *Guidelines for Reintroductions and Other Conservation Translocations* also define other aspects of population restoration such as reinforcement and conservation introductions including assisted colonisation and ecological replacement (IUCN/SSC 2013). Within these terms a conservation translocation is defined as:

> The intentional movement and release of a living organism where the primary objective is a conservation benefit: this will usually comprise improving the conservation status of the focal species locally or globally, and/or restoring natural ecosystems functions or processes (2013, p2).

Translocations and reintroductions are also undertaken for reasons other than conservation. These often relate to the removal of pest species, accidental/intentional releases of wild and captive bred species (Soorae & Launay 2008) and the translocation of a species or population in order to make way for development. In more affluent countries amphibians can also be the subject of informal translocations by pond owners via the exchange of frog and toad spawn or the accidental translocation of newt eggs via aquatic plants. This study however, and the IUCN guidelines are primarily concerned with reintroductions relating to - and as an action of - species conservation.

Reintroduction is often a very lengthy, complex and expensive form of conservation management (Dodd & Seigel, 1991). A variety of factors including species biology, ecology, behaviour and disease, along with social and economic issues must be considered (Ewen et al. 2012) before proceeding with such a complex conservation measure.

Although captive breeding and reintroduction has been shown to contribute to conservation success (Stanley Price 1989; Griffiths & Pavajeau 2008; Germano & Bishop 2009; Ewen et al. 2012) it is often considered a tool best engaged to support in situ methods rather than being relied on as a standalone solution (Dodd & Seigel, 1991; Ebenhard, 1995). In situ conservation, in particular habitat protection, is considered to be one of the most important methods of preserving the world's biodiversity (Stuart et al. 2008; Woodhams et al. 2011). Whilst habitat loss remains the greatest threat to biodiversity; the threats associated with climate change are seen to be having an impact on certain amphibian populations (Young et al. 2001). The extinction rates of amphibians are, at present, exceeding those that would be expected from habitat loss alone (Pounds et al. 2006). Research by McCallum (2007) suggests that extinction rates for amphibians could be hundreds, if not thousands of times higher than those observed previously. Climate change has also been linked to the presence and spread of *Batrachochytrium dendrobatidis*, a recently discovered chytrid fungus thought to be responsible for the loss of numerous amphibian populations in recent decades (Young et al. 2001; Woodhams et al. 2011).

Amphibian declines and conservation

Following the reports of amphibian declines over recent decades, a Global Amphibian Assessment (GAA) was undertaken to establish the status of the world's amphibians (Stuart et al. 2004). The results of the GAA, published in 2004, considered 427 species to be Critically Endangered - the highest threat category on the IUCN Red List (Stuart et al. 2004). A review of the IUCN Red List in 2014, just ten years later, showed that there are now 482 species listed as Critically Endangered (AmphibiaWeb 2014). Figures from these reports show that proportionally amphibians are more threatened than mammals and birds (Hoffmann et al. 2010). Further research by Hoffman et al. (2010) found that between 1980 and 2004, 40 species of amphibian had declined in Red List status, nine species had vanished and a further 95 species were considered likely to have gone extinct.

With such high rates of decline coupled with disease and enigmatic threats, amphibian conservationists face an extremely difficult challenge in terms of the limited conservation measures they can apply. In 2005 an Amphibian Conservation Summit was held to discuss this challenge and its proceedings formed the Amphibian Conservation Action Plan (ACAP). This was published in 2007 and sets out a series of measures to arrest declines and prevent future losses (Gascon et al. 2007). One such measure is the implementation of captive breeding, for which the ACAP states may be the only hope for species at immediate risk of extinction (Stuart et al. 2004; Gascon et al. 2007).

Conservation translocations for amphibians can take place using three methods:

1. captive breeding and reintroduction;
2. head-starting: collecting spawn and raising tadpoles/ juveniles in controlled conditions to circumvent periods of high natural mortality before release; and
3. direct translocation of either eggs and/or individuals (tadpoles, juveniles or adults) from one site to another.

These methods are not necessarily hard-and-fast divisions and programmes may utilise only one, or embrace all three methods depending on the circumstances and requirements of the programme. Each of the techniques has differing benefits; the use of wild stock for direct translocation has often been praised as a more effective method of reintroduction (Griffith et al. 1989). Head-starting individuals has been deemed as a valuable technique as it can help avoid the high mortality of tadpoles and spawn often seen in the wild (IUCN/SSC 2013) and captive breeding of animals can be beneficial when the numbers of individuals left in the wild have reached a critically low point.

Aims and objectives

This study is intended to provide an update on the current use of captive breeding and reintroduction programmes within conservation since the publication of the ACAP in 2007. The study used past data collated by Griffiths and Pavajeau (2008), prior to the ACAP, to provide a comparative analysis. A further 62 reintroduction programmes were identified from within the data and analysed to determine how they met with ten key reintroduction criteria adapted from IUCN and other guidelines and recommendations. In particular, the thesis addresses two fundamental questions:

(1) Has there been an increase in amphibian captive breeding and reintroduction since the publication of the ACAP in 2007?
(2) How well are amphibian captive breeding and reintroduction programmes complying with current guidelines?

Captive Breeding and Reintroduction: How Far Have We Come Since the Amphibian Conservation Action Plan?

Abstract: *Following the publication of the Global Amphibian Assessment (GAA), an Amphibian Conservation summit was held to discuss ways to address the declines and implement conservation measures. The proceedings of the summit were published as the Amphibian Conservation Action Plan (ACAP) in 2007. The ACAP states that 'the only hope in the short-term for populations and species at immediate risk of extinction is immediate rescue for the establishment and management of captive survival-assurance colonies'. This study looked at how and if captive breeding and reintroduction programmes have been influenced by the objectives of the ACAP. The relative numbers of programmes within captive breeding only, captive breeding and reintroduction and reintroduction only categories have changed considerably since the ACAP. In particular, an increasing emphasis on captive breeding programmes was observed. This increase along with a 20% rise in Critically Endangered species within these programmes suggest that ex situ conservation measures outlined in ACAP may be having an impact on the numbers and types of conservation breeding programmes throughout the world.*

Introduction

Conservation breeding programmes are aimed at preventing species extinction through maintaining captive populations for release into the wild (Browne et al. 2011). Generally such programmes are focussed on mammals and birds and tend to include larger and more charismatic species (Balmford et al. 1996; Seddon et al. 2014). Although amphibians have been kept in zoos for decades, it was not until the late 1970's that the first zoo-based conservation breeding programme for an amphibian was established. This programme was for the Houston Toad *Bufo houstonensis*. A captive breeding colony was established at Houston Zoo and the first individuals were released into the wild in 1982 (Dodd & Seigel 1991; Bloxam & Tonge 1995).

Captive breeding programmes can be extremely complex and are often limited by: resources, husbandry methods, domestication and disease (Balmford et al. 1996). Despite these limitations amphibians are often considered suitable candidates for such programmes due to their relatively small body size, high fecundity and low maintenance (Bloxam & Tonge 1995; Griffiths & Pavajeau 2008; Griffiths & Kuzmin 2011). In spite of the traits that make amphibians attractive candidates for conservation breeding, it is only in the past twenty years or so that captive breeding and reintroduction has formed a significant part of amphibian conservation initiatives. This change largely came about after dramatic declines in amphibian populations around the world along with the subsequent discovery in 1998 of a new and deadly chytrid fungus known as *Batrachochytrium dendrobatidis* (referred to from here on as Bd) (Berger et al. 1998; Stuart et al. 2004; Mendelson et al. 2006; Conde et al. 2011).

Field biologists began noticing declines in amphibian populations as early as the 1960's (Dodd, 2005) and by the time of the First World Congress of Herpetology in 1989 these concerns were being voiced from around the globe ((Stuart et al. 2004; Bishop et al. 2012; Stuart 2012). In order to act upon these dramatic declines a Declining Amphibian Populations Task Force (DAPTF) was created by the IUCN Species Survival Commission (SSC) and in 2001 a Global Amphibian Assessment (GAA) was undertaken (Stuart et al. 2004). During the three year process of the GAA all 5743 amphibian species known to science at that time were assessed (Stuart et al. 2004). The outcome of the assessment, published in 2004, identified 427 species as Critically Endangered, 761 as Endangered and 668 as Vulnerable (based upon IUCN Red List criteria). The overall estimate considered at least 1,856 species to be threatened with extinction (Stuart et al. 2004). Following the publication of the GAA, an Amphibian Conservation summit was held to discuss ways to address the declines and implement conservation measures. The proceedings of the summit were published as the Amphibian Conservation Action Plan (ACAP) (Gascon et al. 2007). The ACAP outlines practical means of implementing conservation tasks and addressing the decline of the world's amphibians. The main actions proposed within the ACAP relate to safeguarding Key Biodiversity Areas and habitats, addressing climate change and disease and the use of captive breeding and reintroduction programmes (Gascon et al. 2007).

The ACAP states that 'the only hope in the short-term for populations and species at immediate risk of extinction is immediate rescue for the establishment and management of captive survival-assurance colonies' (Gascon et al. 2007, p36). In 2006 the Amphibian Ark (AArk) was formed and given the task of implementing these ex situ conservation measures for the world's most threatened amphibians. So far AArk has evaluated the conservation needs of 38% of the world's amphibian species through 23 workshops in various countries (Zippel et al. 2011).

In order to provide a clearer picture of the role of captive breeding and reintroduction programmes within amphibian conservation Griffiths and Pavajeau (2008) undertook a study to look at the numbers and trends in this area of conservation science. The study identified 110 programmes, running between 1966 and 2007. These programmes were separated into three categories: captive breeding only (CB), captive breeding and reintroduction (CB&R) and reintroduction only (R). The study identified 52 CB programmes (undertaken for conservation research or education with no reintroduction planned), 39 CB&R and 19 R only programmes. Of the 58 CB&R and R programmes 18 reintroduced species had bred in the wild and 13 were considered to have established self-sustaining populations. Threats for these species were also considered, with the study finding that only 18 of the 58 programmes faced threats that were considered to be reversible.

Since the study by Griffiths and Pavajeau (2008) the ACAP has been published and AArk have begun the implementation of its ex situ components and recommendations.

Aims

The main aim of this study is to assess the impact of captive breeding and reintroduction programmes within amphibian conservation since the ACAP's publication in 2007.

The main objectives of this study were:

1. To determine if the number of CB and R programmes has changed since the ACAP was launched and identify how many CB programmes have since progressed into reintroduction.
2. To establish the number of reintroduction programmes that have become successful or unsuccessful since the ACAP.
3. To determine the main changes in terms of: threats, countries, orders, Red List status and the reasons driving captive breeding and reintroduction programmes.
4. To understand why changes and trends have occurred and discuss recommendations for future captive breeding and conservation of amphibians.

Methods

The methods used to undertake this study were adapted from those undertaken by Griffiths and Pavajeau (2008).

Sources of data

In the Griffiths & Pavajeau (2008) study, data were assembled from a variety of sources, with the main source being the Global Amphibian Assessment (GAA). The GAA data have since been incorporated into the IUCN Red List and the book *Endangered Amphibians of the World* (Stuart et al. 2008). Both sources were utilised for this study.

Web searches were undertaken using the search terms: Introduction, translocation, repatriation, reintroduction or captive breeding, along with amphibian, frog, salamander, newt, toad or caecilian in all combinations. These searches were conducted in Web of Science, JSTOR and Google Scholar. Programmes where captive breeding and/or translocation was carried out for commercial or medical purposes or to resolve human wildlife conflict were not included within the data.

The following online databases were searched for reintroduction and captive breeding programmes:

- AmphibiaWeb http://amphibiaweb.org/ a valuable and up to date resource and links to the IUCN Red List page.
- IUCN Red List http://www.iucnredlist.org/ all the data from the GAA now forms part of the Red List.
- Amphibian Ark online databases have an extensive list of all the programmes they are involved in http://progress.amphibianark.org/progress-of-programs

In addition, the online publications FrogLog and Amphibian Ark Newsletter were searched with the keywords captive breeding, reintroduction and translocation.

A number of websites were visited in order to gain additional programme information and potential new programme information. These included key amphibian conservation sites such as Edge Amphibians http://www.edgeofexistence.org/amphibians/ and the Amphibian Specialist Group http://www.amphibians.org/publications/ along with the local government sites of the United States Fish and Wildlife Service http://ecos.fws.gov and individual zoo or institution websites.

A number of additional publications, including conference proceedings and books, were consulted and relevant information followed up by further journal and web searches for specific species data. Conference proceedings were located via the World Congress of Herpetology (WCH) and the Societas Europaea Herpetologica (SEH) European Congress of Herpetology websites and via congresses and conferences attended in person (such as the Herpetofauna Workers Meetings in the UK and the 7th WCH in Canada).

In addition, amphibian experts, zoo keepers, NGOs and government organisations were contacted via email in order to obtain supplementary information on particular species and programmes.

A cut off date of 31st December 2013 was applied to the searches.

Data collection

Data were gathered from these sources and then cross-referenced against the spreadsheet created by Griffiths and Pavajeau (2008) to ensure no duplicate data were used. When new programmes were identified these were added into a spreadsheet following the same format as Griffiths and Pavajeau (2008).

A detailed list of the type of data obtained for each species can be found in Appendix A and spreadsheets containing full species data for both pre and post-ACAP can be found in Appendix C.

