General guidelines for managers and supporters of amphibian captive breeding programmes

Using lessons learnt from an interview study with programme managers in Latin America, Africa and Asia

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Keeping threatened amphibian species afloat

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Imperial College London

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Version 1.0

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2018

Citation
Karlsdottir B (Ed.). 2018. General guidelines for managers and supporters of amphibian captive breeding programmes: using examples from study results on barriers to programmes in Latin America, Africa and Asia Version 1.0. Durrell Wildlife Conservation Trust / Amphibian Ark p.69

The guidelines are based on study results obtained by the author during a Master's thesis at Imperial College London. The study was supported by the Amphibian Ark and Durrell Wildlife Conservation Trust.

Acknowledgements
These guidelines were made possible by the participation of generous programme managers around the world who provided their valuable experiences for the study. I would like to thank Ben Tapley, Kevin Johnson and Jeff Dawson for their reviews and contributions to the guidelines. I additionally thank Dr Andrew Knight for his supervision of my thesis. I thank Imperial College London for funding to complete the study. I am also grateful to Durrell Wildlife Conservation Trust for the opportunity to further my research in an internship position.

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Cover photo
Masked tree frog by Berglind Karlsdóttir.

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1. INTRODUCTION

1.1. To the reader

These guidelines are produced based on information provided by managers of amphibian captive breeding programmes in Latin America, Africa and Asia, along with input from experts at Durrell Wildlife Conservation Trust, the Amphibian Ark (AArk) and the Amphibian Specialist Group (ASG) Captive Breeding Working Group. This information was gathered as part of an MSc thesis with Imperial College London, looking at barriers which might prevent amphibian captive breeding programmes achieving conservation success. The main body of the guidelines comprehensively discusses these barriers (listed in Figure 3) and recommendations for overcoming them. It also explores enablers, such as partnerships, to increasing the chances of success. The guidelines are designed for readers to **easily flick through** the topics that are of relevance to them (especially the subheadings in Section 3.). To include all relevant information under each topic, there is some overlap and repetition between them. The operational model presented in Figure 1 is intended as an insight into the barriers encountered and the resources needed at different stages of the lifespan of a programme. Following the model will allow you to plan and implement an effective programme.

1.2. To the supporter

The study (on which these guidelines are built) was initiated based on the need for increased support for amphibian captive breeding programmes. There are many programmes with high potential for impact being run by conservation leaders in most regions of the world. However, most of these programmes cannot sustain themselves and produce results without external support. Although funding is the main type of support provided by partners, it is not the only one. Information and expertise, and field work assistance are also commonly provided by partners, with great benefits to these programmes. The main takeaway point for you as a supporter is that every programme needs different resources at different stages. For example, access to a network of experts and donors is important when establishing a programme, while support for conducting field research is needed before reintroductions. The guidelines are designed so that you as a supporter can easily locate relevant information on partnerships and support in the **green text boxes** throughout the document.

1.3. Captive breeding programmes as a complementary tool to conservation

Amphibian populations worldwide have plummeted due to a range of threats, the biggest of which is habitat degradation and loss (Stuart et al. 2008). Amphibians are particularly vulnerable to changes in their environment due to their physiology with very specific environmental requirements. Emerging infectious diseases, climate change, pollution, pet trade, harvesting and invasive species also pose threats to many amphibians (Stuart et al. 2004; Stuart et al. 2008), and over 40% of species are now estimated to be threatened with extinction (IUCN 2017).

The global pattern of decline in amphibian populations was first brought to light at the World Congress of Herpetology in 1989 (Wake 1998). The Amphibian Conservation Action Plan (ACAP) was developed in 2005 to coordinate global strategic actions between relevant partners (Gascon et al. 2007), in the fight against what has been named the "amphibian crisis". As a result of this, 2008 was declared "The Year of The Frog" (Pavajeau et al. 2008) and widespread campaigns raised funds and awareness for amphibian conservation.

Ex situ programmes are intended as a complementary tool to in situ conservation (Pritchard et al. 2011; Byers et al. 2013), in cases where declines and extinctions cannot be prevented by in situ measures alone (Zippel et al. 2011). To address this, the Amphibian Ark (AArk) was established in 2006 by the IUCN SSC Captive Planning Specialist Group (CPSG, then Captive Breeding Specialist Group), the World Association of Zoos and Aquariums (WAZA) and the IUCN SSC Amphibian Specialist Group (ASG). The AArk oversees the captive breeding aspect of the ACAP, which is carried out by partner institutions worldwide.

There are many limitations to captive breeding programmes, which remain somewhat controversial (Bowkett 2008). The establishment of a captive breeding programme paradoxically requires collection of founding individuals from small, vulnerable populations, constrained by preceding declines (see Ralls & Balou 2013; Minteer et al. 2014). Additionally, the survival of collected individuals depends on a programme's success. Captive breeding programmes are resource intensive, long-term investments (Tapley et al. 2015a) running for a decade or more before success can be confirmed (Griffiths & Pavajeau 2008) in a field which suffers from restricted funding. This highlights the need for triage to improve return of investment and chances of success (Bottrill et al. 2008).

For amphibians, this poses a trade-off between prioritising species with lower threat levels and higher chances of success (i.e. species with sufficiently-sized founding population and threats that can currently be mitigated) and those of higher threat levels, with lower chances of success (i.e. species with small founding populations and no foreseeable possibility of reversing threats, such as the chytrid fungus or lack of suitable habitat). The duration of a captive breeding programme has a significant impact on the likelihood of success, due to dependence on continuous management and availability of resources, and to increased risks of inbreeding depression and adaptation to captivity (Balmford et al. 1996; Tapley et al. 2015a). Some authors recommend that resources are spent on proactively implemented programmes with a foreseeable possibility of performing reintroductions (Griffiths & Pavajeau 2008; Tapley et al. 2015a) and the AArk's Conservation Needs Assessment species prioritisation process has been designed to address these factors (Johnson et al. 2018).

Although the cost-effectiveness of ex situ incentives has been questioned (Balmford et al. 1996; Dodd 2005; Bowkett 2014), available resources for these initiatives are not always transferrable (Bowkett 2009). Many of these programmes are set up in zoos by zoo-based staff, to increase the conservation

and education impacts of their collections (Browne et al. 2011). It is perhaps unlikely that this funding and staff time would be reallocated to field programmes. Focus could therefore be diverted to improving the effectiveness of ex situ programmes.

The contributions of zoos and captive breeding programmes towards amphibian conservation have been repeatedly evaluated. In 2008, Griffiths & Pavajeau found that just under half of amphibian captive breeding and reintroduction programmes had no plans for reintroductions but were for research or education purposes. Of the 21 cases where assessment of success post-reintroduction was possible, 13 species had displayed evidence of breeding for multiple generations in the wild, and another 5 displayed some evidence of breeding. A replication of this review by Harding et al. in 2016 found an encouraging 57% increase in programmes since 2007, showing some effect of the extensive awareness raising following the ACAP and the Year of the Frog campaign. However, much fewer programmes were performing reintroductions (down from 41% to 16%). This was suspected to be directly related to the increase in threats that cannot currently be mitigated (i.e. chytrid fungus or lack of suitable habitat).

Zoos collectively are seen as a major partner in the global conservation of amphibians (Browne et al. 2011; Dawson et al. 2016), and with 700 million visitors and an income of $350 million/year (Gusset & Dick 2010), they hold a lot of potential. Zoo collections are considered important as they can act as managers of captive “metapopulations” (Conde et al. 2013; Dawson et al. 2016), contributing to maintenance of genetic diversity. Moreover, partner zoos working on the same or similar species are essential in the developing of husbandry and breeding protocols, and the sharing of knowledge between them. However, calls for zoos to maintain captive breeding collections in-house, outside of their geographic range (Zippel et al. 2011; Dawson et al. 2016; Biega et al. 2017; Brady et al. 2017) have been subject of much debate (Tapley et al. 2015a; Canessa 2017; Griffiths 2017; Martin et al. 2017; Tapley et al. 2017). Amphibian diversity, endemism and threat status is elevated in the tropics (Stuart et al. 2004), and it is recommended that captive breeding programmes are established within the species range. This decreases the risk of disease transmission and builds local capacity for amphibian conservation (Zippel et al. 2011; Pessier & Mendelson 2017). However, capacity for amphibian husbandry is often lacking in these regions (Zippel et al 2011; Tapley et al 2015a)

The *Committing to Conservation* strategic report by WAZA (Barongi et al. 2015) manifests a commitment of the zoos community to contribute to conservation, following best practice standards. In 2016, Dawson et al. found a significant increase in the number of globally threatened amphibians in zoo holdings, following the Global Amphibian Assessment in 2004, now representing 6.2% of all threatened amphibians. This remains much lower than other vertebrate groups (Conde et al. 2013). Furthermore, of the 577 species currently recommended for ex situ research and conservation programmes via the Conservation Needs Assessment process (31% of species have been assessed to date), just 180 are currently held in such programmes (Baker et al. 2017). Barriers to increasing the number of threatened amphibian species in zoos include a lack of resources, disease and biosecurity concerns, lack of staff expertise/knowledge, difficulty displaying amphibians, and difficulty attracting visitor interest (Brady et al. 2017).

These guidelines address knowledge gaps of the resource needs of programmes in target regions, defined here as Latin America, Africa and Asia. They are built on 25 interviews with programme managers based in those regions, which were conducted and analysed as part of a Master’s study. We include an operational model for guiding the implementation of these programmes, with advice on how to increase chances for success and maximise impact; relevant for both managers and supporting organisations.

1.4. The importance of human processes

When amphibians are taken into captivity, their survival becomes entirely dependent on us! Managers tend to have a background in natural sciences, and not in finance, management and social relations. As a result of this, previous studies have largely focused on the impacts of various biological factors on captive breeding programmes, and human dimensions have been largely absent in this discussion (Sutton 2015). They are however of equal importance (O'Rourke 2014) and barriers to keeping more globally threatened amphibians in zoo collections include human factors such as lack staff time, expertise and knowledge (Brady et al. 2017)

Management practices influence every aspect of a programme, and there are numerous examples of cases where poor relationships or the loss of a manager has led to termination of a programme. On the other hand, most programmes would not have been initiated if it wasn't for that single, passionate leader.

Whatever the impact of the leader, it will never be neutral. It will highly depend on the personal values and ethics of that individual, and management models thus vary between programmes. This is further influenced by organisational culture: the behaviours and espoused values that underpin professional norms (Schein 1984) and manifest in management practices and decision making (Schein 2010). To optimise the decision-making process, best practice industry standards should be available, containing uniform and evidence-based advice.

Monitoring and evaluation also play an important part here to ensure that management practices keep the programme on track to achieving long-term conservation goals, or if not, what can be changed? Exit strategies should always be developed for programmes, reflecting on when a programme will be considered finished, whether successfully or not (IUCN 2013). Monitoring and evaluation also plays an important part in the learning process. Too often, best practice conservation methods are built on lessons learnt from successes, often overlooking the influence of luck. Catalano et al. (2017) argue that lessons learnt from failure are essential in challenging and improving current methodologies.

A qualitative approach (a thematic analysis) was adopted to capture the depth and the context of both human and non-human factors as well as the relationships between them. In the guidelines we provide a comprehensive picture of the operational complexity of these programmes, which is simplified in the operational model in Figure 1.

2. THE CURRENT PICTURE

The following section provides a detailed overview of the progression of programmes towards success. The barriers and enablers outlined in Figure 2 are discussed in detail in section 3. The material is based on the results of an interview study of amphibian captive breeding managers in Latin America, Africa and Asia.

2.1. Operational Model

The impact of amphibian captive breeding programmes depends mainly on careful planning and implementation. This was conceptualised in the operational model in Figure 1. Operational models are commonly used in businesses to represent how value is delivered to the customers, and how the business runs itself. The use of operational models in conservation has served the purpose of guiding implementation of conservation action (Knight et al. 2006), bridging the gap between knowing and doing (Pfeffer & Sutton 1999); or in this case, scientific recommendations and management practices. The model in Figure 1 outlines two types of programmes; the first is a reactively implemented programme, which is set up rapidly as a response to critical declines, often without much information or planning at the onset (the norm). The second is a proactively implemented programme where information is available, and planning has ensured higher chances of success in the long run (the ideal). It also provides recommendations on key actions and partnership support. The model further acts as a reminder to both managers and supporters, that the needs of a programme will differ at different times. In fact, different programmes struggle to shift their focus and/or resources depending on their objectives, resulting in a 4-stage process. Although these stages are not necessarily linear, with overlaps between them, barriers and needs often changed between stages. Each stage is briefly described on the following pages.

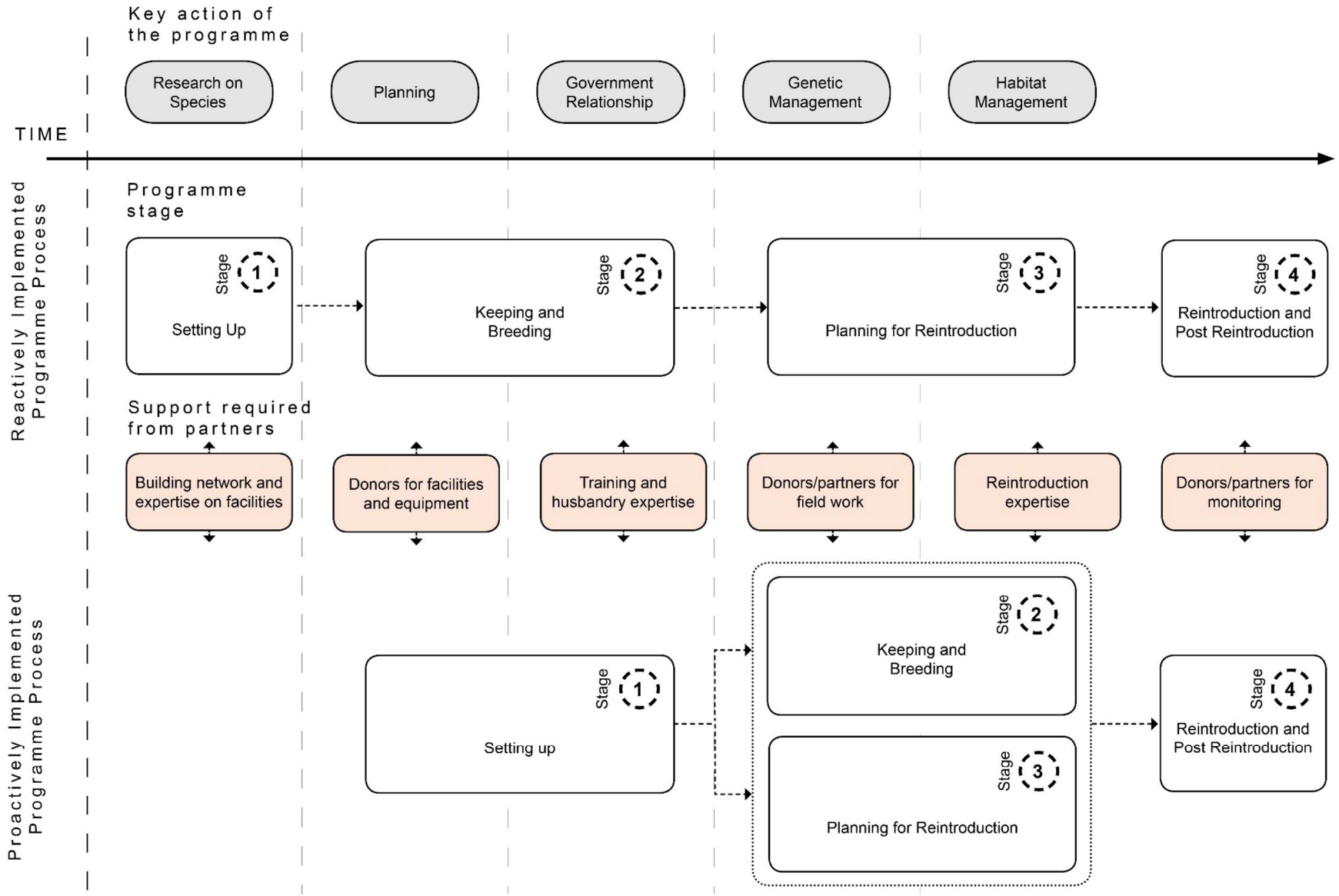


Figure 1: Operational Model. Key actions (grey) and support required (orange), positioned in line with the steps at which they occur, illustrated for a reactively implemented programme process on the top, and a proactively implemented programme process on the bottom. Model taken from the original study.

Stage 1: Establishing a Programme

This stage runs from the initial idea for a programme, to the collection of individuals. It mainly involves selection of priority species and preparation of facilities. Main barriers and enablers relevant at this stage include availability of financial resources, infrastructure for the captive breeding, captive environmental control systems, species-specific information, prioritisation of species, amphibian husbandry expertise, and staff training and expertise.

At this stage, a critical process of decision making and prioritisation of species takes place. Lack or inaccuracy of information on species' threat status and life histories often limits this process, and poor planning and prioritisation of species often leads to barriers at a later stage.

A global and regional network is important for initiating a programme, as local capacity for these programmes is often limited. Partners are instrumental in facilitation of this network with other relevant partners and donors, and thereby resources. Parent organisations sometimes provide facilities and staff, while the AArk seed grant is often critical for acquisition of equipment. Furthermore, input on the training of staff, and the design of facilities and equipment is needed at this stage.

> *"I think the biggest failure was the initial planning. Why? Because I would have liked to start with another [species] not just with what […] is most attractive".*

Stage 2: Husbandry and Breeding

This stage starts when the founders are first brought into captivity. It is dominated by a process of developing and optimising husbandry and breeding protocols, with the aim of breeding a sufficient, genetically and demographically viable population for the perceived duration of the programme. Main barriers and enablers are similar to those in the Establishing a Programme stage: captive environmental control systems, species-specific information (e.g. breeding triggers), permits, food and nutrition, amphibian husbandry expertise, and staff training and expertise.

Although lack of information on the species' captive requirements often poses a significant barrier, many programmes have managed to develop protocols for poorly known species. Staff training and expertise is essential, and when lacking, is a main cause of failures (see quote). For independent programmes, fundraising for staff is often a challenge, leading to low salaries and low staff retention. For programmes within zoos, prioritisation of staff time for amphibians often poses a barrier. This makes staff specialisation in amphibian husbandry more difficult, and in some cases, staff willingness for keeping amphibians is lacking.

> *"And I think […] they sprayed them with F10 [a disinfectant] thinking it was water. So that didn't end well you know. So again, it's coming back to trained personnel being switched on."*

It is important to maintain good relationships with partners during this stage, to maintain the flow of resources and collaboration on target species. Training of staff is the third most common resource provided by partners, including workshops, training courses and internships. Informal discussions between managers and partners further provides context-specific advice, vital in overcoming failures. Some programmes experience difficulties in obtaining the right equipment in-country and use external contacts to facilitate this process.

Stage 3: Preparing for Reintroductions

During this stage, programmes proactively work towards making reintroductions feasible. This includes mitigating threats in the wild and developing reintroduction protocols. Barriers and enablers differ from previous stages, and between programmes. The main barriers and enablers include habitat conditions, government and public relations, bureaucracy, permits, allocation of resources for field work and access to field sites.

The shift to this stage is the most critical transition for a programme, dominated by a research-implementation gap (Knight 2008), as the resources needed here and the focus of the programme in general need to shift towards more field work. The inability to do so results in projects getting stuck at this or the previous stage. Furthermore, partnership relations are very important to maintain support for performing future reintroductions

Partners are important here as the resources and time required for this stage are often not held by the programmes or their parent institutions (see quote below). Required support differs from previous stages, and mainly includes government support, funding and collaborations for field work, research on suitability of habitat, genetic research and technical reintroduction expertise.

> *"We've got a bunch of existing monitoring work. We've got some nascent reintroduction work and we recognize we just don't have the capacity to, to do this ourselves. And we're seeking additional partners who will be able to provide the manpower to come and take this project to the next level."*

Stage 4: Reintroductions and Post-Reintroductions

This stage consists of the release and continued post-release monitoring of reintroduced populations, as it can take over a decade before the success of a programme can be determined, highlighting the need for long term commitment (Griffiths & Pavajeau 2008). This monitoring and assessment is important for evaluating success of individual programmes as well as reintroduction programmes globally. It also allows for the identification of emergent problems, facilitating timely change in husbandry and release methods etc. The main barriers and enablers here include habitat conditions, government and public relations and allocation of resources for field sites.

Reintroductions require time-consuming field work for monitoring and sometimes habitat management. Access to appropriate, often specialised equipment for tagging is important to monitor the survival of reintroduced individuals, as well as managing captive collections. The need for monitoring, stakeholder engagement, and awareness raising is continuous, and external field partners are important actors for some or all of these tasks.

2.2. Measuring the significance of barriers and resources

Common and critical barriers and enablers

Some barriers are common, but not very severe in their consequences while other barriers can be critical, but unique to just one or a few programmes. The graph below highlights the most common and most critical barriers and enablers, four of which are both. These four; habitat conditions, public relations, government relations and captive environmental control systems, are the most important barriers to overcome. The barriers and enablers were identified using a thematic analysis (Gale et al.

2013), which includes the development of a thematic framework (a complete list of barriers and enablers). An adapted version of the thematic framework is shown in Figure 3. Most barriers are described in depth in section 3, providing an account of when and why they occur, how they interact with other barriers, and recommendations on their prevention or solutions.

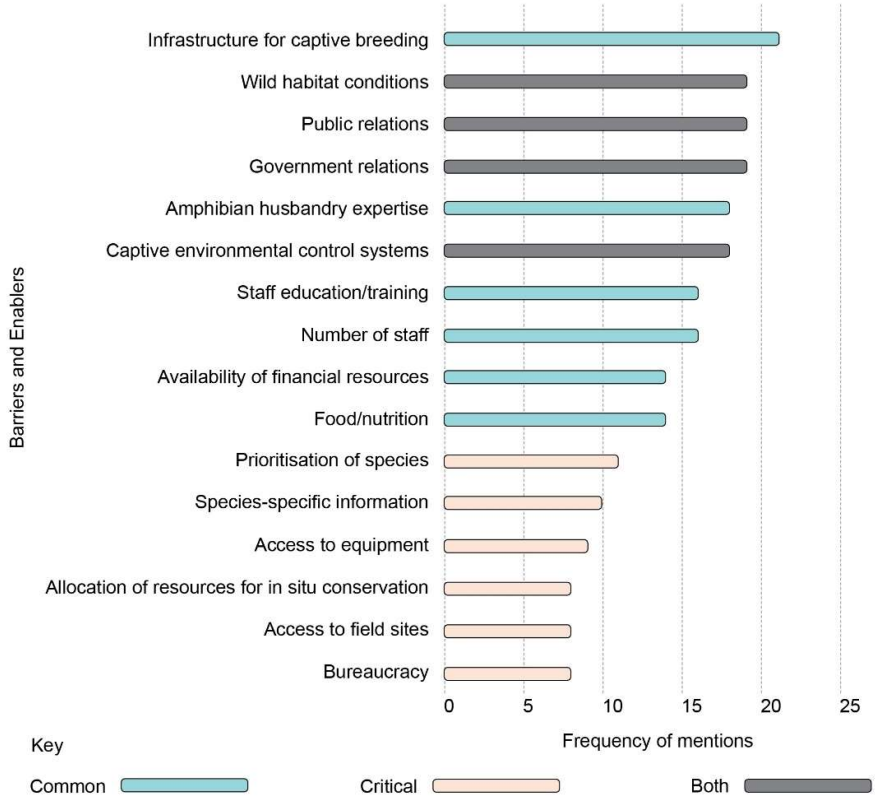


Figure 2: The most critical and most common categories (identified from the thematic framework analysis and a critical barriers summary) based on the number of sources in which a category was mentioned. Data taken from Karlsdóttir et al. In prep. Definitions of the categories are provided in table 1.

Definitions of barriers and enablers in Figure 2:

Infrastructure for captive breeding: Building or other facilities for the amphibians, live food, staff, visitors and equipment.
Wild habitat conditions*:* Conditions of habitat in which the species lives or is to be introduced, and mitigation of threats.
Public relations*:* Education and engagement of the public, stakeholders and communities.
Government relations: Relationship with the government.
Amphibian husbandry expertise: Available expertise for development of husbandry and breeding protocols (including that of staff and managers).
Captive environmental control systems: Equipment to ensure optimal environmental conditions for the species.
Staff training/education: Internal and external training and/or education of staff and its impact on amphibian expertise.
Number of staff*:* Amount of permanent workforce.
Availability of financial resources: *Available sources of financial resources to pursue.*
Food/nutrition: Use of self-bred, wild sourced and purchased food including invertebrates and supplements
Prioritisation of species: Prioritisation of species and how this influences the efficiency of programmes.
Species-specific information: *Information on the species' wild environment and how to recreate this captivity.*
Access to equipment: Access and availability of equipment, imported or in-country
Allocation of resources for in situ conservation: Allocation of resources needed to carry out field work by management
Access to field sites: Proximity and ease of access to field sites, influenced by weather, transport, political situation and land ownership.
Bureaucracy: Bureaucracy of governments or other partner institutions.