In the Griffiths and Pavajeau (2008) study all records of amphibian captive breeding were utilised from 1966, continuing up to and including programmes started in 2006. Therefore any new programmes with a start date preceding 2007 but not identified in the Griffiths and Pavajeau (2008) study were added to the previous data. In total 26 pre-ACAP programmes were identified and subsequently moved to the original spreadsheet. Eighteen of these were from South and Central America; 13 of which formed part of initial rescues following the GAA (Amphibian Ark 2013). It is likely that these additional programmes were not widely publicised or in peer reviewed journals and would have therefore been missed in the initial data search by Griffiths and Pavajeau (2008).

Data Analysis

In order to conduct the analysis, programmes were classified into three main groups, according to Griffiths and Pavajeau (2008):

1. **Captive breeding (CB)**: species solely kept in order to be captive bred with no immediate plans for reintroduction or release. These included: programmes conducting research into species biology to inform in situ conservation, captive assurance colonies, and zoo exhibits for education.
2. **Captive breeding and reintroduction (CB&R):** species captive bred for the purposes of reintroduction. The reintroduction may already have taken place or be planned for the future.
3. **Reintroduction only (R):** for wild to wild species translocations including programmes involving head-starting.

It is important to note that programmes being undertaken for purposes other than conservation such as development or research not directly related to conservation were excluded. A reintroduction was considered as a conservation programme if it was supported by a recovery plan, published data, or other evidence such as support from a conservation body.

Data were then extracted and compared with the pre-ACAP data. Statistical analyses were undertaken using the Chi-square test to identify significant differences in the two sets of data.

Results

Programme Types

One hundred and three programmes consisting of: captive breeding only, captive breeding and reintroduction and reintroduction only were identified. Of the 103, 26 were found to have started before the ACAP and were incorporated into the pre-ACAP data. Of the 26, 22 were captive breeding only; two were captive breeding and reintroduction and two were reintroduction only. A total of 77 programmes were found to have been initiated since the 2007 publication of the ACAP. This represents an increase of about 30% over the past seven years.

Comparing the two sets of data it is clear that there has been a disproportionate increase in the number of captive breeding programmes from 2007 to present but a reduction in both captive breeding and reintroduction and reintroduction (X^2 = 18.4, d.f. = 2, p = <0.001) Figure 1.

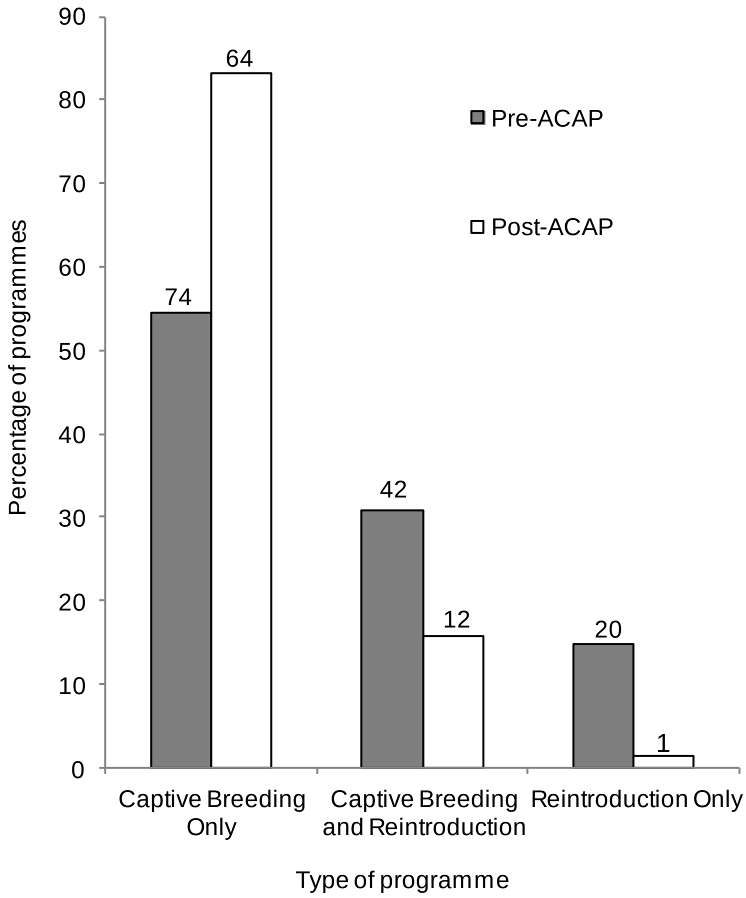

Figure 1. Percentages of species in captive breeding only, captive breeding and reintroduction, and reintroduction only programmes (actual numbers of programmes are shown at the top of the bars).

Orders

A disproportionate increase in anurans and caecilians was observed. This was shown to be marginally significant (X^2 = 6.90, d.f. = 2, p = <0.05) (see Figure 2). Since the ACAP there are nearly half as many anurans within captive breeding only, captive breeding and reintroduction, and reintroduction only conservation programmes as there were before the ACAP.

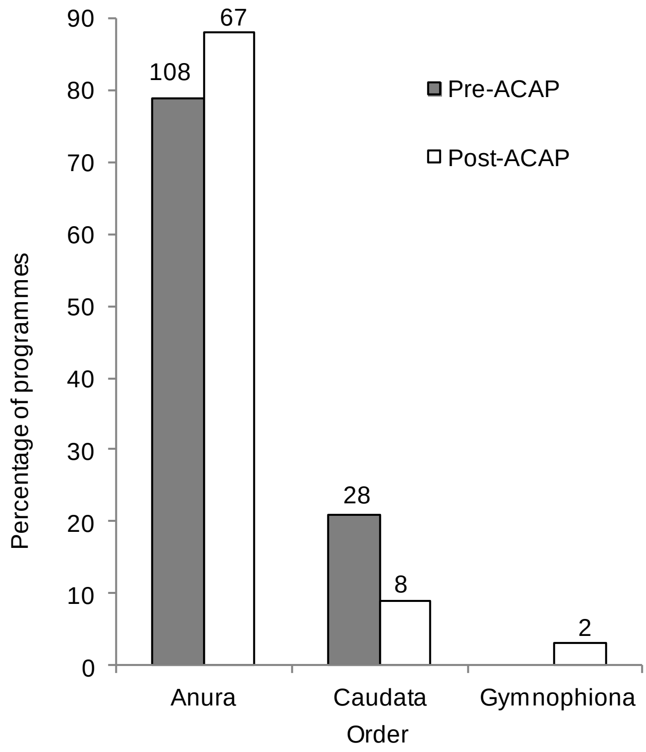

Figure 2. Percentages of amphibian orders within programmes (actual numbers of programmes are shown at the top of the bars).

Geographical Regions

Figure 3 shows that there has been a significant change in the range countries of amphibian species involved in captive breeding and reintroduction programmes (X^2 = 35.3, d.f. = 6, p = <0.001). The most noticeable change has been an increase in species from South America which make up almost 40% of all the programmes identified since the ACAP. Pre-ACAP only 14% of programmes were from South America. Similarly the Caribbean and Central America showed increases, each making up 11% of the total post-ACAP programmes compared to 2% and 8% pre-ACAP. In contrast to this, North

American species, which previously accounted for 22% of programmes now only account for 5% of the programmes post-ACAP. Despite the large increase in programmes in South America the focus in this region has not significantly changed; pre-ACAP 100% of programmes were captive breeding only and post-ACAP it is a similar story with 90% being from captive breeding only programmes. The results shown in Figure 3 present data for species within programmes based in their native countries. A number of these species also form part of partnership programmes outside of their native countries however these are not included as additions to the data.

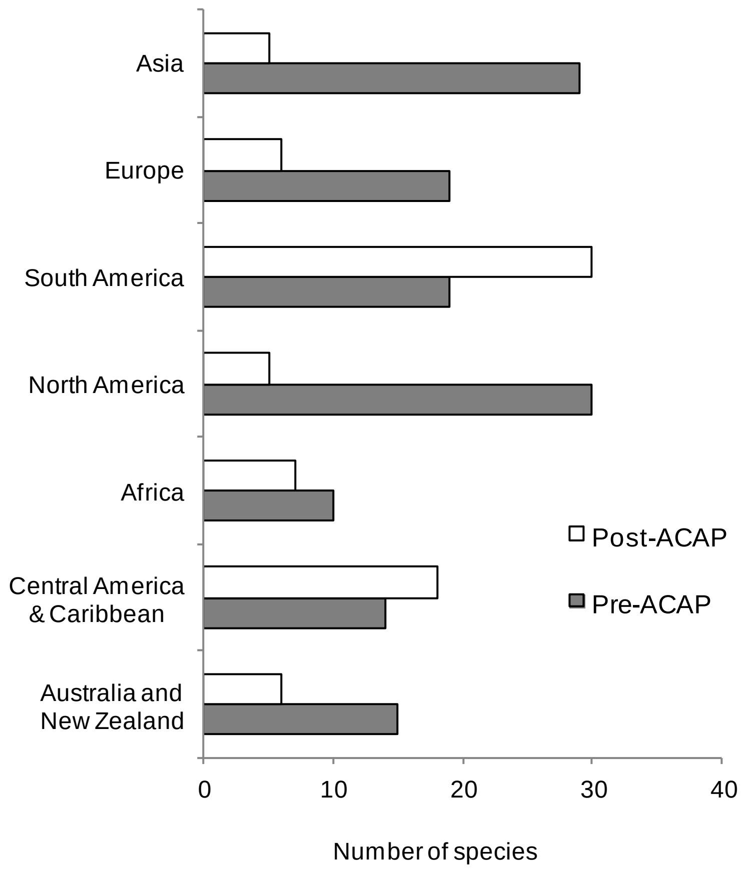

Figure 3. Geographical Regions of species involved in captive breeding and reintroduction programmes.

In situ conservation

There has been a decrease in the number of programmes that involve an in situ component as part of the programme (Figure 4). However the main focus of associated in situ conservation is still habitat management which formed 25% of post-ACAP programmes.

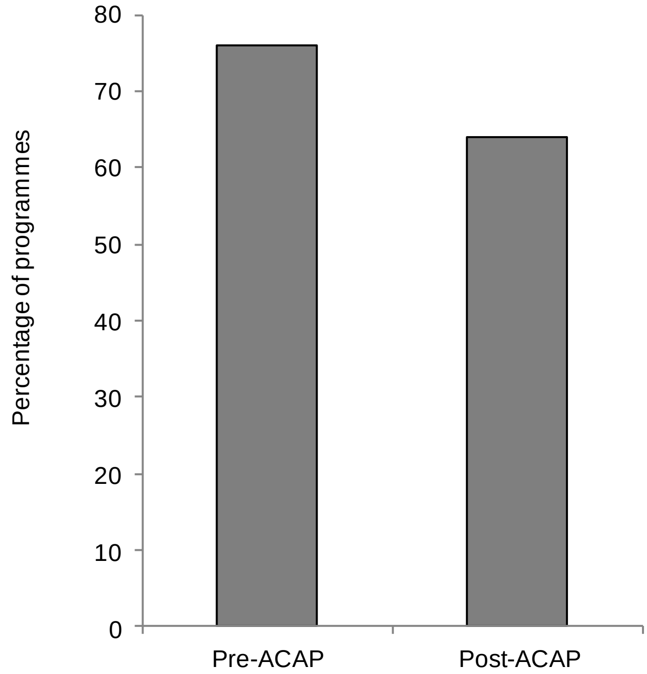

Figure 4. Comparison of pre and post-ACAP programmes with an in situ conservation element.

Reasons for captive breeding

Following the publication of the ACAP, captive breeding programmes are largely being driven by research (68%) and captive assurance (31%) whereas reintroduction as a reason for captive breeding has reduced (Figure 5).

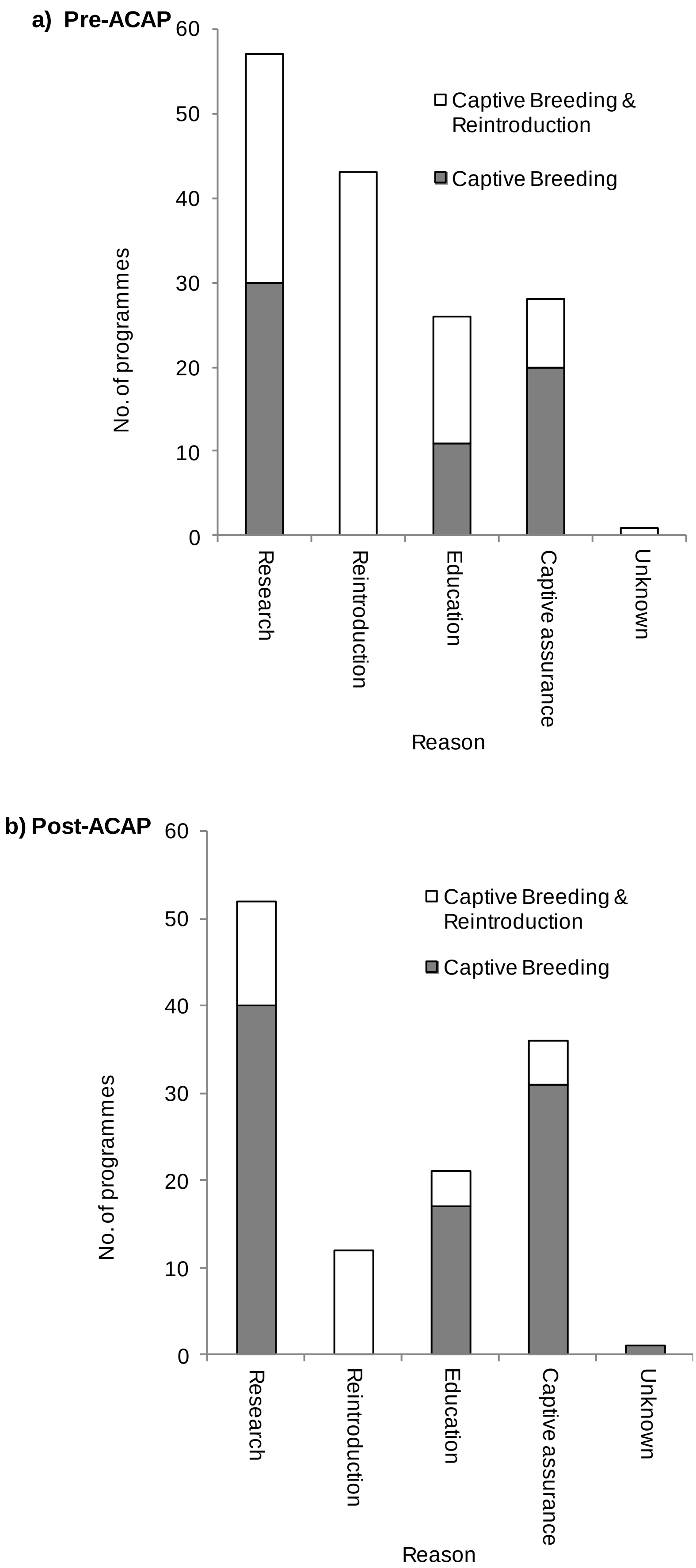

Figure 5. Reasons for captive breeding a) Pre-ACAP b) Post-ACAP.

Threats

The major threat facing amphibians in captive breeding programmes continues to be habitat loss (Figure 6 a, b). Only a small number of species were threatened by human use (hunting and consumption) in the post-ACAP data, whereas this was significantly greater pre-ACAP. This pattern was also similar for the threat of trade ($X^2 = 24.7$, d.f. = 5, $p < 0.001$). Relative to the lower number of species programmes identified post-ACAP; a higher number of species within programmes are threatened by disease than previously.

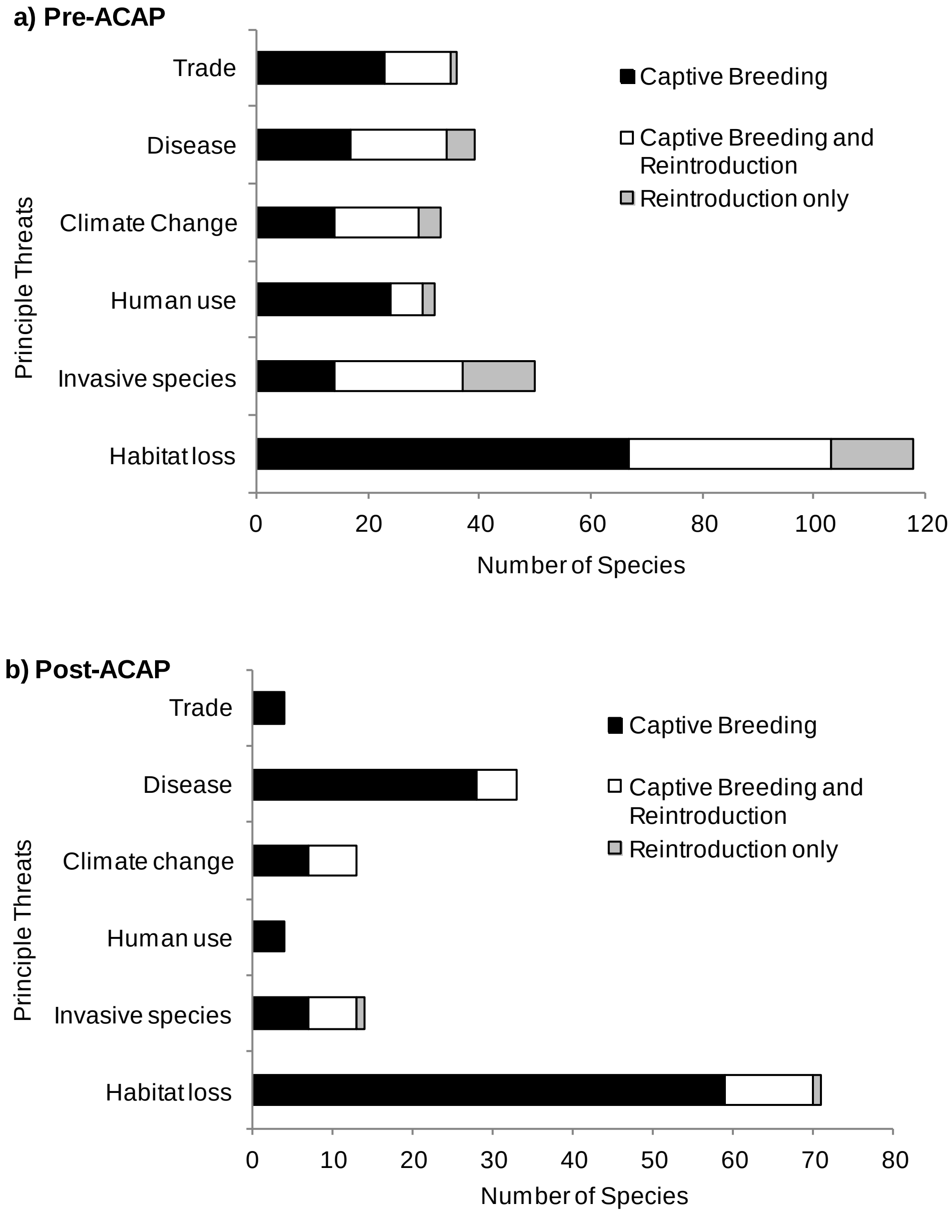

Figure 6. Principle threats facing amphibian species in CB, CB&R and R programmes a) Pre-ACAP and b) Post-ACAP.

IUCN Red List Categories

There was a significant difference between pre-and post-ACAP programmes in terms of threat status (X^2= 33.2, d.f. = 5, p = < 0.01). The number of Critically Endangered species in captive breeding and reintroduction programmes rose from 18% pre-ACAP to 38% post-ACAP. A significant decrease was also seen in species of Least Concern, where pre-ACAP they made up 36% of the species in captive breeding programmes and post-ACAP made up only 16% (Figures 7 a, b).

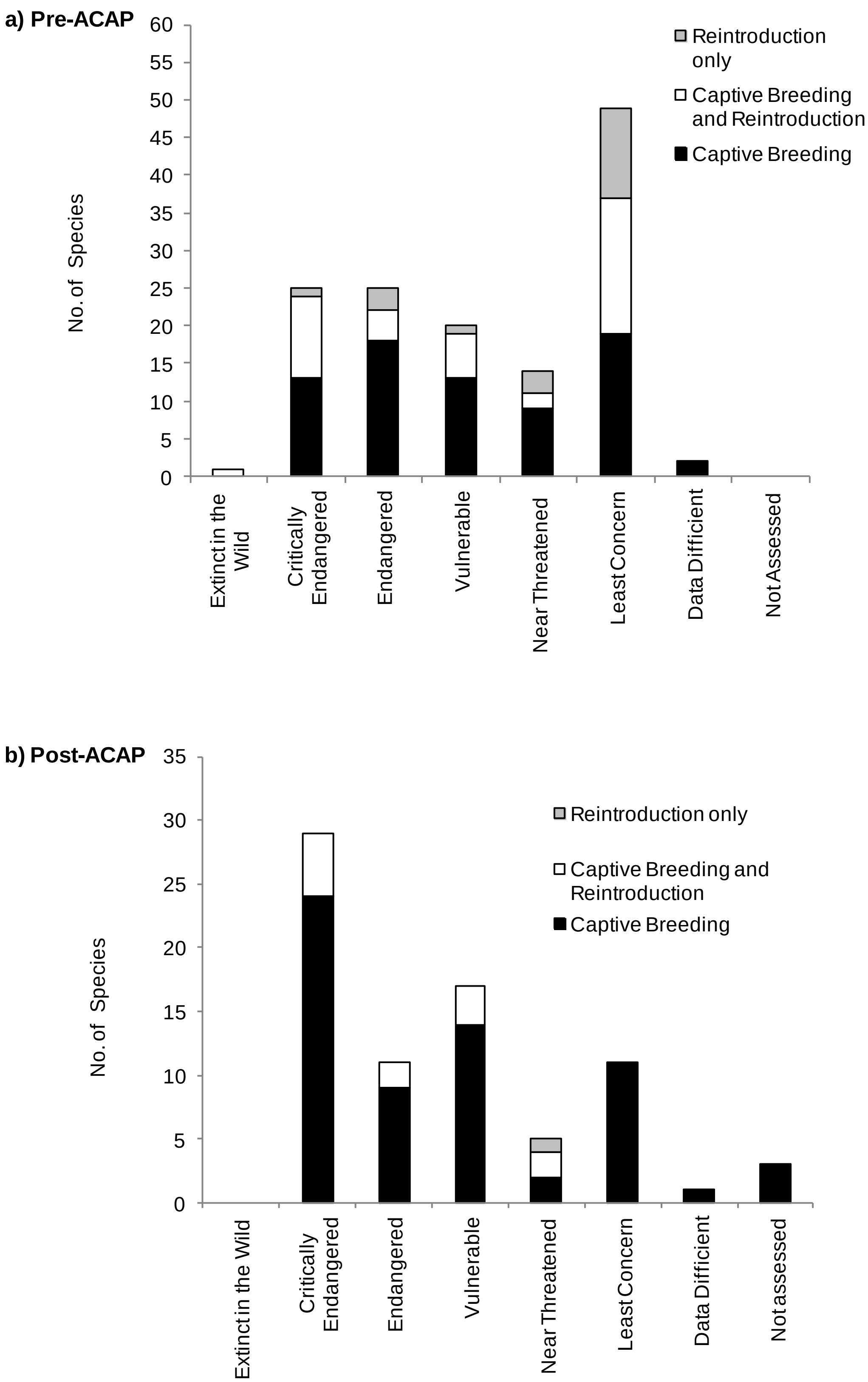

Figure 7. Distribution of IUCN Red List categories across programme types a) Pre-ACAP programmes and b) Post-ACAP programmes.

Programmes that have progressed from CB to CBR

Five programmes that were listed as CBR with future release have now progressed to release since the ACAP was published. These are: the Axolotl *Ambystoma mexicanum,* Kihansi Spray Toad *Nectophrynoides asperginis* and experimental releases have begun for the Ozark hellbender *Cryptobranchus alleganiensis bishopi,* Mountain Chicken Frog *Leptodactylus fallax* and Spotted tree frog *Litoria spenceri.*

Discussion

Since the publication of the ACAP in 2007, captive breeding programmes for conservation have increased by almost 30%. The original study by Pavajeau and Griffiths (2008) identified 136 programmes over almost five decades. This study identified a further 77 in the past seven years, showing a significant increase over a very short period of time. With over 30 of the 77 programmes listed as rescues for captive assurance and a 20% increase in Critically Endangered species the results suggest that ex situ conservation measures outlined in ACAP may be having an impact on the numbers and types of conservation breeding programmes throughout the world.

Programmes/ numbers

The relative numbers of programmes between the three categories have changed considerably since the ACAP and an increasing emphasis on captive breeding programmes has been observed in recent years. AArk estimate that there are 500 species in need of ex situ intervention (Amphibian Ark 2014). A significant rise in captive breeding programmes is therefore perhaps expected.

Five captive breeding and reintroduction programmes were scheduled for future release at the time of the pre-ACAP study. All of these programmes have since undertaken releases into the wild; however three of the five have only been undertaken on an experimental basis. This indicates that current threats such as disease and climate change may be leading practitioners towards a more cautious and experimental approach of reintroduction. Such experimental releases are becoming more commonplace and are recommended as important tools for research and understanding threats in the wild (Caughley 1994; IUCN/SSC 2013).

Reasons for Captive Breeding

The reintroduction of animals is frequently promoted as the primary reason for captive breeding (Balmford et al. 1996; Wilson & Stanley Price 1994). This was the case for many of the programmes beginning pre-ACAP with 41% of programmes citing reintroduction as the main reason; however post-ACAP reintroduction was cited for only 16% of programmes. This is a significant change, albeit not an unexpected one if we consider that captive assurance was the reason given for 31% of captive breeding programmes post-ACAP (Amphibian Ark 2013).

The main reason identified for the establishment of captive breeding programmes was conservation research. A good example of such research forms part of the Booroolong frog *Litoria booroolongensis* captive breeding programme which is using captive bred frogs to try and understand if vaccination in the form of prior infection improves survival with Bd following re-exposure (Cashins et al. 2013). The details of research were not known for all the programmes and it is not clear how many of them feedback into in situ programmes. Feeding research results into active in situ work is vital as research is only of true conservation value when it is relevant to the conservation of wild populations, or with public education (Griffiths & Kuzmin 2011). Zoos are becoming much more focussed on captive breeding programmes that present opportunities for research both in situ and ex situ (Browne et al. 2011).

Threats

Habitat loss continues to be the main threat to the species within these programmes. However, a decrease in human use and trade were not necessarily expected. These results are however supported by apparent declines in live amphibian and amphibian meat export since 2007 (CITES 2014). Additionally there are also now organisations such as, Wikiri in Ecuador, who farm frogs sustainably for trade and allocate profits to amphibian conservation (http://english.wikiri.com.ec/quienesomos.html). It is plausible that this type of action is contributing to a reduction in illegal trade.

Disease has predictably increased as a major threat for amphibians since the ACAP. Work undertaken by Lips et al. (2006) to model the likely spread of Bd directed pre-emptive collections of animals from these regions which now form the basis of many captive breeding programmes (Gascon et al. 2007). In addition, the spread of Bd has led to an increased awareness of disease within reintroduction and as a result will have reduced reintroductions into affected areas.