Thematic framework

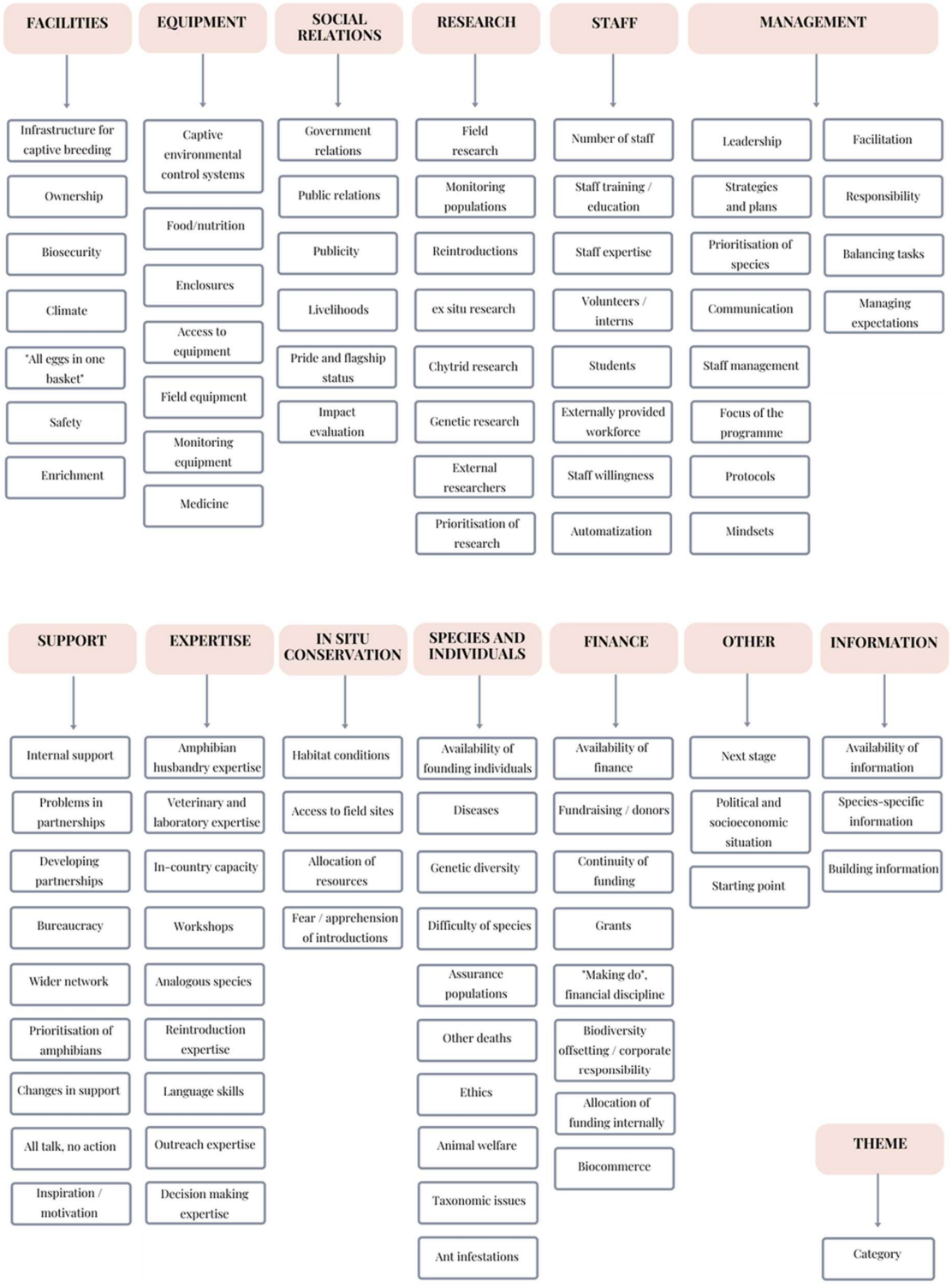


Figure 3: 13 themes and 94 categories of barriers and enablers identified from the thematic framework analysis performed in Karlsdóttir et al. In prep. Section 3 is loosely framed around these.

Measuring resource availability

In some cases, resources are not perceived to be equally important as by experts and practitioners, and are therefore not used or implemented. To identify some of the resource needs of programmes that might not be considered by the managers, short questionnaires were integrated into the interviews. The manager was asked "*on a scale of 1 to 5, how sufficient is your access to and availability of the following resources?*" with 1 being the lowest and 5 the highest. The results can be seen in Figure 4. We then asked managers "*on a scale of 1 to 5, how developed are your following plans?*", again 1 was the lowest and 5 was the highest.

This data was subject to personal interpretation by the respondent, and was further complicated by language barriers. In the case of exit strategies, many respondents were not familiar with the concept, and explanations were needed. Therefore, the following information should be interpreted with care. However, some overall patterns emerged.

Access to facilities overall scored higher than development of plans. This suggests that managerial constraint posed at least an equal barrier compared to lack of material resources. Exit strategies were unsurprisingly the least implemented, in spite of recent highlights of their importance by partners of these programmes (IUCN 2013; Tapley et al. 2016; Dawson pers. Comm.). Studbooks were also often lacking, although these are essential in maintaining genetic diversity in populations for reintroduction. Quarantine facilities, access to a vet and laboratory facilities were lacking for programmes, compromising the health of captive populations and the chances of reintroducing these in the future.

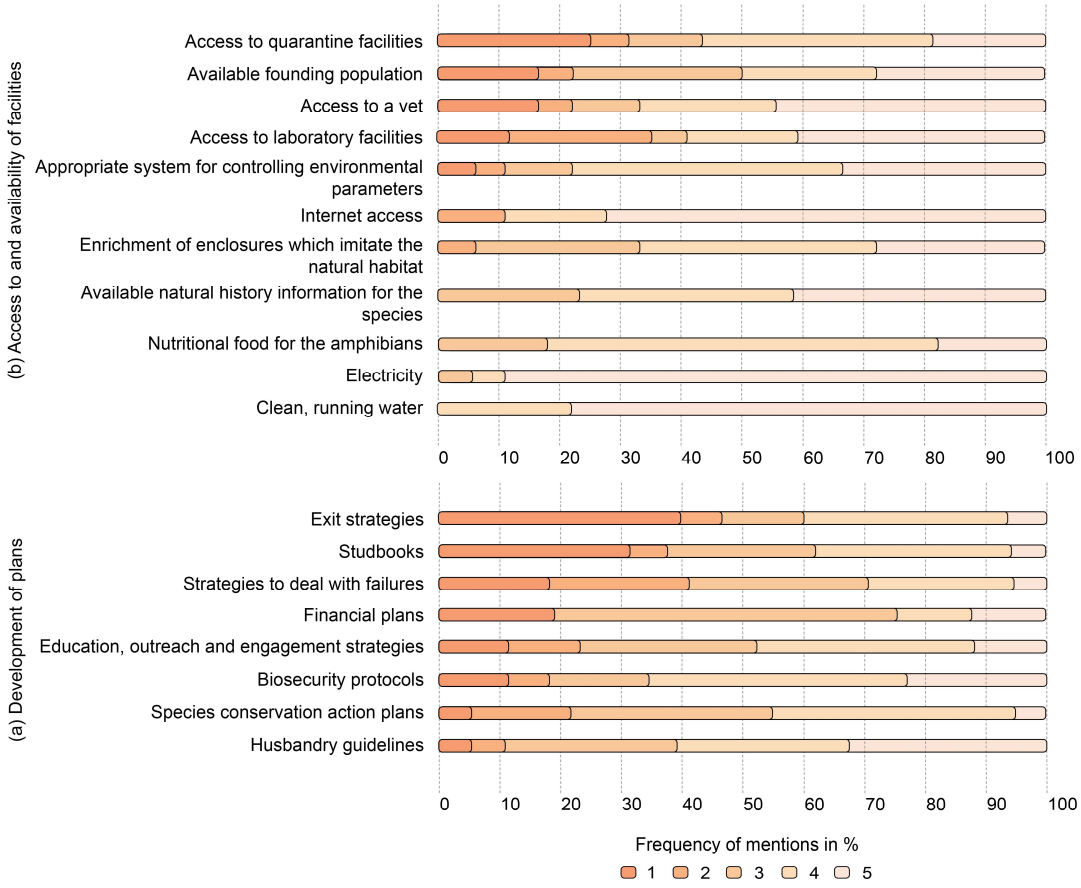


Figure 4: Development of plans (a) and access and availability of facilities (b) measured on a scale of 1 (lowest) to 5 (highest), displayed in percentage of respondents choosing each number. Data taken from Karlsdóttir et al. In prep.

2.3. Partnerships and support

How can we help?

Partnerships and support are essential to these programmes, and green text boxes throughout this document highlight areas of relevance to partners and supporters.

The shifting nature of many of these programmes, with different resource requirements at different stages, highlights the need for **flexibility** in partnerships and support. Common for most programmes is a shortage of funding. However, some programmes have what they need in terms of facilities and equipment but lack the resources and expertise for reintroductions, while other programmes are limited in the availability of funding for staff salaries, and others in purchase or replacement of specialised equipment. It is important for donors and supporters not to provide one blanket solution across all programmes, but to provide tailored solutions to individual programmes with which they engage.

Plan! From the onset of your collaboration, ask your manager for long term aims and objectives with clear conservation outcomes. Or even better, help them develop these. The range of tasks required by the manager of a successful programme is often extremely interdisciplinary and time-consuming, and managers might need assistance with tasks that are not within their area of expertise, or that have been down-prioritised. This often includes planning, monitoring and evaluation (Tools for planning and other relevant tasks are available in section 4). This will also give you an understanding of what kind of support the programme will need years down the line, which is likely to differ from what they are asking for now.

> *"We will need the communities' participation, and not just the elite community or the foreign conservation community or just the zoo community. We will need local community support, educational system support, as well as governmental and civic support."*

In Figure 5 you can see the different types of partners currently engaging with the programmes we surveyed, and the many types of resources provided by these.

The Amphibian Ark

The Amphibian Ark (AArk) is a joint effort of three principal partners: the World Association of Zoos and Aquariums (WAZA), the IUCN SSC Conservation Planning Specialist Group (CPSG), and the Amphibian Specialist Group (ASG).

A number of dedicated AArk positions coordinate all aspects of implementation within the AArk initiative. They assist AArk partners in evaluating the conservation needs for amphibian species and regions for conservation work; lead development and implementation of training programmes for building capacity of individuals and institutions; provide seed grants to support new ex situ conservation programmes; and develop communications strategies, newsletters and other messages and materials to promote knowledge sharing between practitioners as well as understanding and action on behalf of amphibian conservation.

Furthermore, the AArk helps with facilitation between partners. Members of the global AArk network include WAZA members and affiliates, members of regional or national zoo associations, ZIMS, AArk approved private partners and AArk approved museums, universities and wildlife agencies. Together,

they provide a strong network for advice and support. More information about the AArk can be found on their website: www.amphibianark.org.

Tools

In section 3 of the guidelines, you will find text boxes that look like this. They list the tools available from the AArk website and other sources, which are relevant to the theme under which they are mentioned.

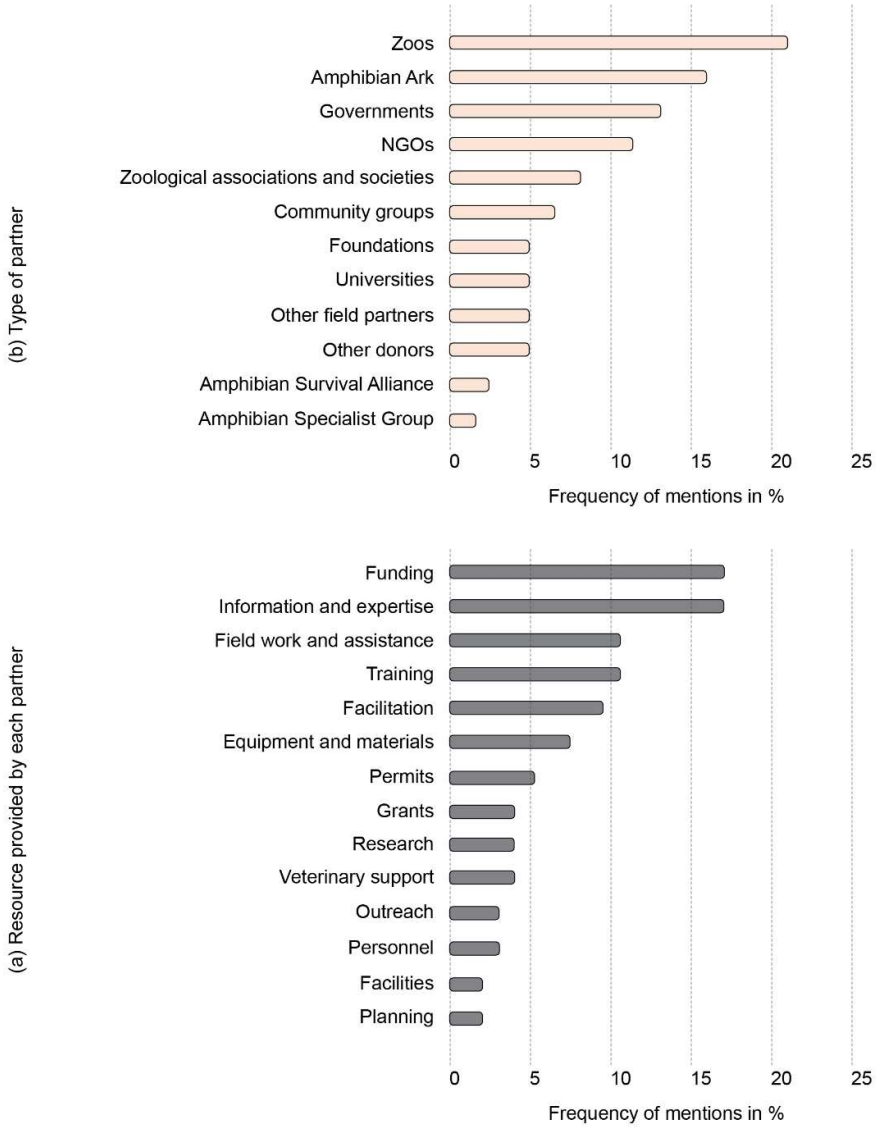


Figure 5: Partner types ordered by percentage of respondents naming them as one of their three most important (a), and resource types ordered by percentage of partners that provided them (b). Data taken from Karlsdóttir et al. In prep.