Many of the threats currently facing amphibians are complex and not easily mitigated (Griffiths & Kuzmin 2011) and in many recent cases are not even fully known or understood (Mendelson et al. 2006). Climate change is a difficult threat to quantify and was only stated as a principle threat for just 14 programmes. Much of the threat data were obtained through the IUCN Red List, which for a number of cases stated climate change as only a possible cause of decline (IUCN 2013) and was therefore not included as main threat for many species. This may lead to an underestimation of the threats posed by climate change. This underestimation is likely to continue until research is able to answer the questions relating to how changes to species life cycle events, health and habitats will be impacted (Bellard et al. 2012). Given that amphibians are sensitive to environmental temperature changes (Wake & Vredenburg 2008) climate change is expected to become an increasing threat.

IUCN Red List status

A comparison of pre and post-ACAP data showed a significant increase in threatened species within conservation breeding programmes including a 20% increase in Critically Endangered species. There are two likely reasons for such an increase: firstly amphibian species Red List Index values were seen to decline by 3.4% between 1980 and 2004 (Hoffmann et al. 2010) and secondly the ACAP outlines the need for species at immediate risk of extinction to form assurance colonies. Contrary to this, a study of aquariums and zoos that form part of the International Species Information System (ISIS) organisation by Conde et al. (2011) showed that less than 3% of the world's threatened amphibians were held in these institutions. Whilst figures from this study alone show that 7% of threatened species are in captive breeding programmes. This variation in results is likely to be due to the concentration of ISIS zoos to temperate regions (Conde et al., 2011) and that we are now seeing are more programmes based in the tropics as part of smaller specialist facilities and institutions (Stanley Price & Soorae, 2003; Zippel et al. 2011). It is also important to point out that although zoos are often the main proponents of captive breeding programmes, they are not necessarily the main executors. Zoos often support programmes by providing resources such as finance and husbandry advice rather than undertaking captive breeding themselves (Beck et al. 1994; Gippoliti 2012).

Geographic Regions Global and Taxonomic Patterns

Another common characteristic of these rapid declines is location; amphibian species from the Neotropics are more affected by these associated threats than anywhere else (Stuart et al. 2004). Consequently there has been an increase in captive breeding programmes in South and Central America and the Caribbean. Many of these programmes, especially in Ecuador and Panama, are being driven by rescue efforts to create assurance populations in regions where Bd and, or other unknown factors are having a dramatic impact.

Previously the distribution of captive breeding and reintroduction programmes often related to countries with the most expertise and facilities rather than the richest biodiversity (Griffiths & Pavajeau, 2008). However, following the ACAP and the AArk initiative this is starting to change and we are now seeing a stronger focus on captive breeding in-country. AArk projects have enabled the training of local biologists via workshops and creation of facilities for projects in countries such as, Bolivia, Ecuador and Panama (Zippel et al. 2011). The move towards more in-country work involving nationals is definitely a positive step, but despite the advantages of cheaper wages, resources and lower disease risks there can be problems. These can include issues relating to politics, lack of funding and relatively few or small zoos that are often under-developed and lack sufficient space (Zippel et al., 2011). Therefore large zoos, institutions and NGOs still have a part to play and can be vital for creating awareness, assisting in captive breeding and sharing the important skills and knowledge required for such programmes (IUCN 2002; Gascon et al. 2007; Gippoliti 2012).

Success rates

Of the programmes that had undertaken reintroductions, 14 of them were classed as having a high level of success; that is they were deemed to have established a self-sustaining population. Success, as previously discussed can be very hard to quantify and the time scale for proving this is likely to be lengthy (Dodd, 2005). In the previous study by Griffiths and Pavajeau (2008) a number of species reintroductions previously regarded as being of high success have since changed. The Ramsey Canyon Leopard Frog *Rana subaquavocalis* was previously considered to have been high success, but current data to substantiate this was unable to be obtained. The latest reports suggest that wildfire and subsequent erosion caused sediment to fill the main pond and chytrid had an impact on other populations (Field, K. Pers. comm. - May 2014). Both *Leiopelma pakeka* and *L. hamiltoni* species were also previously regarded as high success. However, in a recent report by Bishop et al. (2013) it stated that despite evidence of breeding, judging if the frogs have successfully established was difficult to determine.

As well as declines in success some of the programmes considered to be of lower success have shown improvement. *Bombina bombina* was previously considered to be medium success, but due to further releases and improved habitat management population is now considered to be self-sustaining (Andren, C. pers. comm. – March 2014). The Houston toad was previously considered to be a failed reintroduction, but recent surveys have identified genetic signatures of toads released in the 1980s in toads sampled in 2009 to 2011 (Parker, T., pers. comm. – July 2014). Similarly the boreal toad *Bufo boreas*, previously considered unsuccessful, has now been subject to further releases and improved methods which have started to see survivorship of introduced toads (Muths et al. 2014). These improvements suggest that as programmes adapt and improve greater success can be achieved. These findings provide further evidence that longer running programmes can be more successful.

In situ conservation

It is a common principle in conservation management that ex situ programmes can only be of true value when undertaken alongside in situ conservation (Gascon et al. 2007; Griffiths & Kuzmin 2011; Zippel et al. 2011). Sixty-four percent of programmes started after the ACAP had an element of in situ conservation. This shows a 12% decrease compared to the pre-ACAP data. This figure may also be exaggerated as there are a number of projects where there was in situ research but funding for this had run out or the in situ element was limited to local education, which may not have a sufficient impact on its own. Conversely, there are a number of projects where declines and widespread extinctions are occurring despite pristine and protected habitats (Pounds et al. 2006; Bishop et al. 2012). In these cases conservation managers simply do not yet have the techniques or knowledge to address these kind of threats in the wild (Stuart et al., 2004). In many of the areas where Bd is known, work in the field is limited and the main focus of funding is directed towards the ex situ task of finding a cure/ solution (Gascon et al. 2007). In spite of this, in situ conservation is vital to understanding how threats are developing. Even where populations are considered to be extinct in the wild, in situ research and surveys to monitor species, habitats and environmental change should continue. Ideally all captive breeding programmes should be partnered by relevant in situ research. However, due to more and more poorly understood species being bought into captive breeding programmes much of the research relates to understanding basic husbandry needs and observing traits and behaviours (Griffiths & Kuzmin 2011).

The need for in situ

A large amount of the research associated with ex situ breeding is being undertaken by zoos and until recently the only publications coming out of these were husbandry protocols (Griffiths & Kuzmin 2011). Undoubtedly there is value in these protocols however, zoos are now realising the potential for pro-active field work and research to really make a difference in species conservation. This was reiterated by WAZA (World Association of Zoos and Aquariums) in their 2005 *Building a Future for Wildlife: the World Zoo and Aquarium Conservation Strategy* which stated that zoos must 'increasingly commit to conservation in the wild as their primary goal and focus [and] to forge a new identity and purpose or to be left behind by the conservation movement' (2005, p10). Zoos have strong capabilities beyond the realms of captive breeding and their expertise can provide valuable contributions to field based projects, particularly for species programmes in countries lacking such capability (Stanley Price, 2005).

Conclusions

Implementing the ACAP

The increase in conservation breeding programmes indicate that the ex situ recommendations carried out by AArk in response to the ACAP are beginning to influence the types of conservation methods being used to combat amphibian declines. Further evidence for this conclusion is seen in the increase in programmes in South and Central America and the increase in threatened species within these programmes. Despite the increase in captive breeding programmes the number of species in captivity with plans for release has declined. Although there may be a number of programmes where species are simply not ready, the main reason for this is likely to be that the threats facing these species are either unknown or cannot currently be managed (Stuart et al. 2004; Gascon et al. 2007; Bowkett 2009).

Regardless of the reasoning, programmes such as these continue to come under criticism for their potential to be perceived as a one-stop solution, and for taking publicity and funding away from in situ conservation (Rahbeck 1993; Pounds et al. 2006; Gewin 2008). Other arguments state that although captive assurance has its place within conservation, the focus should be on addressing climate change through political advocacy and education (Pounds et al. 2006).

More recent concerns from amphibian scientists have also related to the lack of focus on in situ conservation coming out of the ACAP objectives (Pounds et al. 2006; Gewin 2008; Bishop et al. 2012; Stuart 2012). AArk state that their Conservation Plan is only one part of the ACAP and that ultimately the safeguarding of these species in situ will be the real measure of success (Zippel, 2007). Despite this, there appears to have been a great effort to first target populations for captive assurance colonies. Whilst this is understandable, and arguably necessary, a similar stance for in situ work does not appear to be present. The AArk was developed to cater for ex situ conservation and whilst there are a number of working groups and projects to cover the other objectives of the ACAP, many ex situ programmes do not include an obvious partnership with in situ conservation.

In response to the apparent shortfall in this area, an amphibian mini-summit was set up by the IUCN SSC in 2009 to prioritise implementation of sections of the ACAP linked to habitat conservation. These objectives would be led by the inter-institutional Amphibian Survival Alliance (ASA) (Bishop et al. 2012; Stuart, 2012). The main approach of the ASA is to form collaborations with organisations including those supporting other taxonomic groups and key partners such as Ramsar Convention on Wetlands and the Inland Water program of the Convention on Biological Diversity (CBD) (Bishop et al. 2012). In order to fulfil their own ambitious goal of restoring all threatened native amphibian species to their natural roles and population levels in ecosystems worldwide (Bishop et al. 2012), the ASA has an enormous challenge ahead. Echoing the words of Stuart (2012) it is hoped that the ASA will become a major player in driving amphibian conservation forward.

In addition to a more focussed and collaborative approach to active in situ conservation, a vital step will be to progress captive animals towards reintroduction. In order to do this further research will be needed in order to establish how many species fit the necessary criteria to enable reintroduction to proceed.

Are Amphibian Reintroduction Programmes Compliant with Current Guidelines?

Abstract: *Despite the existence of guidelines and best practice procedures, many reintroductions take place without considering all the necessary information. This study assesses amphibian reintroductions against a set of ten criteria adapted from existing recommendations and guidelines relating to species reintroduction. All programmes were compliant with criteria relating to reintroductions of threatened populations and species. However, criteria on establishing viable populations and having sufficient resource were difficult to fully meet. Reintroduction programmes of longer duration and higher success were shown to meet reintroduction criteria more completely, indicating that a programme needs to run for around 15 years or more in order to show a high level of success. Longer-running programmes were more compliant with reintroduction guidelines and demonstrated the highest levels of success. In general successful programmes were long running with a wide-range of published data and were led by strong collaborations between government agencies, NGOs and zoos*.

Introduction

The reintroduction of threatened species can be an effective conservation tool both alone or in combination with other conservation measures. It is imperative however, that any form of reintroduction is supported by scientific knowledge and strong justification (IUCN/SSC 2013).

The first publication relating specifically to reintroduction guidance was produced in 1987 in the form of 'The IUCN Position Statement on Translocation of Living Organisms' (IUCN 1987). This was followed in 1998 with the *'IUCN Guidelines for Re-introductions'* produced by the Re-introduction Specialist Group (RSG) (part of the IUCN's Species Survival Commission) in response to the need for more detailed and specific policy guidelines in light of an increase in species reintroductions (Seddon et al. 2007). The main objective of the guidelines is to ensure that reintroductions achieve their intended conservation benefit and do not cause adverse side effects as a consequence (IUCN 1998).

The guidelines were updated again in 2013 when the IUCN published *'Guidelines for Reintroductions and Other Conservation Translocations'.* The 2013 guidelines were once again driven by the RSG who formed part of a task force that included the Invasive Species Specialist Group and insight from a number of specialists and species specific experts (IUCN/SSC 2013). In addition to the IUCN formal guidelines, various other publications have provided commentaries and advice on species reintroductions. These have either been written in relation to general principles and practice (Reading et al. 1991; Ewen et al. 2012; Pérez et al. 2012) or for specific taxa or species (Kleiman 1989; Soorae and Launay 2008; Khatibu et al. 2008; Kavanagh & Caldecott 2013). These additional publications can provide a useful resource for species specific details and explicit examples that cannot be covered in the formal guidance.

Despite the existence of guidelines and best practice procedures, many reintroductions take place without considering all the necessary information. This is one of many reasons why reintroduction as a conservation tool is often considered controversial (Griffiths & Pavajeau, 2008) and has been the subject of much debate throughout the conservation sector (Griffith et al. 1989; Reading et al. 1991; Snyder et al. 1996; Seddon et al. 2014). Even with opposition from many conservation biologists who believe most ex situ funds would be better directed in situ (Rahbeck 1993; Snyder et al. 1996), zoo based reintroduction programmes are considered valuable vehicles for publicity and awareness of endangered species conservation (Lindburg 1992; Fischer & Lindenmayer 2000). Even so, the need to develop more comprehensive reintroduction strategies and include additional funds for habitat protection and species research is also recognised as a key component of such programmes (Lindburg 1992).

Perez et al. (2012) created a set of ten criteria designed to assess the necessity and usefulness of translocations. Perez et al. (2012) derived the criteria from a wide range of reintroduction publications, guidelines and best practice methods. Perez et al. (2012) assessed a number of reintroduction programmes against the criteria and discussed the criteria's use as a decision making tool for establishing if a reintroduction should go ahead. Using criteria adapted from Perez et al. (2012) this study assesses the compliance of 62 amphibian reintroduction programmes with the adapted criteria and compares the results against programme duration and success.