3. SUMMARY OF BARRIERS AND ENABLERS TO PROGRAMMES

The following summary is produced based on the information provided by managers of amphibian captive breeding programmes during interviews. These were analysed using a Framework Approach (Gale et al. 2013) and split into categories (Figure 3), basing the structure of this section. Everything documented here is a direct interpretation of the experiences of participating managers (unless references are provided), offering an opportunity to learn from both the successes and the failures of current and past programmes.


Calling hourglass tree frog
Berglind Karlsdóttir

3.1. Facilities

Building

This barrier/enabler is, for obvious reasons, essential to a programme from start to finish. If an appropriate building is not secured from the onset, many resources can go into securing and/or renovating a building further down the line. There were big differences in the standard of facilities and equipment, and in the perceived importance of these. While building and captive environmental control systems are among the most common categories of barriers/enablers, some managers mentioned the ability to make do with the resources available to them, and financial creativity/discipline as an important role in this. For example, some programmes use shipping containers instead of a building. Few managers perceive a need for the highest standard equipment, which can also be a product of institutional interest rather than conservation cost-efficiency. This is where tailoring comes in. It is important for the programme to have the right equipment and environment for their target species allowing them to keep healthy individuals, and in some cases, trigger their breeding. This needs a high level of expertise, which is discussed separately in section 3.8. Common for all is a need for a lot of space to be able to breed sufficient individuals to maintain genetic

diversity, and for many programmes also the space to breed live food. Although good facilities and equipment is certainly an advantage, it did not necessarily hinder nor enable success in achieving programme aims and objectives.

Ownership

If the managers of the project are not the owners of the land or the facilities, changes in management or disputes further down the line can cause the need to relocate or even close the project. This is rare but has serious consequences when it happens. Furthermore, ownership of reintroduction habitat can be important for securing the habitat of the species in the long term.

Biosecurity

Biosecurity reduces the risk of disease transmission between captive and captive populations of amphibians, and captive and wild populations, as well as between other wild populations. Its importance is increasingly understood following the emergence of infectious diseases such as the amphibian chytrid fungi and ranaviruses. As a result, the AArk and the IUCN/SSC CPSG **recommend that captive breeding for conservation occurs within the native range of the species** (Pessier & Mendelson 2017), and that 'cosmopolitan' collections – collections keeping amphibians from multiple geographic regions – are avoided as hosts for programmes where the aim for the target species is future reintroduction. Biosecurity aims to prevent the exposure of collections to novel pathogens, through creating 'permanently isolated' facilities and through protocols of husbandry, work-flow and veterinary practices that assess and reduce the risk of exposure to pathogens. Some programmes do not ensure that their facilities are biosecure and that appropriate biosecurity protocols are developed and implemented from the onset (just 65% of programmes follow biosecurity protocols of a high standard; see Figure 4 in Section 2). Relatively simple but appropriate biosecurity can be put in place at a low cost as long as the species is kept within its native range (see Tools box). Sometimes, the level of biosecurity is restricted by the quality of the facilities. If programmes wish to reintroduce their captive populations, this must be addressed.

Climate

Programmes located within the climatic range of the species find it much easier to recreate the environmental conditions needed by the species in the captive setting. Programmes that keep different species from different climates often need more specialised equipment and find it harder to accommodate all those species at the same time. In addition, to avoid disease transmission, it is not recommended that species for future reintroduction are housed with species from different regions. It is important to consider differences in climatic variables when attempting to recreate methods used at different facilities, especially outside of the tropics.

"All eggs in one basket"

Captive breeding programmes often run for decades, during which the survival of the captive population is entirely dependent on humans. It is therefore risky to keep "all the eggs in one basket". There are several reasons for this. It is easier to maintain genetic diversity when you have the space to breed at several facilities. Furthermore, a population at a facility can be lost, for example, due to fire, diseases, unsuitable environment, ant infestations, lack of breeding success or as a result of financial instability, changes in management or personal disputes. For the same reasons, partnerships between several institutions collaborating on the captive breeding on the same target species must be managed carefully, and input will be needed from the studbook coordinator to manage the metapopulation.

"Sometimes we have very bad discussions with like personal level… and that can be dangerous. For that reason I'm trying to start some captive breeding programmes in other cities and also in other countries. Because monopoly is dangerous sometimes, because also for us as project I don't want to have the monopoly."

Enrichment

Enrichment is often considered by programme managers not to be of particular importance, and furthermore increases cleaning efforts. Near-empty tanks are often considered sufficient unless the amphibians are on display. This raises questions regarding adaptation to captivity and suitability for release. This is often not a concern for managers of amphibians but has been raised as a realistic issue by Tapley et al. (2015a).

Partners and support

When multiple programmes keep and breed the same species, useful partnerships often arise between them, with collaboration on developing husbandry protocols and on genetic management for the target species. Sometimes partner institutions also contribute financially. For partners that do not keep the amphibians in-house, there are still many ways of helping. Programmes will need money and technical support for the building and ensuring it is suitably designed for the species in mind, with a high standard of biosecurity. Breeding of live food is often a big aspect of this.

Tools

Amphibian husbandry resource guide: These guidelines, developed by AZA, are long and detailed guidelines, covering a wide range of husbandry topics including a short paragraph on enrichment: http://www.amphibianark.org/wp-content/uploads/2018/07/AZA-Amphibian-Husbandry-Resource-Guide.pdf

Biosecurity and permanent isolation of ex situ conservation populations: Biosecurity manual for amphibian survival assurance colonies and reintroduction programmes. http://www.amphibianark.org/wp-content/uploads/2018/07/Biosecurity-Manual-2017.pdf

Facility design guidelines: These brief guidelines on *Facility design and associated services for the study of amphibians* include general information on enclosures, light, water, substrate, quarantine facilities and more: http://www.amphibianark.org/wp-content/uploads/2018/07/Facility-design-and-associated-services-for-the-study-of-amphibians.pdf


Gliding tree frogs in amplexus
Berglind Karlsdóttir

3.2. Equipment

Captive environmental control systems

Captive environmental control systems are for this purpose defined as the equipment needed to maintain a suitable environment for the target species. This includes air conditioning, heating, cooling, UVB provision, management of water quality, and misters. Due to the lack of ecological information on many species, programmes often adopt a trial-and-error approach rather than evidence-based. This often requires tweaking the climate till it's thought to be right. Field work, literature reviews, expert advice and trial and error all feed into this process of adjusting and tweaking. Issues with water quality are common, and some managers choose reverse osmosis as a basis with added minerals etc. (see Tools box). Some programmes need specialised temperature control that can incorporate both daily and seasonal fluctuations in temperature. Programmes located within the range of the species usually find temperature control easier, often not needing specialised equipment. Access to specialist equipment can pose a barrier, and many programmes import expensive equipment from abroad. Some experience bureaucratic constraints in the timely delivery of these materials.

Food/nutrition

Nutritional problems are a major barrier to the implementation of amphibian captive breeding programmes (Gagliardo et al. 2008; Antwis and Browne 2009; Pryor 2014; Tapley et al. 2015b), and metabolic health problems are frequently a concern (see Tools below). While some programme managers believe they understand the nutritional requirements of their species, and are largely able to accommodate for it, other managers highlight species-specific nutritional requirements, the difficulty of catering to these and the general lack of knowledge (see Tapley et al. 2015a). There is a clear need for improved research on amphibian nutrition, and increased sharing of available information and expertise. Some programmes are restricted by the commercial availability of suitable food, and breed their own invertebrate colonies for the amphibians. It is recommended to start breeding invertebrates before bringing in amphibians, and it is important that only native or naturalised invertebrate species are bred. Breeding non-native, potentially invasive species is not recommended (Nicholson et al. 2017). Supplied food often consists of just a few species of insects,

although diversification of the diet is important and diet supplements are sometimes required (and often need to be imported). The breeding of food requires a lot of extra space.

Enclosures

Enclosures are needed by every programme. While some programmes import expensive tanks, other programmes highlight the importance of being creative and using in-country resources, with the ability to assemble your own tanks. It might initially be costly and difficult but will pay off in the long run. Tank design will vary according to species. Drainage needs to be considered, especially for species whose breeding events are triggered by the monsoon. Separate containers are sometimes needed for breeding, raising tadpoles and live food.

Field and monitoring equipment

Usually this means vehicles for field surveys, which are sometimes shared within an institution and are therefore not always available. This equipment also includes tagging equipment, diving equipment, water testing and treatment equipment, data loggers etc. All of which can be quite costly.

Monitoring equipment is needed both in the field and at the facilities. Depending on the programme, this includes monitoring for health and disease (such as chytrid fungus), water quality and other environmental variables (equipment like data loggers). In some cases, CCTV cameras and audio recorders are used to monitor behaviours and breeding events in-house. Again, this type of equipment can be very costly for programmes, and funding might need to be sourced externally.

Access to equipment

Access to equipment is often restricted in many of the countries with the greatest need for amphibian conservation breeding programmes, as many resources are not available locally. International deliveries can take a long time. Internal or governmental bureaucracy in some cases delays the process further. In rare cases, basic resources such as medicine are unavailable due to political restrictions and sanctions. It is usually specialised equipment that is ordered internationally such as UVB lights, enclosures, nutrient supplements etc. although some have suggested that if you look hard enough, it is sometimes possible to find identical products in-country, breed your own food, or creatively construct alternative equipment such as tanks. The price of international delivery and specialised equipment itself is also very restricting, especially for equipment that needs to be replaced regularly (like UVB lights needing to be changed frequently as the UVB emitted declines with time).

Partners and Support

This is an area where programmes can greatly benefit from expertise or knowledge sharing on where to source materials from, or how to make their own. These materials are often highly specialised, such as monitoring equipment or breeding of live food. Partners also contribute with access to equipment, sometimes being ordered and shipped by a partner abroad. In other cases, partners will bring equipment when they come to visit the programme.

Tools

Amphibian husbandry resource guide: These comprehensive guidelines developed by AZA cover a wide range of husbandry topics including a short paragraph on enrichment: http://www.amphibianark.org/wp-content/uploads/2018/07/AZA-Amphibian-Husbandry-Resource-Guide.pdf

Ex situ management of amphibians: Shorter but more recent guidelines than the AZA guidelines above: http://www.amphibianark.org/wp-content/uploads/2018/07/Ex-situ-management-of-amphibians-Gupta-et-al.pdf

How much UV-B does my reptile need? The UV-Tool, a guide to the selection of UV lighting for reptiles and amphibians in captivity: The UV-Tool is a working document that seeks to address the lack of guidance on UV lighting for herpetofauna, by considering the range of UV experienced by each species in the wild: http://www.amphibianark.org/wp-content/uploads/2018/07/How-much-UV-B.pdf

Information on equipment and enclosures: The AArk's husbandry documents page provides numerous resources on how to design your captive environment: http://www.amphibianark.org/husbandry-documents/

Managing water quality for amphibians in captivity: An in-depth guide to water quality: http://www.amphibianark.org/wp-content/uploads/2018/07/Managing-water-quality-for-amphibians-in-captivity.pdf

Nutrition and health in amphibian husbandry: This commentary provides an overview of amphibian nutrition and other captive factors to improve population health: http://www.amphibianark.org/wp-content/uploads/2018/07/Nutrition-and-Health-in-Amphibian-Husbandry-Ferrie-et-al-2014.pdf

School children in Borneo
Patrick Roman Hoque

3.3. Social relations

Government relations

Governments act as one of the main common and critical barriers and enablers. However limited the interaction, government support is a critical component of a programme with the need of legal status and permits for collecting founding individuals, transferring individuals between institutions, culling surplus stock and performing reintroductions. It is important for a programme to build a relationship with the government and understand the legal framework within which they need to work from the onset. Governments also play an important part in approving and implementing mitigative actions. Some programmes work to incorporate amphibians into national Red Lists, to incorporate conservation into planning policies, or to change agricultural policies etc. Even with appropriate legislation in place poor enforcement can hinder this work, and bureaucracy can cause extreme delays in permits, which in some cases could take several years. Perceptions and attitudes of government individuals highly influenced this, including lack of understanding of how these programmes work, and fear of approval of permits potentially leading to unwanted outcomes. Furthermore, government relations can be influenced by a turnover in government officials and building of relationships can sometimes need to start over. One programme has been hindered in achieving their goals due to lack of approval of permits for a decade. However, when governments act as supporters, they can act as essential partners, providing the necessary permits, financial support and habitat management or protection.

Public relations

Public outreach is very context specific depending on the goals of a programme. Zoo based programmes have the unique opportunity to spread the message of the amphibian crisis to a large number of visitors but are sometimes forced to consider the display value of their species. Independent programmes sometimes open public display facilities for the same purpose. Many programmes mentioned the lack of interest in amphibians generally and a fight to change these perceptions – perceptions which often limit the level of support a programme receives in the beginning but is possible to change over time.

"it's kind of a slippery slope to think that science has now saved frogs when its people. These people in the local communities around these streams everything else are going to be the ultimate people that will be saving and helping us report you know sightings and all of these things that so these people that are going to be saving the frogs at the end of it."