Methods

Case Studies

All reintroductions identified in Chapter 2 were considered for analysis in the current chapter. Projects with no published data (i.e. 'published literature' defined as grey literature, peer-reviewed literature or websites) or that were solely anecdotal with insufficient information and no contactable project lead, were not considered further. Reintroductions carried out for purposes other than conservation such as development or research not directly related to conservation were not included. A reintroduction was considered as a conservation programme if it was supported by a recovery plan, published data, or other evidence such as support from a conservation body.

Following the removal of programmes that did not meet these criteria a total of 62 amphibian species were identified as being part of a reintroduction programme for the conservation of the species. All 62 programmes relate to a different species; three of the species programmes assessed (natterjack toad *Epidalea calamita*, European treefrog *Hyla arborea* and Oregon spotted frog *Rana pretiosa)* had more than one confirmed reintroduction programme. The European treefrog programmes both met the same criteria and were included as a single project. For the natterjack toad and Oregon spotted frog programmes, sufficient information was only available for one project for each species, therefore the others could not be assessed. Two separate programmes were assessed for the hellbender, as the Eastern hellbender *Cryptobranchus alleganiensis alleganiensis* is considered to be a different subspecies to the Ozark hellbender *Cryptobranchus alleganiensis bishopi.*

Data Gathering

The data for each of the studies was gathered using the following method:

- Published data and literature were obtained via searches for specific species previously identified using search methods outlined in Chapter 2, using Web of Science; Google Scholar and access to online journals. The recently published synopsis of amphibian conservation interventions (Smith & Sutherland 2014) was also reviewed.
- An additional internet search using species names was undertaken for non-published data, or data not easily found such as, action plans and conference proceedings. Search criteria used species name and action/ recovery plan/ reintroduction and conservation.
- Additional methods included accessing government and state websites to obtain protected species plans and data.
- Any remaining data gaps were followed up with direct questions to individuals leading or working on the programme. If a response was not provided within the given time frame the data gaps were classified as 'No information'.

Additional data concerning success and duration of the conservation programme was also gathered. 'Success' was assigned to one of three levels as defined by Griffiths & Pavajeau (2008):

- **High Success:** self-sustaining populations established in the wild
- **Medium Success:** evidence of successful breeding in the wild
- **Low Success:** evidence of survival of released animals in the wild.

Success was only determined for programmes with reestablishment as a clear goal and not for reintroductions that were undertaken as part of an educational, pilot or research project. Similarly, programmes at a very early stage of release and with no field data did not have a success level determined.

Duration of the programme was considered to be from the year of programme initiation to the last reintroduction and/or site monitoring. The start date varied depending on the programme design and data available and included initiation of a recovery plan, captive breeding or when animals or spawn were first collected.

Assessment Criteria

The programmes were assessed against a set of ten criteria adapted from Perez et al. (2012). These criteria were based on data obtained from recommendations and guidelines relating to reintroductions and included IUCN (1987; 1998); Williams et al. (1988); Griffith et al. (1989); Kleiman (1989); Dodd and Seigel (1991); Reading et al. (1991); Stanley Price (1989); Short et al. (1992); Kleiman et al. (1994); Cunningham (1996); Wolf *et al. (1996); Miller et al. (1999). The Perez et al. (2012*) study did not encompass the new 2013 IUCN Guidelines for Reintroduction. Consequently, the new IUCN guidelines were appraised and the Perez et al. (2012) criteria modified accordingly. Specific information relating directly to amphibians was also included within the criteria. Each of the 62 case studies was then assessed against the following ten expanded criteria:

(1) Is the species or population under threat?

The first step is to assess the extent to which the target species or population is threatened, as well as to determine its conservation status (IUCN 1987, 1998). This must be evaluated within metapopulation and regional contexts (Palsbøll et al. 2007; IUCN 1987, 1998) thus including populations threatened at a local, regional, national and international level.

(2) Have the threatening factors been removed or controlled, or were they absent in the release area?

Prior to translocation, it is essential to analyse the factors that threaten the target species or population. A translocation is not advisable if threatening factors are sustained or uncontrolled in the release area (IUCN 1987, 1998; Kleiman 1989; Kleiman et al. 1994).

(3) Are translocations the best tool to mitigate conservation conflicts?

Before translocation is undertaken, the best available management options must be selected to eliminate threats and to assess the reason for population decline (IUCN 1987; Griffith et al. 1989; Kleiman 1989; Kleiman et al. 1994). If the species or population is not at risk because of small population size but is instead declining as a result of direct or indirect human impacts, solving or compensating such impacts by in situ conservation actions could be a better alternative (Caughley 1994).

Undertaking modelling to predict the outcome of a translocation under various scenarios will provide information and highlight risks. If a translocation is the right option the risks should be low, if the risks cannot be determined or are considered high then translocation should not proceed (IUCN/SSC 2013).

(4) Are risks for the target species acceptable?

Translocations are also inadvisable if they may threaten either the source or recipient populations (Kleiman 1989; Kleiman et al. 1994; IUCN 1998; Carrete and Tella 2012). For example, translocations can promote disease spread, genetic mixing, and change in social structure or behaviour among other outcomes (IUCN 1987, 1998; Griffith *et al*. 1989; Cunningham 1996). The possibility of contemporary evolution (Pelletier *et al*. 2009), as well as behavioural and physiological changes in captive populations (Archard and Braithwaite 2010; Mason 2010), should also be considered when evaluating source populations.

Disease and biosecurity are important risks to address and at the present time are a major issue for amphibians. *Batrachochytrium dendrobatidis* (Bd) has been spreading across continents with disastrous effects on amphibian populations. Any amphibian translocation must understand the risks of Bd, the presence of Bd in founder populations and receptor sites and must be able to address these risks by testing individuals and adopting strict biosecurity measures. In addition all disease risks should be known and understood as far as possible; which diseases can exist within a population naturally without causing significant harm and which diseases could potentially be a significant threat (IUCN/SSC 2013). Animal welfare issues must be considered and recognised standards adhered to along with the recognition of factors linked to the stresses of captive breeding and translocation (IUCN/SSC 2013).

(5) Are risks for other species or the ecosystem acceptable?

Translocations may impact other species (Williams et al. 1988; Stanley Price 1989; Cunningham 1996) or the source or recipient ecosystem (Cunningham 1996; IUCN 1998). This is especially relevant for keystone species such as top predators for release sites when target species have long been extirpated (Rees 2001), and for assisted colonisations where translocated species may become invasive (Ricciardi & Simberloff 2009).

(6) Are the possible effects of the translocation acceptable to local people?

An analysis of potential conflicts and risks to the socioeconomic system of release sites must be carried out (Stanley Price 1989; Kleiman et al. 1994; IUCN 1998). The attitudes of people who might be affected by the translocation should be investigated and, if necessary, modified in an effort to improve local acceptance (IUCN 1987, 1998; Stanley Price 1989; Reading et al. 1991). Translocations are inadvisable if target species could jeopardize human lives or diminish quality of life, or if human behaviour could substantially affect the survival of the released individuals (Stanley Price 1989; Kleiman et al. 1994; IUCN 1998).

(7) Does the project maximise the likelihood of establishing a viable population?

All factors that might affect the survival of the released individuals and the establishment of a viable population should be taken into account. Several aspects – including release site selection, the number and composition of individuals to be released, and the methodology used – should be considered before release at the new site (Williams et al. 1988; Griffith et al. 1989; Kleiman et al. 1994; Wolf et al. 1996). During the development phase, efforts should be focused on ensuring that animals can easily adapt to their new surroundings (IUCN 1987, 1998; Kleiman 1989; Reading et al. 1991).

Knowledge of species critical needs such as biology, resources, biotic and abiotic habitat needs and inter-specific relationships is essential (IUCN/SSC 2013). A translocation will need to determine numbers of individuals required in order to succeed, along with how these individuals can be sourced from the wild and requirements for captive breeding. If captive breeding is required an investigation into past breeding programmes with this species or a similar species would be required in order to understand the associated risks (IUCN/SSC 2013).

(8) Does the project include clear goals and monitoring?

Translocation should include long-term monitoring to assess progress toward explicit objectives (Williams et al. 1988; Kleiman 1989; Dodd and Seigel 1991). An adaptive management approach should be pursued to provide evidence for cause–effect relationships and to find optimal strategies that will improve results (IUCN 1987, 1998; Short et al. 1992; Miller et al. 1999) which should then be made readily available to scientists and managers (IUCN 1987, 1998; Williams et al. 1988; Miller et al. 1999).

Creating programme specific guidance at the pre-translocation stage can assist with the translocation and provide an important resource for similar programmes in the future. As translocations do not always go to plan, an exit strategy should form an integral part of the preparation. This should state a point that if reached, resourcing the translocation can no longer be justified. Halting a project is defensible if the design indicators set out alongside the goals are not met or not desired, and unacceptable consequences have occurred (IUCN/SSC 2013). Dissemination of methods and results of both successes and failures creates awareness of the programme and contributes to existing knowledge and science (IUCN/SSC 2013). Defining the timeframe needed to assure 'success' is needed. Amphibian populations fluctuate naturally, and the length of the monitoring period will depend on the desired level of success and the generation time for the species - long-lived species will take longer.

(9) Do enough economic and human resources exist?

During all phases of a translocation project, sufficient economic resources (IUCN 1987; Kleiman 1989; Stanley Price 1989; Kleiman et al. 1994) and trained staff (Reading et al. 1991; IUCN 1998; Miller et al. 1999) must be available. Detailed estimates of expenses for the duration of the project, including post-release monitoring, are key to evaluating whether a given project meets this criterion (Karesh 1993). A feasibility study is vital preparation for all translocations in order to understand the full resource requirements, costs and risks (IUCN/SSC 2013).

(10) Do scientific, governmental, and stakeholder groups support the translocation?

Participation by and interaction between the different stakeholders interested in, associated with, or affected by the translocation (e.g. local government, non-governmental organisations, the scientific community) are vital to ensure successful project management. To help achieve this, among other things, all pertinent laws, treatises, and agreements – at international, national, state, and local levels – should be respected. An investment in environmental education is also highly recommended (Kleiman 1989; Reading et al. 1991; Kleiman et al. 1994; IUCN 1998).

As it is extremely difficult to address a reintroduction programme in absolute terms, the programmes were assessed against each of the criteria using the following scale:

- **Criteria fully met:** addressed all points in the criteria
- **Criteria partially met:** addressed some points or all points were addressed but not comprehensively.
- **Criteria not addressed criteria:** the criteria do not appear to have been considered at all.
- **No information:** No information was available relating to these particular criteria.

The scale allows the study to consider the general terms of the criteria whilst highlighting gaps in the programmes. A full set of programme data can be found in Appendix C.

Data Analysis

As the variables (duration, criteria met and success rates) do not follow normal distributions non-parametric tests were applied.

The median duration of the programme and the median number of criteria met were compared between programmes classified as having low, medium and high success using a Kruskal-Wallis ANOVA. Post-hoc analysis was then undertaken to identify where any differences lay. Spearman's rank correlation was used to identify any positive association between the length of the programme and the number of criteria met.

Aims

- To understand how amphibian reintroduction programmes are meeting guidelines and criteria.
- To establish which criteria are being met, which criteria are not being met and the reasons pertaining to this.
- To ascertain if longer running reintroduction programmes meet a higher number of criteria than relatively new programmes.
- If there is a relationship between success level and the number of criteria being met.
- To highlight how reintroductions, and reintroduction guidance and resource can be improved.

Results

Specific criteria addressed

Criterion 1 was the only criterion fully met by all 62 programmes. This implies that all species or certain populations of species within the reintroduction programmes are under threat. Each of the criteria was fully met by over half of the programmes, with the exception of criterion 7: maximizing the likelihood of establishing a viable population (Figure 8). For ten programmes there was no information in published data relating to the consideration of risks to other species and the ecosystem.

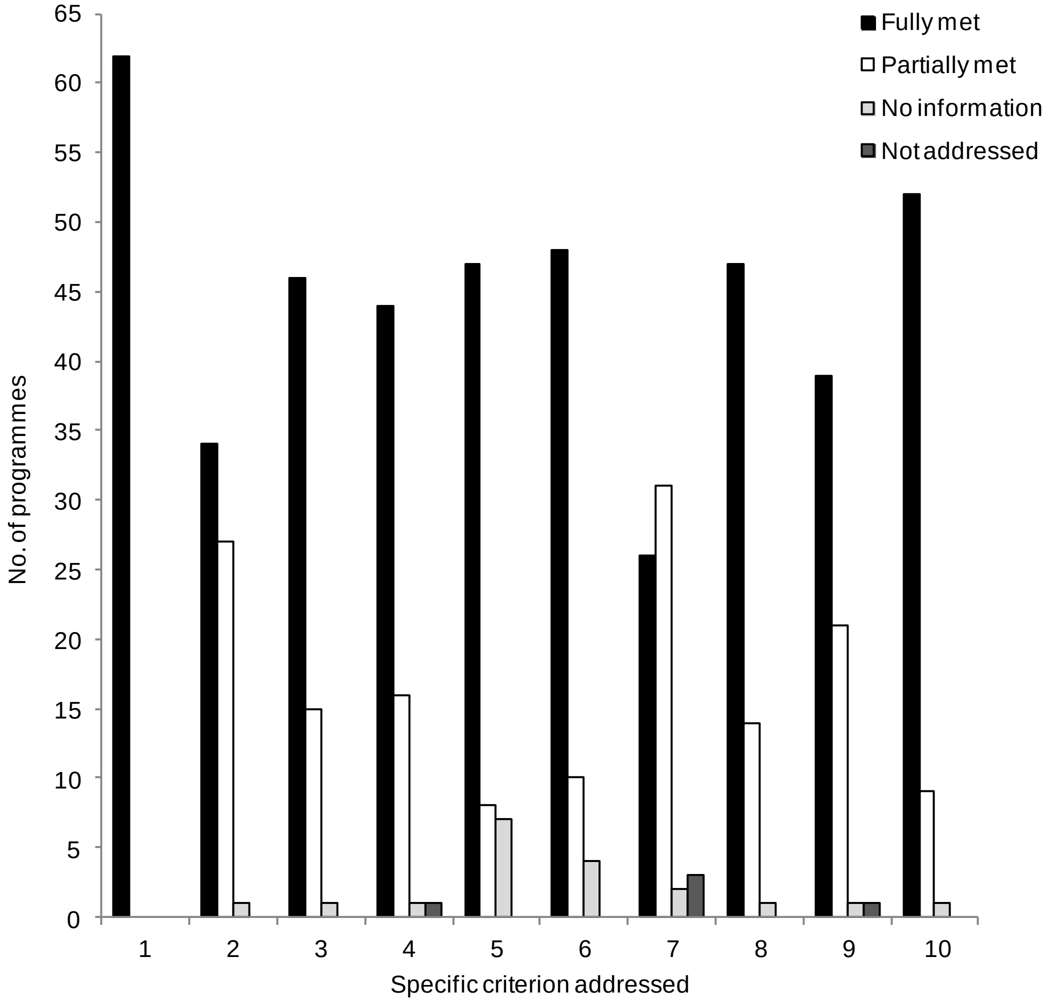

Figure 8. Number of programmes meeting specific criteria.