"for example, the polar bear, if it's disappearing… if it's endangered people will realize because it's a large animal, obviously. But for that kind of small frogs, actually the total number is decreasing every year from a long time ago, but people won't maybe notice about this because it's so small"

"Because of the message you send with the frogs it's not the same that you say with a giant panda or with an elephant. So that is also one of the limitations. But I think amphibians are very good conservation ambassadors for the close encounter, close view, so it's a different way of conservation that we need to… we need to enhance."

Education and outreach sometimes needs to extend beyond the general public and target specific issues such as preventing the harvest of wild amphibians or changing land use practices. The messages communicated through education also vary from general amphibian biology, to awareness of chytrid, to programme-specific threats and actions.

Some programmes consider education and engagement to be their biggest achievements. However, the purpose of education is not always clearly defined, and to our knowledge, no programmes conduct impact evaluations of their education efforts (see Impact evaluation in this section). Engagement with local communities and stakeholders is generally important when habitat protection, habitat management or new sites for reintroductions are needed. Local community authorities can provide important access and support, while conflicts with land use and livelihoods can cause tensions and hinder progress. Lastly, education can be crucial in building in-country capacity for the longevity and expertise of programmes, which often depend on a single leader. See Tools below for education resources.

Publicity

Media coverage is perceived as important by programmes and is often done by partners and supporters in country and abroad. Publicity can be anything from school bake sales, to TV coverage, to social media channels. Publicity can be used to attract donors and sponsors and to advocate for support. It also stems from a desire to let people know about the work the programme is doing. Ex situ programmes are "attractive" in comparison to other efforts, and can be a good tool for communicating the "amphibian crisis" to a wider audience.

Livelihoods

Whether some important amphibian habitats are protected or not is impacted by the financial cost or opportunities to businesses or communities in doing so. Opportunities include hydroelectric projects, mining, logging, agriculture such as coffee and rice farming etc. The resource use is often needed to sustain local livelihoods, or if this is not the case at the moment, changes in population sizes or market prices for different products can change the habitat use in the future. In one programme this has been mitigated somewhat by converting farms to organic practices and working with a certification company to sell the product at a higher price.

Pride and flagship status

Programme managers sometimes experience that promotion of a species as a flagship species can increase awareness of, interest in and even pride towards that species. This can help to facilitate public and government support. Unfortunately, it can also be used as a front by the government and other supporters to claim that they are taking action, when in fact they're not.

Political situation

The wider political situation does not often act as a barrier, but when it does, it can pose serious consequences such as lack of access to goods and medicine, dangers of field work and plight or death of staff and partners. In these situations, difficult decisions must be made about how to proceed, evaluating the importance of the work and the safety of the staff. It is often worth putting a programme on hold and continuing when the political conditions are more suitable.

Impact evaluation

Education and outreach appear to be a component in most amphibian captive breeding programmes. However, it is unclear to what level these programmes determine their messages and target audiences, and they do not evaluate the impact of their education and outreach efforts. In order to ensure that education and outreach has the desired impact, and that it is done in the most efficient manner possible, continuous monitoring and evaluation of such initiatives should be carried out.

Partners and support

Most programmes undertake public engagement and are the best assessors of how to approach this within their local context. Partners mainly assist in terms of promoting communication such as through social media, which the programmes value highly. Furthermore, something that's not necessarily on managers' minds is impact evaluation, but it's certainly important, so any partnership support, either in terms of funding (it can be very difficult to find funding for this aspect), or perhaps student researchers to undertake the evaluations, can be useful here.

Tools

Curriculum materials: Further education materials are available from AArk's website: http://www.amphibianark.org/education/links-to-curriculum-materials/

Education activities and materials: This list of suggestions and materials for educational activities is provided by AZA: https://www.aza.org/amphibian-education-resources.

Monitoring and evaluation: The following papers provide a good overview of the importance and use of monitoring and evaluation in conservation:
Kleiman DG, Reading RP, Miller BJ, Clark TW, Scott JM, Robinson J, Wallace RL, Cabin RJ, Felleman F. 2000. Improving the evaluation of conservation programmes. Conservation Biology. 14(2):356-65. Mascia MB, Pailler S, Thieme ML, Rowe A, Bottrill MC, Danielsen F, Geldmann J, Naidoo R, Pullin AS, Burgess ND. 2014. Commonalities and complementarities among approaches to conservation monitoring and evaluation. Biological Conservation. 169:258-67.
Stem Stem C, Margoluis R, Salafsky N, Brown M. 2005. Monitoring and evaluation in conservation: a review of trends and approaches. Conservation Biology. 19(2):295-309.

Stakeholder engagement handbook: This handbook developed by Biodiversa in 2014 is a practitioner's guide to identifying and engaging stakeholders:
http://www.biodiversa.org/stakeholderengagement

Golfo Dulce poison dart frog
Berglind Karlsdóttir

3.4. Research

Field Research

Field research should be an essential part of most programmes, with ex situ conservation operating as a complementary tool to in situ conservation (Pritchard et al. 2011; Byers et al. 2013). Field research includes researching the species' taxonomy; population status; behaviour and ecology (environmental parameters of the species' habitat niche, the quality of the habitat such as water quality); threats to the species and mitigation of threats; searching for founder individuals; disease monitoring and mitigation; assessing suitability of reintroduction habitat; and the exploration of new potential reintroduction sites. This component is often done by field biologists and is sometimes separate from the ex situ project. Nevertheless, this research produces information which is often lacking for species in the relevant regions. This information is important for programmes to prioritise the right species, to provide the right captive environment and to proceed to reintroductions. Availability of relevant information at the beginning of a programme can be an important prerequisite for success.

Searching for and monitoring populations

Monitoring of wild and captive populations should be an integrated part of a programme. Lack of accurate information on population statuses which hinders prioritisation of the most suitable species for captive programmes (see Section 3.6). In some cases, species are down-listed on the IUCN Red List after more populations are discovered in the wild. Although positive, this can have undesirable consequences such as reducing funding opportunities, or the captive species taking up resources which could have been dedicated to a species in more need. Monitoring of the wild populations is also important for assessing whether acquiring new founders for captive populations is feasible, and to ensure that reintroductions can take place in the event of further declines. Being able to monitor means availability of time, funding and access to the field sites. This is discussed under in situ conservation (section 3.9). Captive populations are monitored to ensure their continued health, and to conduct research on the species (section following category).

Ex situ research

As well as gathering information on the species in the wild, the collection of data on environmental variables, behaviour, nutrition, health and genetics is required in captivity to ensure the most suitable management of the species. Especially in species for which information from the wild is not available, a trial-and-error approach is often used, and managers may have to adjust the captive conditions repeatedly until the individuals are thriving and breeding (see captive environmental control systems in section 3.2). Likewise, the husbandry of poorly-known species can produce information about the species' biology and ecology in the wild (Michaels et al. 2015). Captive breeding programmes hold a great potential for conducting ex situ research, and reintroduction programmes usually rely partly on information produced by those. For example, ex situ research contributes to the development of disease treatment protocols and field monitoring protocols, including marking techniques. Other areas of ex situ research include display and education, population genetics, and reproduction technologies. For a review of the contributions of zoos towards ex situ research, read Browne et al. (2011).

The lack of documentation and dissemination with regard to keeping and breeding practices and events can prevent a timely learning process and adjustments of protocols. Some programmes use technical equipment such as data loggers, audio recorders and even CCTV to monitor activity and breeding events. Although advantageous, under-resourced programmes can do well without this.

Reintroductions

For programmes, where planning and field work have been an integral part from the beginning, the progress to undertaking reintroductions is generally well-planned and the process understood. For many other programmes, especially those which keep numerous different species, this process becomes more complex. It must first be decided that reintroduction is the best option for the target species. Plans, monitoring and evaluation strategies are then designed. The process for this is detailed in the IUCN Guidelines for Reintroductions and other Conservation Translocations (IUCN 2013; see Tools box).

Suitable habitat for the reintroduction must then be selected (see *habitat conditions* under section 3.9). The habitat from which the species disappeared might no longer be suitable, and the last site at which the species was seen is not necessarily the optimal site for reintroduction. Therefore, it is important to understand the biotic and abiotic habitat needs of the species and assess whether proposed reintroduction sites meet these requirements. Climate change could also render the site unsuitable in the foreseeable future, and bio-climate envelope models can be used to assess climate suitability. (IUCN 2013).

The suitability of individuals for introduction needs to be ensured with health screening, studbooks and genetic testing in place, which can incur big costs to the programme (refer to the Tools box and the *Genetic and taxonomic research* in this section). Release individuals need to be genetically, physiologically and behaviourally comparable with the original or any remaining wild population (IUCN 2013). The importance of learnt behaviours and adaptation to captivity is sometimes understated for amphibians and should be taken into account (Tapley et al. 2015a). The risks of these as well as loss of genetic diversity increases with time emphasising the need for efficient, well-planned captive breeding programmes. Reintroduction trials and studies on locomotion and nutrition are among initiatives being undertaken by the programmes surveyed to assess the suitability of captive populations for reintroduction. Concerns were raised about the amount of space needed to breed a sufficiently large captive population to retain genetic diversity for just one species. The negative effect of removing individuals on the remaining captive population must also be assessed, and the welfare and stress reduction of these animals ensured (IUCN 2013). Individuals must be health screened to

ensure their fitness for reintroduction. Health screening and disease risk assessment also reduces the risk of introducing diseases to other individuals or species in the wild. It is not desired that individuals are completely parasite and disease free, however, many organisms don't become pathogenic until co-infection or other factors promote pathogenicity. As host immunity can decrease the risk of pathogenicity, the individuals' abilities to survive and thrive with pathogens and stresses at the reintroduction site must be assessed (IUCN 2013). Guidelines for Wildlife Disease Risk Analysis can be found in the Tools box. Other risks of reintroduction include invasion by the reintroduced species, intraspecific and interspecific hybridisation, (IUCN 2013). For populations affected by chytrid, high population densities can promote the infection and growth rate of Bd chytrid fungus (Briggs et al. 2010) and reintroductions can therefore change the disease dynamics negatively. A full risk assessment will include: risk to source population; ecological risk; disease risk; associated invasion risk; gene escape; socio-economic risks; and financial risks (IUCN 2013)

Monitoring is an important part of reintroductions and measures of success should be clearly defined. Monitoring can be expensive, with the need for tailored or specialised tagging equipment. Staff time and funds for this aspect should be secured before reintroductions take place. Monitoring provides a further tool to evaluate how many individuals must be introduced, how often and at what time of year, to ensure optimum survival (IUCN 2013).

Chytrid research

There is a need for monitoring of chytrid and assessment of its impact on populations in chytrid-prevalent regions. For some programmes, research into solutions for chytrid-related declines is an integrated aspect, and is important for ensuring a future for captive populations that can't currently be reintroduced due to chytrid prevalence in the habitat. Monitoring of chytrid requires collection of swabs in the field (See Chytrid test sets and swabbing protocols in the toolbox). More advanced research requires dedicated staff, students, lab space and costly equipment.

Genetic and taxonomic research

Genetic research is used to ensure preservation of the genetic makeup of a captive population and species. Studbooks are needed for all programmes but are currently of varying quality (see Figure 4 in Section 2). For some species represented in ex situ programs, the necessary data collection and subsequent genetic analyses have not been completed, and these can be costly (depending on the number of populations, type of test, and including materials and lab staff costs, prices range from a hundred dollars to a few thousands). In some cases, research is needed to solve taxonomic issues, or to determine genetic differences in metapopulations. In some cases, individuals have been collected from different locations and later been found to be genetically distinct from one another, reducing the founding individuals for each population. Programmes similarly have problems with hybridisation in closed populations.

Prioritisation of research

The amount of research carried out by programmes varies depending on the programme type. Programmes located in zoos in less-developed countries generally have fewer opportunities (time, money, equipment) for carrying out field research, although they are better positioned for carrying out husbandry research programmes using surrogate species. Furthermore, it can sometimes be difficult to build support for research on amphibians as opposed to other, more charismatic taxa (Bonnet et al. 2002.; Griffiths & Dos Santos 2012).

Partners and support

External partner organisations or independent field biologists are sometimes able to fill research gaps, which is key in ensuring that important work is carried out alongside the captive breeding aspect of a programme. External partners are often especially needed for conducting field and lab-based research, when the captive manager and staff do not have the resources to carry out the research themselves. This can be anything from NGO's to the government, to partner universities, to individual biologists and student researchers, to donors who fund the research activities. Technical expertise on reintroductions is sometimes needed by programmes which have no experience with this aspect. Financial contributions towards genetic tests are in high need for many programmes planning to reintroduce.

Tools

Amphibian and reptile conservation: This is an open-access, peer-reviewed journal for publishing of amphibian related research: http://amphibian-reptile-conservation.org/

AZA Guidelines for reintroduction of animals born or held in captivity: The Association for Zoos and Aquariums guidelines on reintroductions from 1992. Available at: https://www.speakcdn.com/assets/2332/aza_guidelines_for_reintroduction_of_animals.pdf

Chytrid test sets: A new, cheap method of testing for chytrid is currently being developed by researchers at Exeter University and the Whitley Wildlife Conservation Trust. The method is less precise than current methods, but is more convenient and comes a lower cost. The product is not currently available commercially. Read more in: Dillon MJ, Bowkett AE, Bungard MJ, Beckman KM, O'brien MF, Bates K, Fisher MC, Stevens JR, Thornton CR. 2017. Tracking the amphibian pathogens Batrachochytrium dendrobatidis and Batrachochytrium salamandrivorans using a highly specific monoclonal antibody and lateral-flow technology. Microbial biotechnology, 10(2), pp.381-394.

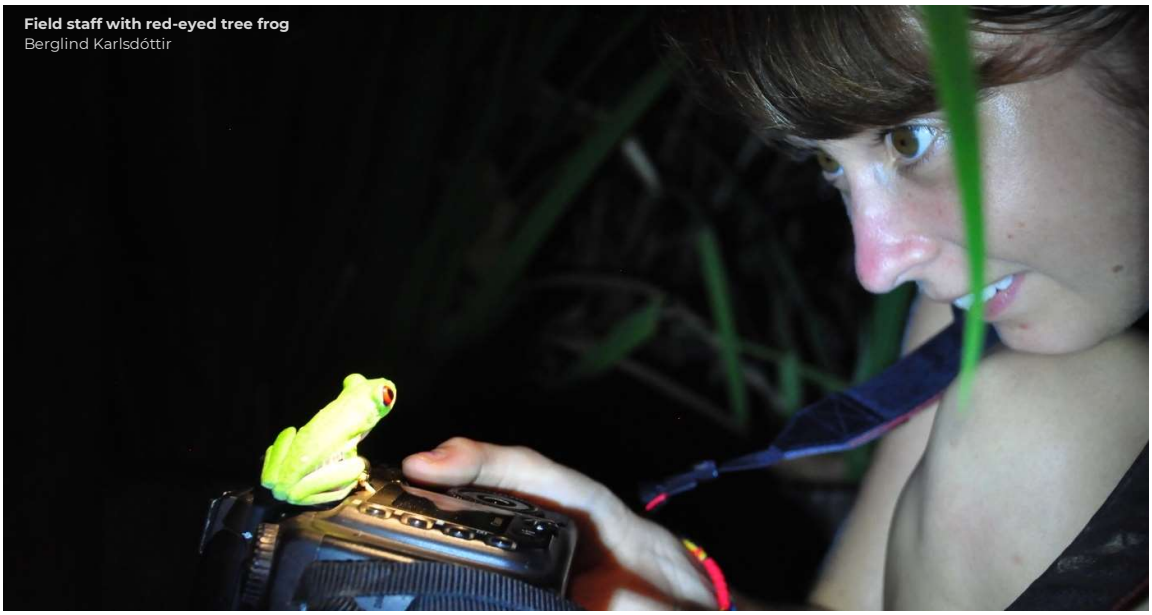
IUCN guidelines for determining when and how ex situ management should be used in species conservation: Guidelines published by the IUCN in Conservation Letters found here: http://onlinelibrary.wiley.com/doi/10.1111/conl.12285/full

IUCN guidelines for reintroductions and other conservation translocations: The IUCN guidelines on planning and implementing reintroductions from 2016. Available here: https://portals.iucn.org/library/efiles/documents/2013-009.pdf

IUCN guidelines for wildlife disease risk analysis: Detailed guidelines for assessing disease risks. https://portals.iucn.org/library/sites/library/files/documents/2014-006.pdf

Swabbing protocols for chytrid: This simple website with videos outlines what you need and shows how to swab an amphibian for chytrid: https://amphibiaweb.org/chytrid/swab_protocol.html

ZIMS for Studbooks: Studbooks are managed through the Species 360 ZIMS tool. It is designed to make the job of the studbook keeper easier. Read more and access the tool at: https://www.species360.org/products-services/zims-for-studbooks/



Field staff with red-eyed tree frog
Berglind Karlsdóttir

3.5. Staff

Number of staff

When it comes to keeping and breeding amphibians, the number and expertise of the programme's staff is essential. For programmes within zoos, staff are often permanently provided by the institution, although prioritisation of staff time for amphibians is mentioned as a barrier as they often work with other taxa as well such as reptiles, fish or even mammals. For independent programmes especially, fundraising for staff can be a challenge, often leading to low salaries and thus low staff retention. The generally low availability of trained and experienced staff in-country adds to this problem. Staff duties expand past husbandry of amphibians, to breeding of live food, observation, research and captive studies, field work, education, management, and veterinary work etc.

> *"I think number one resource that is needed is human resource. You know we have to have people to be able to take care of these frogs. And then of course everything else. And it's not just frogs…. We have to breed all of our own insects. So, human and the education aspect, like people are the most important thing really in this whole project."*

Staff training and education

Training and education of staff is a cornerstone component in ensuring an expert workforce. In some cases, staff (who don't already have them) pursue graduate degrees in the field, which adds to the programme's capacity and builds leadership, however, this can also be a big loss to the programme when they leave. Programme managers themselves often hold an MSc or PhD in the relevant field or species. Some programmes send their staff on international training courses (see the Tools box), while the AArk facilitates training workshops in-country (see Workshops under Expertise) In this study, untrained staff were one of the leading causes for failures, where otherwise simple tasks were being done wrong with potentially negative consequences.

"when our captive breeding responsible quit the first time and the person that was in charge had not enough experience and had to take all… we had different mortalities because of water quality problems. The second time it happened… with the same person that quit a second time. Yeah the guys had to learn from the fast and they had the same problems, like various stupid mistakes that could be avoided."

"Of course there's training of the keepers. amphibians are very sensitive animals. They require very specific training and very specific profile of keeper to work with them."

Staff expertise

Expertise (information and knowledge) is essential in the successful implementation of each stage. Keeping of amphibians can be very complicated and a lot of specialist knowledge must go into the design of the captive environment (biological, chemical and physical parameters). An expert workforce is paramount in a timely learning process for developing protocols and problem solving, and the increased use of an evidence-based approach where possible. Low salaries, low staff retention, high turnover, and a low number of staff can have big implications on the expertise of the staff and the quality of the work, as the learning process goes back to the beginning for each new staff. This is a main cause of failures. Furthermore, some programmes struggle with the lack of in-country expertise, which takes a lot of time and effort to build up.

"And then even here in the town the people that we have to pull from… there's really no science background so it's you know an education… kind of aspect. The high school here is a technical school and it's a fine school but it's all towards more tourism and these kinds of things so finding somebody that even has enough background in science, biology is… there's a limitation for sure."

Volunteers and interns

Internships and volunteer positions are also used for building in-country capacity, assessing future potential staff and providing an addition to the workforce. However, while long-term volunteers are often seen as an asset, and sometimes make up a big part of the workforce, short term volunteers do not always provide return on investment and should be used thoughtfully. Interns are more highly valued but will often expect some financial contribution. For a few programmes, permits for volunteers are a time-consuming, bureaucratic issue.

Externally provided workforce

Students from local or international universities, at different stages of their degrees, can be a great resource for assistance with field work, monitoring and other research. External researchers from national or international institutions can provide an important addition to the knowledge base. External biologists, local organisations, governments, volunteer groups, or even hobbyists sometimes run entire activities or programmes on the side, such as habitat management, monitoring or awareness-raising. These contributions are highly valued by programmes.

Staff willingness

Most programmes have enthusiastic and dedicated staff, although there are some obvious challenges. Low salaries can decrease the morale of the team. Additionally, in some programmes (mainly in zoos)

staff time is split between different groups of animals. This makes specialisation harder and can in some cases mean that staff willingness or passion is not directed at amphibians.

Automatization

Although not necessary, the use of automatic systems has been highlighted as a means to reduce staff hours. This includes CCTV and audio recordings used for identifying changes in behaviour and calling activity of the amphibians. They also reduce the need for incursion into enclosures, reducing the risk to animals from stress, pathogen introduction etc.

Partners and support

In order to solve problems relating to staff retention and level of expertise, more funding needs to be available for staff salaries. Funding aside, external partners provide much needed training for staff. Training workshops can be facilitated by the AArk, external zoo partners or even other amphibian captive breeding partners in the region. Amphibian husbandry courses or other conservation courses are provided by zoos such as Durrell, universities and other organisations, but can be a costly investment for the programme. See a list of training opportunities in the Tools box below. The biggest contribution of partners in this aspect however, is likely continuous knowledge sharing and expert input, to guide the current workforce on everything from husbandry and breeding protocols, identifying causes for diseases, performing reintroductions, developing outreach materials, designing and building facilities, choosing specialised equipment etc. In a few cases this extends to a highly involved management and decision-making collaboration. This is all discussed in section 3.8.

Tools

Amphibian husbandry workshops: The AArk run amphibian husbandry training workshops in priority areas. For more information see: http://www.amphibianark.org/about-us/workshops/husbandry-training/

Amphibian management school: AZA runs a range of training courses relevant to species management. Specifically, they run an amphibian management school at the beginning of the year. Keep an eye out on their calendar: https://www.aza.org/calendar, http://saveamphibians.org/2018-advanced-course/

Durrell Conservation Academy: Durrell Wildlife Conservation Trust does several training courses on practical conservation work. These include the Durrell Endangered Species Management Graduate Certificate, which provides students with a wide set of skills needed for implementing successful conservation interventions and a two-week endangered species recovery course. For more information see: http://wildlife.durrell.org/courses/

EAZA Academy Courses: EAZA occasionally run courses on ex situ programme management and funding for in situ conservation. See their calendar here https://www.eaza.net/academy/courses/

Smooth newt
Phil Jervis

3.6. Management

Leadership

The initial phase starts when the idea is sparked and developed. It is worth mentioning that external motivation from others as well as individual passion is a critical driver for leaders to set up relevant conservation programmes in the first place, and without them, these programmes would not happen. Following this, a programme leader's ability to demonstrate their capabilities or the value of the project is a driver for building support and developing partnerships. Needless to say the loss of a leader can have a tremendous impact on a programme, and there are examples of programmes which have become inactive after the departure of a leader, or a change in management.

Prioritisation of species

Prioritisation of the target species is a main component of planning a programme, which is often brought up as a concern with difficulties in obtaining accurate information on species threat statuses. Opportunities, personal interests and charismatic features of the animals often influence this decision-making process, but are largely invalid reasons for selecting a species. Severity and reversibility of threats, available founding population and ease of keeping and breeding on the other hand need to be considered to ensure the highest chances of success in the long run. Adding to this problem, some institutions are faced with the dilemma of display value, and depending on local attitudes, programmes might avoid dull or ugly species to prevent worsening perceptions. (See the IUCN guidelines on prioritisation in the toolbox below)

> *"If they see a golden poison dart frog they will say: "that's a cute animal that moves, that jumps, that is nice". But if they see a frog that, well, maybe they didn't even see because it's too cryptic or too difficult to spot or it's even an ugly warty toad that they don't like. It's really…. This this is something to consider when you talk about display because people might see the animals the other way around; they*

might think oh my god this is disgusting. They should be all gone and we want to kill all toads in the world. So that's not what we want to get"

This dilemma of display value versus conservation value is frequently cited in the literature (Frynta et al. 2013; Martin et al. 2013; Bowkett 2014), but did not appear to be a significant perceived barrier to the programmes in this study. Little attention was paid to the availability or potential availability of reintroduction sites in the prioritisation process, which often poses problems at a later stage. Furthermore, some species are selected based on threat status, without a sufficient available founding population. In some emergency situations the remaining individuals of a Critically Endangered species have been collected, making captive breeding the last resort for the species. Collection of individuals for programmes can have a negative impact on vulnerable wild populations (see Ralls & Balou 2013; Minteer et al. 2014)

"… at first we were working with [lots of] species which is you know pretty ambitious but we were also very young. And you know just this whole thing, like if we don't take them in they're going to die. So if they die here I mean you know just like kind of utter overwhelmed like everything is going to die."

Some decisions strongly contrasted with the AZA and the IUCN guidelines for captive breeding programmes. These state that wild individuals should only be collected for captive breeding when the population is large enough to be able to cope with the loss of individuals, and that threats to the species in the wild must be mitigatable. This raises the question of whether the guidelines are too generalised to apply to complicated, context specific situations. Conversely, perhaps the success of some programmes is hindered by personal decisions overriding well-reasoned guidelines. Indeed, lack of suitable reintroduction sites is a common barrier.

Strategies and plans

For some programmes, developing the protocols and achieving breeding success is very resource intensive. Programmes based in parent institutions can struggle with receiving the support for anything additional to the captive breeding component. Planning is therefore important to ensure that programmes can address other identified priorities needed to achieve conservation success. The starting point of the programme should involve a professional level of planning including how to prioritise the species (see *Prioritisation of species* in this Section), secure financial resources, the setting of clear aims and objectives, determining when and where to reintroduce the captive individuals, and what to do in the case of success or failure in meeting set aims and objectives: a so-called exit strategy. Programmes take up vast amounts of resources and should therefore evaluate their cost effectiveness and plan for the potential scenario of poor success. This requires a set of objectives and performance indicators. In spite of their perceived importance (IUCN 2013; Tapley et al. 2016) most programmes do not have an exit strategy at all. It is likely that the same people who initiate the programme - and feel a sense of attachment or responsibility towards the species - are not capable of recognising lack of progress as failure, and of changing the species or closing down the programme.