Total number of criteria addressed

Eleven percent of projects fully met all of the criteria and 29% met nine. 15% of the projects assessed did not have information for one of the criteria and only 4% had no information for more than one of the criteria. A relatively high number of projects partially met low numbers of criteria with 16% meeting five of them. Relatively few projects did not address criteria with 2% not addressing one and 3% not addressing two (Figure 9).

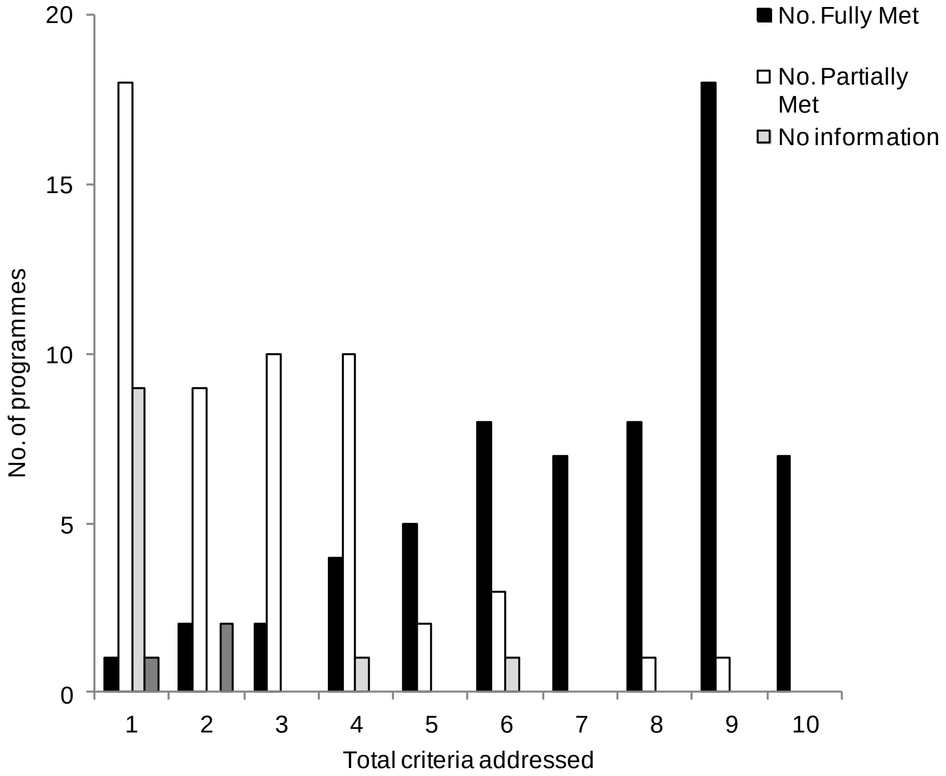

Figure 9. Total number of criteria addressed by programmes.

Duration of programme against number of criteria met

Wide variation was seen in the number of criteria fully met by programmes that have been running less than 15 years (Figure 10). However, for programme durations above 15-20 years a significant positive relationship can be seen between the number of criteria fully met and the duration of the programme ($r_s = 0.36$, $n = 62$, $p = 0.004$).

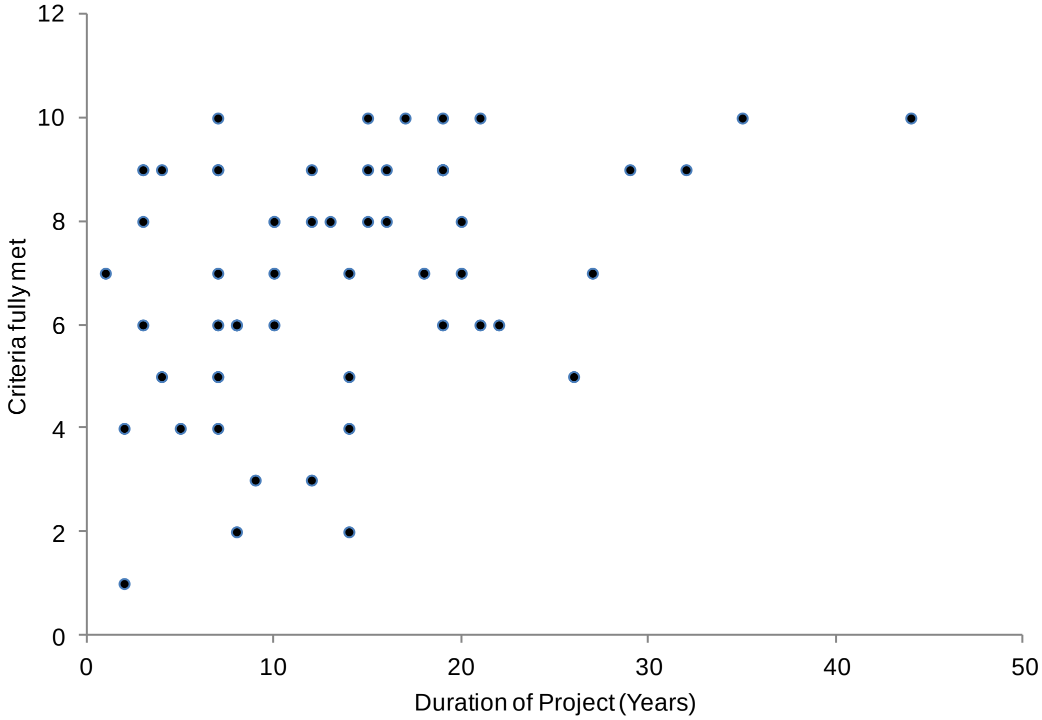

Figure 10. Scatter plot showing duration against criteria fully met

Duration and success

Forty-three out of the 62 projects examined contained sufficient information to have their level of success determined. Of these 28% were considered to be of low success, 40% medium success and 33% high success.

Programmes which have been in place for less than seven years do not show high levels of success. Long-running programmes showed a higher level or success and only 2% of programmes showed a high level of success if under ten years of age (Figure 11).

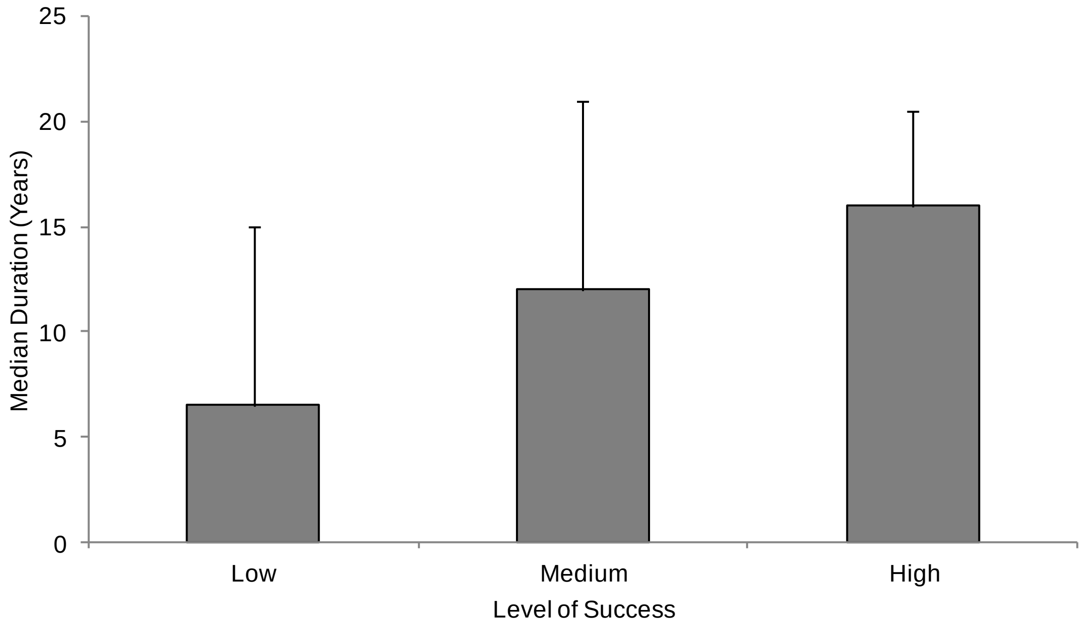

Figure 11. Duration of programme in relation to level of success

A Kruskal-Wallis test showed that there was significant variation between levels of success in terms of the duration of a project, $\chi^2 = 68.5$, df = 2, $p = 0.039$. Post-hoc analysis using a pairwise comparison showed the relationship between low and high success to be the most significant ($p = 0.012$) but no significance was found between Medium and High ($p = 0.240$).

Criteria met against success level

Figure 12 shows a trend between the number of criteria being met and the relative success of reintroduction projects. Projects of high success tended to meet more criteria than those of low success.

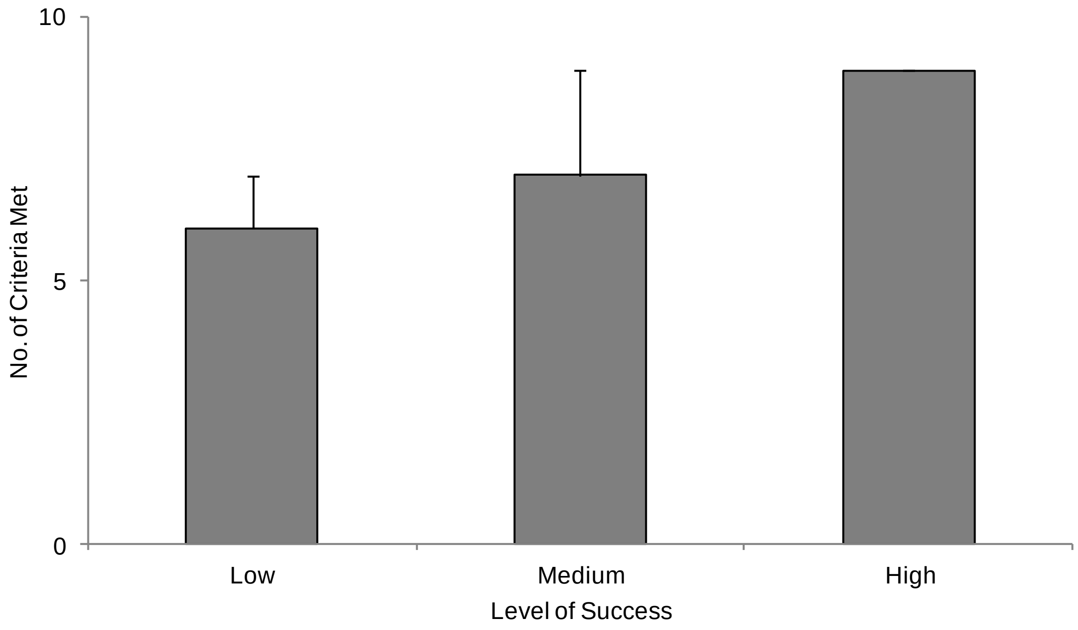

Figure 12. Median number of criteria against success of project

A Kruskal-Wallis test showed that there was variation between levels of success in terms of the number of reintroduction criteria met (χ^2 = 13.3, df = 2, *p* = 0.001). Post-hoc analysis using a pairwise comparison showed the relationship between low and high success to be the most significant (*p* = <0.001). The relationship between medium and high success and criteria met was also significant (*p* = 0.019).

Discussion

Criteria and Guidelines

Of the 62 amphibian reintroductions assessed, over 75% met with more than half of the ten reintroduction criteria. However, only seven programmes fully met all of criteria. Assessing the programmes in an absolute sense was not straightforward, particularly when relying on published material alone. To provide a clearer insight into the details of each of the criteria the following section discusses each of the key issues in turn:

(1) Is the species or population under threat?

All of the reintroductions assessed met this criterion as they all involved species or a particular population that was considered to be threatened. Although many of the species assessed may not be threatened in IUCN Red List terms, all species were under threat either nationally as a species or as an individual population. In terms of conservation reintroductions this was fully expected.

(2) *Have the threatening factors been removed or controlled, or were they absent in the release area?*

Half of the programmes fully met this criterion, with the other half meeting it partially. This indicates that although programmes are aware of, and are addressing threats they are not succeeding in managing and/or removing all threats completely. Given the current crisis amphibians are facing and that many threats remain unknown or unmanageable (Stuart et al. 2004), it is understandable that programmes are unable to address them. One example from the study is the Australian *Geocrinia alba* and *G. vitellina* species. This reintroduction programme has managed to successfully address site specific threats including the removal of feral pigs, drug crops and implementation of fire protection. However the programme co-ordinators are struggling with how to address environmental factors such as reduced rainfall and climate change (Williams, K. Pers. comm. - 13 March 2014).

In particular the presence of chytrid fungus is making it extremely difficult for programmes to be able to address threats. One such example includes the extirpation of the Mountain Yellow-legged frog *Rana muscosa* from areas within the southern Sierra Nevada which were thought to have been caused by chytrid (Fellers et al. 2007). This was further substantiated when all current remaining *Rana muscosa* populations tested positive for chytrid (Backlin, A. Pers. comm. – 6 May 2014). The encouraging news for this species however is that research is finding that some populations appear to be extremely resilient to the disease. As a result current reintroductions are being carried out using donors from populations that are believed to be at least partially resistant to chytrid, with the expectation being that they can persist and form viable populations (Freiermuth 2014).

(3) *Are translocations the best tool to mitigate conservation conflicts?*
Most programmes had implemented reintroduction after considering and undertaking other conservation measures or were confident that it was the only option remaining for the species. However, in some publications and action plans the issue of the best conservation measure was not always discussed. Without an assessment of alternatives the decision making process for these programmes were often unclear. Comparing alternative conservation options before embarking on a reintroduction is an important process, not only to justify reintroduction but to allow consideration of other methods. For example, published literature on the conservation of the axolotl *Ambystoma mexicanum* recommends that reintroductions should not be undertaken until a number of important issues including threats, disease and genetic management are addressed (Griffiths et al. 2004; Zambrano et al. 2007). In spite of this, reintroductions for the axolotl have been undertaken without these recommendations being implemented.

(4 & 5) *Are risks for the target species/ other species or the ecosystem acceptable?*
Risk considerations encompass a variety of factors including: disease, release sites, animal welfare and stress as well as a series of environmental and genetic factors (IUCN/SSC 2013). Currently, one of the largest risks to any amphibian reintroduction programme is disease. When chytrid fungus was identified within a population of Mallorcan midwife toads *Alytes muletensis* it was traced back to the captive breeding

facilities in the UK (Walker et al. 2008). As chytrid was unknown to science at the time it would have been impossible to detect it in the captive population. However, since the discovery of chytrid biosecurity measures are higher (Pessier & Mendelson 2010) and have been implemented at regulated breeding centres. The majority of case studies assessed had stringent disease screening in place prior to release, particularly those starting after chytrid was discovered. However, reference to post-release screening was limited.

When a reintroduction is undertaken, factors affecting other species and ecosystems also need to be considered (Armstrong & Seddon 2008). This is especially important for releases outside of the species known range and for species that have been extirpated from areas for an extended period (Wilson & Stanley Price, 1994). Very few programmes specifically referred to impacts upon other species and/or the ecosystem within published material. The most direct reference was identified within the Pool Frog Reintroduction Strategy where the issue was specifically discussed in relation to harm to other species or habitats at recipient sites (Buckley & Foster 2005). Similar strategies are outlined in most states in Australia where reintroduction programmes have to adhere to certain legal requirements which include a detailed reintroduction proposal to be submitted in which disease and impact on the existing species/ecology must be considered (McFadden, M. Pers. comm. - 6 June 2014).

(6) *Are the possible effects of the translocation acceptable to local people?*
Reintroduction has been quoted as being an important tool to engage the public with nature and gather their support (Reading et al. 1997; Seddon et al. 2012). Most of the programmes fully met this criterion and a number of recovery plans explicitly detailed community education and relations. For example, the conservation programme for the axolotl in Mexico held training workshops with the local boatmen (remeros) so that they could in turn promote conservation through tourism (Bride et al. 2008). A number of projects directly involved the community through education projects and volunteer monitoring. The Puerto Rican crested toad *Peltophryne lemur* programme involves a

local school and other members of the community in the monitoring of the toad populations (US Fish and Wildlife Service 1992). As well as community issues, cultural issues also need to be respected and addressed. In New Zealand prior to *Leiopelma* spp. reintroduction, consultation with local Maori tribes ensured that releases were culturally sensitive (Bishop et al. 2013). Human-wildlife conflicts however, are not always as straightforward. The reintroduction of the Kihansi spray toad *Nectophrynoides asperginis* in Tanzania faces a common issue in many developing nations where a poor country has to prioritise species conservation along with issues relating to poverty and access to fertile land (Rija et al. 2011). On the other hand reintroduction programme may not always require local support. A number of wildlife managers and biologists reported that community issues were considered irrelevant as releases took place within protected areas and national parks where public interface was extremely limited.

(7) *Does the project maximise the likelihood of establishing a viable population?*
Less than half of the programmes fully met this criterion. In terms of viability many of the case studies had not fully established whether they were releasing enough individuals or taking enough measures to ensure a viable population. Population Viability Analysis (PVA) is a useful management tool but is difficult to apply to amphibians unless you have sufficient data on survivorship, fecundity and dispersal rates (Griffiths, 2004). Studies by Canessa et al. (2014) looked at optimal release strategies in relation to life stages and cost-effective programmes. Their study found that releasing different life stages can maximise survival and cost-effectiveness, although this is dependent on insurance populations and of course the vital rates of released individuals. For threatened and poorly understood species obtaining such data can be extremely difficult and as a result knowing how many individuals, what life stages and time of year to release is often complex.

This is where adaptive management can be considered a key component of reintroduction success (Sarrazin & Barbault 1996; McCarthy et al. 2012). For example, the reintroduction of the Iberian frog *Rana Iberica* and Common Midwife toad *Alytes* *obstetricians* in Spain found that larval stages were heavily predated during the winter releases. As the programme was able to adapt the problem was solved by releasing larvae at the beginning of the season (Martín-Beyer et al. 2011). With a changing climate it will most likely become even more difficult to predict factors relating to population viability and how reintroduced species growth rates will respond. Therefore monitoring and recording changes and how programmes adapt to deal with them can form part of key ecological research (Sarrazin & Barbault 1996; Rout et al. 2009).

(8) *Does the project include clear goals and monitoring?*

The success or failure of a project can only be determined through sufficient long term monitoring (Seddon et al. 2014). However, monitoring is often the most challenging, (Muths & Dreitz 2008) yet frequently the least prepared for, part of a species reintroduction programme. Post-release monitoring will very much depend on the specific goals of the programme and how much continuous management is needed for the species and the habitat (Nichols & Armstrong 2012). In order to declare a reintroduction as successful the population should be self-sustaining, therefore monitoring should be undertaken until this is established (Dodd & Seigel 1991). Dodd (2005) suggests that for amphibians populations should be monitored for several generations, which can often mean at least 10-15 years of monitoring. Establishing if a programme is successful can be problematic for many reasons, including: difficulty in finding amphibians during survey, natural population fluctuation and survey methods used (Griffiths & Kuzmin 2011).

Monitoring is essential in determining how the reintroduced population is faring and if there is a need for further releases or management of the species or habitat (Sarrazin & Barbault 1996). Detailed monitoring undertaken for the Booroolong frog identified high mortality due to drought and high infections of chytrid. This prompted halting of further releases in line with the recovery plan goal that, should success not be seen at the level expected no further animals would be released (Mcfadden et al. 2010). Lack of post-release monitoring and reporting not only limits knowledge of success, it also withholds important data regarding reasons for failures (Seddon et al. 2012).

Lack of reporting continues to be an issue for reintroduction programmes particularly in the case of those that are unsuccessful. Very few of the case studies assessed published data on the reintroduction process and/or detailed results. The reasons behind this could relate to a lack of solid data or results and perhaps a lack of time to produce such publications. Recovery and reintroduction plans are often not available publically. As pointed out by Fischer & Lindenmayer (2000) even review papers of reintroductions are based on data not readily available to practitioners, and wildlife managers. Longer-running programmes such as the natterjack and boreal toads have been well documented in peer reviewed journals and the published data provides good critical reviews and data from the project (Denton et al. 1997; Buckley & Beebee 2004; Muths & Dreitz 2008).

(9) *Do enough economic and human resources exist?*
Generally most programmes felt that funding resource was available to them, if only for the initial stages. Reintroductions of *Leiopelma* spp. in New Zealand have secured initial funding through the Department of Conservation, however the programme is aware that additional funds will be needed in order to fully implement the species recovery plan (Bishop et al. 2013). Other programmes reported having no funding at all; the Cape platanna *Xenopus gilli* in South Africa had a goal to re-establish the species yet the project had no funding or capacity for systematic monitoring (Measey & de Villers 2011). Similarly the experimental releases of Andean marsupial treefrog *Gastrotheca riobambae* in Ecuador stated that there was no funding and the future for the project was unclear with monitoring only able to continue as long as the research facilities remain in place (Coloma, L. Pers. comm.. - 12 May 2014). The issue of resource in terms of conservation funding is complicated as most funding tends to be short-term (Wilson et al. 2011).

(10) *Do scientific, governmental, and stakeholder groups support the translocation?*
The majority of programmes appeared to receive support from stakeholders and scientific backing. Additionally in all of the programmes assessed (where the information was available) government permits and/or licences were required in order for the

reintroduction to take place which provides an indication of some government support at least. Despite this, government support can often change when different parties or individuals take charge. Such changes can have significant impacts upon programme support and funding. It can therefore be difficult to secure any long term financial security or support if political situations are volatile (Kleiman et al 1994). Reading et al. (1991) suggested that many programmes may fail due to a lack of consideration for non-biological factors. It is therefore important to gain support from key stakeholders as Sarrazin and Barbault (1996) state in reference to Kleiman et al. (1994) the success of reintroductions can often be more greatly influenced by bio-political conditions and long term funding rather than scientific rigour.

Duration and Criteria Met

The positive relationship between the number of criteria met and programme duration indicates that longer running projects are meeting more criteria. This relationship is likely to relate to the planning and adaptability of a project. Long-standing projects may not have fulfilled all of the criteria initially but with the benefit of experience, and perhaps failures, most have been able to address and rectify them. For example, in the case of the natterjack toad research relating to habitat preference identified that juvenile natterjacks preferred grazed over ungrazed heathland. These findings were then fed back into the programme, enabling better management measures to be employed at release sites (Denton & Beebee 1996). Although longer running programmes meeting more criteria was expected, it would also be reasonable to expect recent projects to be addressing more criteria. This theory is based on the assumption that newer projects would be more likely to consider emerging guidelines (that perhaps were not available for older projects) and have a greater level of understanding (due to the increased experiences and publications of reintroductions for similar amphibian species). There are two probable reasons that this is not the case. Firstly, established guidelines are not used as the basis for beginning a reintroduction and secondly that information and experience of reintroductions from within the amphibian conservation sector are not being shared and used as well as they could be. Additionally, although this was not quantified, there may be a potential bias in the data in that longer-running programmes have more accessible published data and research.

Duration and Success

The relationship between the duration of a project and its success level proved to be significant and longer-running projects showed higher levels of success. As it can take a number of years, even decades before a population can be considered self sustaining (Dodd & Seigel 1991; Griffiths & Kuzmin 2011) this result was expected. The median duration for successful projects was 16 years. The shortest duration for a high success project was the Common toad and frog reintroduction undertaken by Cooke and Oldham (1995) and monitored over a period of seven years. This reintroduction was successful early on with the population deemed as stable six years after reintroduction (Cooke & Oldham 1995) but as monitoring ceased in 1993 it is not known if the site still contains a viable population and if the project can still be deemed a success.

The findings that longevity is linked to success is supported by previous studies where long running programmes were seen to be more successful (Griffith et al. 1989; Beck et al. 1994). A similar study by from Beck et al. (1994) showed that projects with longer duration, based upon release years, contributed to success, whilst Griffith (1989) found that projects were more successful with longer duration and more animals released. Further research looking into the release years of the programmes in this study would be beneficial into further understanding factors contributing to reintroduction success.

Success and Criteria Met

Fourteen of the 62 programmes assessed were deemed to be highly successful, with an average of nine of the ten criteria met. Whilst the 12 programmes considered to be of low success met an average of six criteria. This provides a strong indication that meeting with the criteria is linked to achieving reintroduction success. As previously mentioned success is also extremely difficult to quantify; how many years and what results indicate a population is self-sustaining? Are all projects following a similar method before claiming complete success? Strictly speaking, very few reintroduced amphibian populations can be entirely self-sustaining (Burke 1991; Fischer & Lindenmayer 2000), even when a population becomes stable there are very few habitats that can remain stable without some intervention or protection (Seddon, 1999). The guidance from IUCN (2013) states that the intensity and duration of monitoring of translocated populations should be appropriate to the situation. However, this statement would benefit from further guidance that details different scenarios and examples such as the explicit criteria adopted by Denton et al. (1997) to measure success for reintroduced natterjack populations.

Conclusions

Reintroduction Guidance

Whilst reviewing published data for the reintroduction programmes there were very few cases that referred directly to any of the IUCN Guidelines for Reintroduction. The pool frog Reintroduction Strategy (Buckley & Foster 2005) was the only document found to include a specific assessment of the proposals against the IUCN criteria. Other reintroduction strategies such as the Kihansi Spray Toad (Khatibu et al. 2008) created a set of project specific guidelines which covered most of the criteria. However, most cases included only Recovery Plans which did not fully encompass the details of a reintroduction strategy. The reasons for the lack of reintroduction plans could be that much of the initial planning is not documented and, or these details are only made available to the relevant government authorities and, or that IUCN Guidelines are not used as a basis for reintroduction plans.