"So we are still keeping these because we have the most important amphibian collection in the country and the, probably the most important poison frog collection in the world. So you can't abandon that just because you don't have the permits and the money."

A set of tools are available for different aspects of planning. The AArk provides a number of amphibian related tools aimed to help plan viable captive breeding programmes for the right species. General guidelines on conservation planning are provided by the Conservation Measures Partnership, the

Open Standards for the Practice of Conservation, covering threat assessments, theories of change, results chains and much more. The IUCN has also published essential tools including the IUCN guidelines for determining when and how ex situ management should be used in species conservation; IUCN guidelines for reintroductions and other conservation translocations; and the IUCN guidelines for species conservation planning. WAZA has similarly developed the Global Species Management Plans; a tool for developing a globally agreed set of goals for a given taxon, through inter-regional collaborations. More help can be sought from the IUCN Conservation Planning Specialist Group. All of these tools are available in the Tools box at the end of this section.

Effective planning includes identifying monitoring and evaluation of progress, ensuring that programmes remain on track toward achieving desired outcomes and goals. If processes and outcomes are not aligned, programmes can operate smoothly without achieving their desired outcomes (Kleiman et al. 2000; Meredith et al. 2017). Additionally, evaluation of clear targets for progress will likely improve cost effectiveness of a programme (Kleiman et al 2000; Kapos et al. 2008; Bottrill et al. 2011; CMP 2013) and improve the decision-making progress. Unfortunately, only one programme in this study mentioned the use of monitoring and evaluation. A few papers on the topic are available in the Tools box.

Analogous species

Analogous species refers to the use of a similar, but more common species to the species targeted for conservation action. The analogue species is used to develop protocols through a captive research programme, before the target species is brought in and bred based on the knowledge gained from the analogue species. There are however limitations to this method as captive breeding requirements are not always transferrable between similar species (Michaels et al. 2015).

Communication

Communication must be carried out both internally and externally with the public, governments, funders and partners. Communication includes a lot of public relations and media (see *Social relations*, section 3.3). One manager mentioned having to communicate the science behind reintroductions to the public and government who were pushing for these to take place before genetic diversity and suitable habitat conditions had been ensured. Understanding how to communicate best with individuals is also important. Some managers mention having to plant the seeds of ideas in certain individuals' minds and allow that individual to think of it as their idea for them to take an interest and engage in actions. Communication must also occur between staff, partners and funders to share successes and failures or barriers. A failure to discuss the latter gets in the way of transparency and efficient problem solving. In rare cases, poor internet or phone signal limits communication. A strategy for communication can provide a useful tool for many programmes.

Staff management

Staff management is often complicated by issues such as low salaries, high turnover and low in-country expertise. It involves ensuring a content, expert workforce. The lack of training or expertise can lead to husbandry failures and loss of individuals. The lack of contentment or willingness in the workforce can similarly lead to sloppiness and loss of staff members, in which managers might have invested considerable training and development (see Section 3.5). Such failures can be prevented by increasing salaries, providing career opportunities and by changing the managerial structure, allocating tasks, and implementing standardised rules, daily controls, accountability and supervision.

Protocols

For biosecurity protocols see *Biosecurity* under Section 3.1.

Husbandry and breeding protocols are needed to develop the best practice guidelines for keeping the species. The development of these guidelines often happens through a trial and error approach, combined with an evidence-based approach in cases where information on the species is available. This process is important for documenting errors to prevent them in the future. For many species, keeping and breeding is difficult in the beginning when information on the species is lacking, but this challenge can often be overcome by long term efforts. In some cases, analogous species may be appropriate for developing the protocols (See *Analogous species* in this section). Studbooks are needed to ensure the maintenance of the genetic diversity. Unfortunately, just over 60% of managers in this study reported that their studbooks were of high quality (see Figure 4, Section 2).

Mindsets

Many programme managers discuss a need for a change in mindsets. Some experience a lack of initiative and independence in staff, and seek a more interdisciplinary workforce. Some want to ensure that they are streamlined with global views on amphibian conservation. Creativity and "thinking outside the box" is desired, especially when it comes to finance (see *Finance*, section 3.12). The mindsets of partners and governments are also relevant, with a need to ensure an understanding of the function of captive breeding programmes (see *Social relations*, section 3.3). Lastly, a shift in focus towards more in situ work is advocated to challenge the potential preconception that captive breeding programmes are the silver bullet to saving threatened species.

Responsibility

Running a captive breeding programme can be extremely challenging. One of the things that makes managers initiate these programmes, and keeps them going for decades, is the feeling of responsibility. Managers are often aware that if they do not do the work, no one will. They feel that the survival of a species depends on their continuing work. The feeling of responsibility sometimes extends to institutions who feel that they need to use their capacity to contribute to amphibian conservation specifically. Sometimes the level of responsibility and therefore the level of ambitions does not necessarily correlate to available resources and capacity. Programmes can therefore end up taking too many species on, without realising the time and resources that a successful conservation programme for just one species will require.

> *"For example, my main concern now is like if I die tomorrow probably the year after the project is also going to die."*
>
> *"But we, you know, we're in that classic herpetology trap of trying to do as much as we can with as little as possible."*
>
> *"I mean it's an extraordinary commitment. So our philosophy is then we will give it a shot. We need to operate at a scale at which the problem… we don't get to dictate the size of the problem. The problem dictates its own size and then we need to respond appropriately."*
>
> *"It's too hard, so, we are working here from the heart. So everything we do here is from the heart. It's too difficult, but […] we are going to succeed"*

> *"*that's why we keep doing this because frogs are more important than us you know."

Balancing tasks

Being a captive breeding manager involves a wide variety of tasks, which expand past the fields of biology and conservation. Some tasks can easily take up big chunks of a manager's time, such as writing grant proposals, or day-to-day husbandry. This might be a cause for the down-prioritisation or delay in tasks that are pivotal to achieving long-term objectives, eventually hindering the progress of a programme.

> *"Yeah, one main thing that is only for me a problem is like, I'm not octopus…. Yeah because I need to write applications, write reports, to work with my PhD, to coordinate things in [my country]. Meetings with government in [my country], meetings with other institutions. Now I have two kids so, it's difficult to increase. Sometimes I feel that I'm less active now in the project because of my PhD and my family but yeah, you have to find a balance with all this*."

Managing expectations

All managers have to be clear to their partners, staff, directors, governments and the public about what is feasible and achievable to avoid a lack of understanding and support based on overpromised and under-delivered objectives. For example, if amphibians in a given habitat have a high chytrid prevalence, and the target species is particularly susceptible, be clear that the programme is likely to run for decades without the possibility of conducting reintroductions.

Partners and support:

There is a real need for improved planning processes for these programmes although this is not an area of expertise that many managers hold, or even something they consider a priority. Therefore, partner input on planning is not just beneficial, it's essential. The prioritisation of species requires specialised input from a range of contributors. The AArk's Conservation Needs Assessment process is designed for this purpose (Johnson et al. 2018), but there is a lot of work to be done and not all species are assessed precisely. A lot more research needs to feed into this process. Lastly, partners can assist with the facilitation of programmes. This generally entails putting managers in touch with contacts that are interested in funding a project, in providing expert advice, or in partnering and supporting project activities. The AArk acts as the main facilitator of ex situ programmes and distributes newsletters and notifications of funding opportunities. See Tools text box below for details.

Tools

Amphibian Husbandry Chat group: A WhatsApp group for amphibian experts to discuss husbandry issues: https://chat.whatsapp.com/59Ckh74mNxd78PVfU1xObp

AArk programme implementation tool: This tool helps determine when a programme should be initiated, and what components to ensure before the initiation: http://www.amphibianark.org/adequate-resources/ it can be downloaded and used offline at: http://www.amphibianark.org/tools/AArk%20Program%20Implementation%20tool.xls

Amphibian Conservation Needs Assessment: The Conservation Needs Assessment identifies priority amphibian species for ex situ research (such as analogous species) and conservation through an objective and consistent prioritisation process. The webpage is in English, Spanish or French, and can be found here: www.ConservationNeeds.org The full assessments can be seen here: www.ConservationNeeds.org/AssessmentSearch.aspx or you can read about their assessment process here: http://www.amphibianark.org/pdf/AArk-Conservation-Needs-Assessment-tool.pdf

Captive programmes pages: This AArk page provide access to a set of pages on amphibian husbandry skills and standards, establishment of new programmes, species knowledge, programme resources, population management and founder animals: http://www.amphibianark.org/conservation-programs/captive-programs

Global Species Management Plans: A resource template for developing a species management plan with globally agreed goals, through an inter-regional approach. Produced and made available by WAZA here: http://www.waza.org/files/webcontent/1.public_site/5.conservation/conservation_breeding_programme/resource_manual/GSMP%20Resource%20Manual_10Sep2015.pdf

IUCN guidelines for determining when and how ex situ management should be used in species conservation: Guidelines published by the IUCN in Conservation Letters found here: http://onlinelibrary.wiley.com/doi/10.1111/conl.12285/full

IUCN guidelines for reintroductions and other conservation translocations: The IUCN guidelines on planning and implementing reintroductions from 2013. Available here: https://portals.iucn.org/library/efiles/documents/2013-009.pdf

IUCN guidelines for species conservation planning: Written by the SSC Species Conservation Planning sub-committee, these guidelines follow a planning, implementation, learning and adaptation cycle. It also emphasises the One Plan Approach which promotes collaboration between all relevant stakeholders and streamlining of goals and vision. Available here: https://portals.iucn.org/library/sites/library/files/documents/2017-065.pdf

Monitoring and evaluation: The following papers provide a good overview of the importance and use of monitoring and evaluation in conservation:
Kleiman DG, Reading RP, Miller BJ, Clark TW, Scott JM, Robinson J, Wallace RL, Cabin RJ, Felleman F. 2000. Improving the evaluation of conservation programmes. Conservation Biology. 14(2):356-65.

Tools continued

Monitoring and evaluation continued: Mascia MB, Pailler S, Thieme ML, Rowe A, Bottrill MC, Danielsen F, Geldmann J, Naidoo R, Pullin AS, Burgess ND. 2014. Commonalities and complementarities among approaches to conservation monitoring and evaluation. Biological Conservation. 169:258-67.

Stem C, Margoluis R, Salafsky N, Brown M. 2005. Monitoring and evaluation in conservation: a review of trends and approaches. Conservation Biology. 19(2):295-309.

Kapos V, Balmford A, Aveling R, Bubb P, Carey P, Entwistle A, Hopkins J, Mulliken T, Safford R, Stattersfield A, Walpole M. 2008. Calibrating conservation: new tools for measuring success. Conservation Letters 1(4):155-64.

Open Standards for the Practice of Conservation: The open standards developed by the Conservation Measures Partnership provide a guide for conservation planning based on the newest industry standards. It follows a cycle of conceptualizing, planning, Implementing and monitoring, analysing and adapting, and learning. The use of the Open Standards is accompanied by the Moradi software. See the newest version in English, Indonesian, Portuguese, French, Albanian or Spanish here: http://cmp-openstandards.org/download-os/

PopFrog: This is a set of tools that assist in setting goals and management of ex situ populations. The tool was developed to provide guidance to managers, but now also includes analysis of species with a low reproductive rate. Find it here: http://www.popfrog.org/

Species for ex situ research programmes: All species recommended for captive research programmes, as identified by the Conservation Needs Assessment can be found here www.amphibianark.org/species-for-ex-situ-research/ and in Spanish here: www.amphibianark.org/es/species-for-ex-situ-research/

Species for rescue programmes: All species urgently in need of captive breeding rescue programmes as identified by the Conservation Needs Assessment can be found here: www.amphibianark.org/rescue-species/ and in Spanish here: www.amphibianark.org/es/rescue-species/

Template and guidelines for developing a Species Action/Recovery Plan: The following template by the AArk guides the development of the taxon management plan for in situ, ex situ and education and awareness information and strategies: http://www.amphibianark.org/pdf/Species-Action-Plan-template-EN.docx or in Spanish at: http://www.amphibianark.org/pdf/Species-Action-Plan-template-ES.docx

Template for developing husbandry guidelines: The AArk has also produced a template for developing the husbandry guidelines of your project, in English: http://www.amphibianark.org/pdf/AArk-WAZA-Husbandry-Guidelines-template-English.doc, Spanish: http://www.amphibianark.org/pdf/AArk-Husbandry-Guidelines-template-Espanol.doc and French: http://www.amphibianark.org/pdf/AArk-WAZA-Husbandry-Guidelines-template-French.docx

ZIMS for studbooks: Studbooks are managed through the Species 360 ZIMS tool. It is designed to make the job of the studbook keeper easier. Read more and access the tool at: https://www.species360.org/products-services/zims-for-studbooks/

3.7. Support

Internal support

Internal support refers to the amount of support a manager receives for their programme from the internal management of the parent institutions (unless the programme is independent). Internal support if often something managers have to advocate for at the beginning of the programme, but as the programme develops and achieves its objectives, directors and other management are often keen to support it. Support is often lacking for conducting field work, and in rare cases, institutions focus on research without supporting conservation. However, this lack of support generally has to do with the type of institution and their capacity and budget rather than a lack of desire to support such activities. Therefore, it seems more likely that this issue can be resolved through partnership support rather than increased internal support.