Ideally IUCN guidelines would form the basis of a reintroduction plan with each programme having considered each of the key points. To encourage this approach within amphibian conservation it would be beneficial to have a set of guidelines produced specifically for amphibians. This would not only create a more direct, relevant and comprehensive set of guidelines but would also go some way to ensuring wider adoption of the guidelines within the amphibian conservation sector. Reducing the guidelines to a more manageable set of criteria such as the one used in this research or those developed by Seddon et al. (2014) to select de-extinction candidates could be a useful tool for the initial assessment and planning of proposed reintroduction programmes.

Amphibian Reintroductions Recommendations for success

This study looked at the methods, criteria adopted and relative success achieved by amphibian reintroduction programmes. Due to the selection criteria used there is a natural bias towards projects with publications and available data. As a result, programmes with little/no data or contacts were unable to be assessed. This study may not therefore present a full picture of amphibian reintroductions.

The analysis of 62 amphibian reintroduction programmes highlighted a number of positive and negative aspects of specific programmes and the wider process. The key findings from these programmes highlight the following measures can help a programme towards long term success:

- Research: Having data on or undertaking field studies to understand species, ecology, behaviour and biology is critical for any conservation project. Additionally, with habitats changing and populations adapting, habitat and climate data are essential.
- Planning: If reintroduction is the only option then a detailed plan containing the evaluation process along with a project specific set of guidelines should be produced. A comprehensive plan such as the Pool Frog Reintroduction Strategy (Buckley & Foster 2005) is a good example.
- Monitoring and Reporting: Monitoring reintroduced populations allows programmes to adapt to new threats and changes to the environment and apply adaptive management where needed. Reporting these data provides an invaluable resource for conservation practitioners considering undertaking similar approaches and can contribute to species research and knowledge.
- Release sites: Habitat quality is not emphasised in this study but is nevertheless a vital part of species reintroduction (Seddon et al. 2012) and considered to be a key

determinant of reintroduction success (Griffith et al. 1989; Wolf et al. 1998). When basing the release site on current population habitat it is important to consider if the habitat is suitable and if the population is still thriving. Monitoring existing populations to understand status is important before introducing the species to other areas (Osbourne & Seddon 2012).

- Experimentation: Experimental releases were not assessed in terms of success in this study. However, the experimental stage of a project is vital for any reintroduction programme (Dodd & Seigel 1991). Undertaking these releases gives a level of understanding of reintroduced individual's ability to survive and adapt and may offer important insight into age classes needed to establish a viable population (Trenham & Marsh 2002). Trial releases must also follow the same stringent procedures as a full reintroduction (IUCN/SSC 2013) as they still carry the same risks and requirements
- Resource and Support: Ensuring adequate resources such as funding and personnel were found to be key drivers of success. Support and partnerships with governing authorities, NGOs and universities were also common denominators of success.

Despite these key contributors towards success, ideally programmes would be assessed against the ten criteria in advance of any reintroduction programme taking place. Perez et al. (2012) suggest that if a programme fully complies with the criteria it is justifiable as a conservation reintroduction. As we have seen, longer running programmes meet more criteria; however it is debatable that this would have been the case before the programme began. Establishing if a programme will establish a viable population and if enough resource is available long term are difficult criteria to fully comply with at the outset. It is therefore important to consider that even with the best planning some criteria will not always be fully met.

Future

This study shows that longer-running programmes were more compliant with reintroduction guidelines and demonstrated the highest levels of success. All of the programmes involved threatened species or populations. However, it was the threats facing them and ascertaining their viability that were identified as the most difficult factors to fully address. There are a number of highly successful projects that, as a whole, appear to be working towards clear goals and monitoring with the adaptability to reassess depending on their results. In general successful programmes had wide-ranging published data and were led by strong collaborations between government agencies, NGOs and zoos. This level of expertise along with stronger guidelines and legislation will help to ensure that future reintroductions are carried out to a higher standard.

General Discussion

The deterioration in amphibian species is currently outweighing efforts to improve their conservation status (Hoffmann et al. 2010). Finding solutions to address these declines and extinctions is considered to be one of the greatest conservation challenges of the 21st Century (Bishop et al. 2012). Based upon data from this study approximately 3% of all amphibian species, which equates to 7% of all threatened species (listed in IUCN Red List as Vulnerable, Endangered or Critically Endangered), are part of ex situ conservation programmes; that is they are, or have been in captive breeding, captive breeding and reintroduction or reintroduction programmes.

Conservation breeding and the ACAP

The ACAP states that captive breeding programmes should not be seen as a final solution and are not aimed at replacing important in situ conservation and research, but are rather a way of enabling the survival of species through captive assurance colonies whilst research proceeds (Gascon et al. 2007). In spite of this, there is logic in reintroducing species that are understood well e.g. their threats, biology and ecology. The trade-off here is that the species we know most about and whose threats can be more easily addressed are likely to be the least threatened (Caughley 1994; Griffiths & Kuzmin 2011).

Amphibian Ark's future plans include an increase in efforts towards reintroduction, release, translocation and head starting to tie ex situ work with in situ partners and programs (Johnson et al. 2012). However the ACAP conveys concern regarding recommendations for species reintroduction within the GAA. Stating that there is a wide variation between regions and that this may be a reflection of regional expertise and personal interests rather than suitability and need for reintroduction (Gascon et al. 2007). Therefore it is vital when considering species for future release that they follow assessment criteria such as that listed within the ACAP and the IUCN Reintroduction Guidelines (2013).

Current captive breeding data also showed that there are now a large number of programmes within the tropics. Whilst reintroduction is a fairly common conservation strategy in the temperate developed world, it is uncommon in the tropics (Beck et al. 1994). In a similar way to how AArk delivered husbandry workshops, if amphibian reintroductions are to take place, additional resources will be needed in order to train and provide support for practitioners in these areas. An additional issue here is that in developed countries, particularly Australia, USA and EU countries, reintroductions follow strict methodologies which must be approved by and are often assisted by governing authorities (Beck et al. 1994; Wilson & Stanley Price 1994). Although permits are generally required in most developing countries the same level of understanding and consultation is unlikely to occur. Assessing proposed reintroductions as the ACAP intends, following appropriate criteria and ensuring practitioners and governments are armed with enough expertise, will help to ensure reintroductions are carried out to the highest possible standard.

Guidance & Decision Making

Research undertaken in Chapter 3 showed that there is a relationship between meeting key reintroduction criteria and programme success and a significant relationship was seen between high success rates and longer programme durations.

In addition to meeting key criteria, the criteria themselves also need to be relevant and accessible. Therefore having a set of guidelines specifically for amphibians and published examples of successful and unsuccessful programmes would be a valuable resource. However, such published examples are still limited (Grow & Poole 2007). For example within the four IUCN compilations of reintroduction case studies (Soorae, 2008, 2011; 2010, 2013) amphibian reintroductions contributed the fewest number of examples whereas mammals and birds tended to dominate. An encouraging step and solution to at least some of the accessibility issues has been the publication of the Amphibian Conservation Evidence Synopses (Smith & Sutherland 2014). This is one of many valuable free resources set up by the University of Cambridge which provides evidence about the effects of a variety of conservation intervention and management (Sutherland 2014).

In addition to access to publications, the issue of collaborative relationships between conservation practitioners, zoo specialists and research scientists is considered by many to be a key component of successful conservation (Stanley Price 2005; Seddon et al. 2007; Arlettaz et al. 2010). With such a large part of amphibian conservation focussed on ex situ methods, zoos are augmenting their role in species conservation. This is something that is being actively encouraged by the World Association of Zoos and Aquariums (WAZA) through the publication of conservation strategies (WAZA 2005; 2006; Grow & Poole 2007; Penning et al. 2009). To promote this further the IUCN Conservation Specialist Group (CBSG) has adopted a One Plan Approach designed to improve conservation planning by ensuring a wide range of parties are involved in the early stages. This approach is intended to create more comprehensive plans and bridge the gap between wild and captive population management (IUCN CBSG 2014).

Future

Implementing strategies for the release of captive species and forming partnerships to improve conservation research linked to ex situ conservation will no doubt play an important role in the fight against amphibian extinction. However, amphibians are continuing to decline at an alarming rate and the threats they face appear to be increasing. As ex situ conservation is a long term initiative its efforts are unlikely to show an improvement in the status of threatened amphibians for some time. It is therefore clear that much more needs to be done and that ex situ conservation alone cannot solve the current crisis.

Amphibians are a highly diverse group and as such it is likely to take a diverse set of tools to address the threats they are facing. However, such efforts may be in vain unless we can learn as human beings to protect the ecosystems amphibians depend on.

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Appendix A: Species Data Obtained for Pre and Post-ACAP Analysis

Data obtained for all species

1. Scientific name, common name, order and family
2. Country(ies) of distribution
3. Country of programme (if different from the country of distribution)
4. Type of conservation programme (1) Captive breeding only, (2) Captive breeding and reintroduction, (3) Reintroduction only
5. IUCN Red list status and in-country status and protection
6. Threats to species: (1) Habitat loss; habitat degradation, loss & fragmentation/pollution/development, (2) Invasive Species: introduced/alien species, (3) Human use; consumption/hunting/medicine, (4) Climate Change; natural disasters fires, droughts, fires, volcanic activities/other related weather conditions, (5) Disease; all diseases and pathogens that may be considered a threat to amphibians, (6) Trade; illegal and/or legal trading of species, (7) No major threats; no threats identified that could cause a major decline of species and (8) Other threats; all that do not fall within the above or were recorded at very low numbers such as; Intrinsic Factors (Poor recruitment/ reproduction/regeneration/restricted range), natural predators/competitors and already extinct in the wild.
   NB: Only the first 6 categories were used in the analysis as these were considered to be the principle threats.
7. Links to in-situ programmes
8. In situ programmes: (1) Habitat management, (2) Control of invasive species, (3) Public education, (4) Research, (5) Training local conservationists, (6) Public/political awareness, (7) Protected areas/conservation, (8) Land purchase, (9) Unknown
9. Programme dates: (1) Year started, (2) Year ended, (3) Ongoing, (4) Future

Data obtained for species in captive breeding programmes

1. Success of programme: (1) Successful captive breeding, (2) Difficult to breed but some success, (3) Unsuccessful captive breeding.
2. Reasons for captive breeding: (1) Research: Relates to all research being undertaken to contribute to the species conservation (2) Reintroduction: Primary reason to release captive bred stock (3) Education: used as a tool to raise awareness for the species protection (4) Commercial (pet trade, etc), (5) Fund-raising, (6) Medicine, (7) Bred in zoos, (8) Rescue* (9) Unknown.

** Programmes identified on the AArk ex-situ database as taking place as a rescue following a conservation needs assessment workshop (CNAW) identified as being a species that is in imminent danger of extinction (locally or globally) and requires ex situ management, as part of an integrated program, to ensure its survival or Rescue or, nNot designated as rescue during an assessment, but managed by national/local experts as such because no assessment has been completed.*

Data obtained for species with reintroduction programmes

The following data was obtained in relation to reintroductions already undertaken or planned for the future.

1. Reintroduction (1) Yes (2) No
2. Translocation of wild individuals/tadpoles/eggs (no captive breeding) (1) Yes (2) No
3. Re-enforcement/Supplementation (1) yes (2) no.
4. Conservation Benign Introductions (outside recorded distribution).
5. Only re-introductions of captive bred individuals: (1) Already carried out, (2) Planned for the future (Future reintroduction programmes where considered only when the program, the funding or the facilities were in place).
6. Level of success (1) Lowest level of success: Simple survival but insufficient evidence of long-term viability. (2) Medium level of success: Breed successfully in the wild. (3) Highest level of success: Self-sustaining viable population. Those species that did not survive were defined as 4) Unsuccessful.
7. Year since release started (number of years).
8. Release in the wild in recorded distribution or outside recorded distribution -or to ponds/artificial.
9. Re-introducability: (1) No threats reversible, (2) Some threats reversible, (3) All threats reversible, (4) Unknown
10. Objectives of releases: (1) Re-establish an extinct species, (2) Enhance long-term survival of endangered species, (3) Economic/commercial use, (4) Promote conservation awareness and education.
11. Reasons for unsuccessful releases: (1) Disease, (2) Juvenile/adult mortality, (3) No breeding in the wild, (4) Catastrophes, (5) Dietary deficiency, (6) Unknown.

When categorisation was used, multiple selections were permitted therefore each programme can be linked to more than one reason, threat, in-situ programme or objective.

Appendix B: Publications by the Author

- Valenzuela-Sánchez, A., Harding, G., Cunningham, A. A., Chirgwin, C. and Soto-Azat, C. (2014), Home range and social analyses in a mouth brooding frog: testing the coexistence of paternal care and male territoriality. Journal of Zoology. doi: 10.1111/jzo.12165

- Germano, J.M., Field, K.J., Griffiths, R.A., Clulow, S., Foster, J., Harding, G. and Swaisgood, R.R. (in press) Mitigation-driven translocations: are we moving wildlife in the right direction? Frontiers in Ecology and the Environment.

Appendix C: Species and Programme Data (CD-ROM)

- Chapter 2 Spreadsheet data:
    - Pre-ACAP Species Data
    - Post-ACAP Species Data

- Chapter 3 Assessment Criteria Data