> *"Yeah…. I can tell you that one day I got 100% support, the next day they basically told me if you want, you can leave it."*
>
> *"… we already did the most difficult part which is convincing the bosses to invest in amphibians, we are already, we already got that so that if you do this interview one year ago I will tell you that it's really difficult to convince people to, to give money for this species"*
>
> *"Resources have been really difficult. And it's going back to that exactly what I just said to the, the, the whole buy in is very difficult. Even though we are a research organization it's just really difficult to, to sell that idea. Only now have actually just acquired my own dedicated area, so everything before that was done I basically did in in current rooms that were housing reptiles."*
>
> *"I think our directors since the beginning supported the idea of the amphibians, to work with the amphibian conservation… yeah but I think is not enough… because*

the Zoo doesn't work only with amphibians. We have to share the money with all the other animals so not all the time we have the money for only for to this group."

Complications in partnerships

There is a wide variety of complications and conflicts between partnerships, most of which are not unique to amphibian conservation or captive breeding programmes. Government relationships are the most complicated with lack of action, insufficient policies and legislation, and delays in permits (see *Government relations* in Section 3.2). Internal conflicts also occurred with changes in internal support, and conflicts over ownership and credit for programmes. Some programmes had issues with streamlining goals both internally and between partners. In one case, a partnership with the ASG has become a hindrance as the local ASG did not follow up on their responsibilities but caused delays in legal processes. In some countries, there is little or no collaboration between institutions holding the same species, and sometimes even rivalries occur. This is extremely counterproductive and does not benefit conservation of the species. Neither does institutional monopoly over a programme and their species, which should be accessible to interested researchers and local scientists. Having said that, most programmes have productive partnerships and good relationships with their stakeholders, with an understanding of their importance. Memorandums of Understanding (MoU) can be used as agreements of responsibilities between partners. Although they cannot completely prevent complications in partnerships, they can in some cases reduce complications and resolve them when they happen. Unfortunately, the use of MoUs amongst participating programmes did not appear to be widespread, and when mentioned, did not appear effective. This due to either lack of action from partners, or changes in the programme structure over time.

Bureaucracy

Bureaucracy is a very common cause for delays and limitations in programmes. Generally, these delays come from governments rather than partners or internally. Bureaucracy can affect the import of resources, exchange of amphibians between partner institutions or for biocommerce purposes, harvest of wild individuals for the breeding programme, permits for reintroduction, research permits, access to field sites, changing of policies, international transfers etc. For example, it can take three months to get permits for a volunteer (see quote below). Bureaucracy can be extremely difficult to overcome. The laws and operation of the government of the country in which you want to work, should be understood from the beginning, and delays be prepared for as much as possible. A good relationship with the government is most effective in optimising these processes (see *Government relations* in Section 3.3).

"But the authorities here are… the bureaucracy here is incredible. And nobody cares about the environment. So this is, this stuff is something that is really important. And the problem is that my activity the activity of [my programme], incredibly is located in the same bag of control as activities as oil production and mining […] So I have to have a lawyer to explain all the environmental impacts of breeding endangered species to bring them into the wild. And the same person that will go to the oil production place you know, and [they] keep asking for all the emission, all the water use and all the garbage and things like, will go to the lab in which we are breeding the species and ask me for all of that. And you understand? So this is crazy […] That is why it's extremely expensive to do such a such a project of breeding Endangered species… and the project is located on the follow up of an agency that doesn't have persons really well-trained because they have to deal with other kind of really heavy impact industries."

"So every time if there is overpopulation in a facility you have to kill animals. And even you want to reduce this, you have to ask permits from them. So if you want to do euthanising animals even a sick animals you cannot euthanize by yourself. So you have to call the Amphibian Specialist Group in [my country]. You have to send an email to the government because they have to give you permits before you kill something. So that is also one problems. So what we want is to facilitate these things. I think we could have like organization inside [my country] to facilitate these things […] so that is why even there is as a volunteer want to work with the association we have to send to them the entry form they have to fill it. They send it back to the facility. Then we send this form to ASG and to the government. So if one of them is not sign the paper it means we do not have permission."

Network and partnerships

The wider network of a programme can consist of partner institutions hosting the same species, funders, donors, facilitators, external researchers, students, the government and local communities. The development of useful partnerships is essential, especially at the onset of a programme. These partnerships can act as a stepping stone through facilitation and networking, or they can act as direct providers of needed resources. A good network provides access to opportunities such as donors or other funding opportunities, training, equipment of specific interest, new research findings, PR and media assistance and other partners with the relevant resources for the programme. This will help to ensure that the programme is being managed holistically, including both in situ and ex situ conservation actions. Most importantly though, a good network can provide the right advice and expertise, and in some cases mentoring. Experts should be chosen based on their understanding of the local context and species and therefore experts from overseas are not necessarily the right experts for the target species. A good network also offers credibility amongst peers, local communities and the government. A manager's proactiveness and reputation influences their ability to build meaningful partnerships. Several years are often spent searching for new partners, and it must be ensured that partners fit into the needs and goals of the programme. When a partnership is established, it is important to manage the relationship and avoid conflicts or other complications. MoUs are a useful tool for this (see Complications in partnerships)

Prioritisation of amphibians

A lack of interest in amphibians and understanding of their importance, value and declines is perceived as a barrier. In general, it is difficult for managers to build support for amphibian conservation in comparison to more charismatic species, and amphibians remain underrepresented in zoos compared to other taxa (Conde et al. 2013). In some cases, false myths and perceptions of amphibians can generate negative perceptions. If a programme is up and running, it has likely managed to build some support, but general perceptions and attitudes towards amphibians from the public, from governments and within the conservation community are often cited as a barrier in building the needed support, or in advocating for the implementation of certain actions (see *Social relations*, section 3.3.). Specifically, some programmes struggle to get amphibians included in national species conservation lists.

Changes in support

A captive breeding programme relies on human and financial support. Some programmes run for decades, during which it is not unlikely that there will be a change in levels of support (managerial, financial etc.). Not only can this divert programmes from their goals and objectives, but it can

endanger whole captive collections, and therefore it is important that there is a shift towards more long-term support for these programmes, both internally and externally (See also *Financial continuity* in Section 3.12). Sometimes, increases in support (institutional, governmental, public and financial) occur after programmes have produced good, demonstrable results. This allows programmes to plan and to address all necessary actions to progress towards its goals.

All talk, no action

Some programmes experience partners or governments which commit to contributing to a programme, but a lack of action follows the commitment. Whilst the optimal situation would be more international and national pressure on governments, and more accountability, the more likely solution to this is that programme managers are aware that promises might not be fulfilled, and where possible, prepare a backup plan.

Inspiration/motivation

National and international appraisals from the public and the scientific community is a factor in maintaining the motivation of captive breeding managers, while other amphibian advocates are essential in inspiring local leaders to set up such programmes in the first place. The AArk Newsletter is one medium of providing an opportunity for managers to showcase their achievements (see the Tools textbox for more details).

Partners and support

As this section focuses entirely on support, no additional information is provided here.

Tools

Amphibian Conservation Needs Assessment: The Conservation Needs Assessment identifies priority amphibian species for ex situ research (such as analogous species) and conservation through an objective and consistent prioritisation process. The webpage is in English, Spanish or French, and can be found here: www.ConservationNeeds.org The full assessments can be seen here: www.ConservationNeeds.org/AssessmentSearch.aspx or you can read about their assessment process here: http://www.amphibianark.org/pdf/AArk-Conservation-Needs-Assessment-tool.pdf

AArk newsletter: The AArk newsletter is available in English and Spanish. See previous newsletters here: http://www.amphibianark.org/news/aark-newsletter/ or subscribe for free here: http://www.amphibianark.org/news/subscribe/

Directory of husbandry experts: The AArk has created an international directory of amphibian husbandry experts, with information including the experts' contact details, country and categories (nutrition, population management, enclosure design, developing new programmes, live food production and more). Find it at: www.amphibianark.org/amphibian-husbandry-experts/ or in Spanish at: www.amphibianark.org/es/amphibian-husbandry-experts/

Amphibian Husbandry Chat group: A WhatsApp group for amphibian experts to discuss husbandry issues: https://chat.whatsapp.com/59Ckh74mNxd78PVfU1xObp

Amphibian Veterinary Outreach Programme: The AVOP WhatsApp group is available for assistance on veterinary issues in captive amphibian collections, for managers in Latin America who have limited access to veterinary expertise. See http://www.amphibianark.org/about-us/workshops/veterinary-program/

Red-skirted tree frog
Berglind Karlsdóttir

3.8. Expertise

Amphibian husbandry expertise

Programme expertise in amphibian husbandry requires a very specific profile of staff, an in-depth knowledge of the species and their physical environment, and an ongoing learning process. At the beginning of a programme, there is often a shortage of husbandry expertise in-country, and the programme will need to build this expertise through staff training and seeking external advice. (see *Staff expertise* in Section 3.5). A lot of initial expertise will come from the manager's personal experience in keeping species in the past, or from the use of analogous species (see Section 3.6). Expert input from partner organisations and training of staff is essential in this process, and different training opportunities are available through AArk workshops, informal internships and zoo-based courses (see *Staff training* in Section 3.5. and the Tools box below). Over time, husbandry and breeding will become easier and staff will become more professional (unless turnover is high). Unfortunately, lack of expertise and training is one of the leading causes of failures and can lead to the death of several individuals from unsuitable husbandry conditions.

Veterinary expertise and laboratory expertise

Programmes vary a great deal in their access to veterinary expertise and laboratory facilities, and it seems that the two don't always go hand in hand. Zoo-based institutions often have access to both, but the level of veterinary specialisation can be poor as veterinarians must focus on all the animals in the zoo. In these cases, veterinary teams effectively undergo a learning process alongside the programme staff. For big, independent programmes, an individual veterinarian is often employed and will be more specialised. For small individual programmes, access to a laboratory is often provided through an external institution such as a university. Lack of expertise on how to use these facilities renders them less valuable. For all three types of programmes though, external expertise and insight into veterinary practices is considered a valuable resource, and a lack of availability of these resources prevents identification of malnutrition, unsuitable conditions of light, temperature and humidity, and

causes of deformities, diseases and other deaths. Veterinary advice is available from the AArk associated veterinarians (see Tools box below)

In-country capacity

Unfortunately, the level of amphibian husbandry expertise is often low in-country, or at a given location, and it can be hard to find candidates for the jobs, with a good scientific background and prior experience working with amphibians. Low salaries exacerbate this problem. This highlights the need for capacity building, usually achieved through work placements or workshops (see *Staff training* in Section 3.5)

Workshops

Husbandry workshops are often facilitated by the AArk and other institutions to meet a range of needs. Training workshops allow the AArk to share knowledge and build in-country capacity. Conservation Needs Assessments are carried out to generate prioritised lists of recommended conservation actions, through evaluations of species in a country or region. Some programmes carry out their own workshops to share their knowledge. These workshops come at a relatively high cost, but the contribution towards the learning process of individual programmes, and improvements in decision making is significant.

Reintroduction expertise

Reintroduction of captive bred individuals to the wild comes with a range of risks. This includes the inability of captive bred individuals to adapt and survive in the wild, the risk of introducing diseases into existing populations, and the risk of mortalities due to persisting threats. Many pathogens of concern, such as ranaviruses, cannot currently be screened or treated effectively and species from different ranges that share facilities, risk exposure to novel pathogens, putting programmes and sympatric species at risk (Tapley et al. 2016). This is why the AArk and the ASG recommend that captive breeding programmes which will likely include a reintroduction component occur within the range country of the species. There are a number of guidelines that advise on when to reintroduce, and how to do it. Find these in the Tools box below. The process should always be carried out with tremendous care and a high level of professionalism. Technical input from experts is often needed here to guide the managers, advising on details of the process (such as tagging and tracking, or disease management).

> *"Yeah, conservation... I was not thinking of introduction at [the beginning], I just wanted to speed up the learning process and also to think, start thinking about conservation not reintroduction because I didn't know too much about that."*

> *"… I think we still need some technical support on preparing the animals. I mean how to choose environments in the wild to release frogs into the wild again. Or how to prepare the animals from a disease point of view, I mean we don't want to introduce diseases into the wild. I mean we don't have protocols to follow to release animals to the wild, so I think that's one of the main resources that we miss. So have this technical support to develop the reintroductions projects"*

Language skills

In some cases, the inability to speak and read English poses a barrier to the learning process of staff and managers, as they struggle to access the newest, international research or communicate with

peers. However, this only appears to be an issue in very few programmes, mainly in Asia or among the older generation.

Outreach expertise

Some programmes receive input or assistance on producing outreach content such as photography, filmmaking, radio broadcasting and organising of events. This is considered useful for building local and international support. Monitoring and evaluation though is not carried out to evaluate the true impact of these activities. Such studies could potentially be designed and carried out by student researchers (see Section 3.3). For communication of your work within the amphibian community, the AArk newsletter or FrogLog are good options (see Tools below)

Partners and support

Information and expertise is the second highest resource provided to captive breeding managers by their partners (Figure 5, Section 2), and there is a good reason for that. Expertise is needed for every aspect of a programme, at every stage of a programme. The AArk does much in terms of facilitating expertise, and they provide a newsletter, a husbandry WhatsApp chat for programme managers, and a directory of experts (which you can find in the Tools textbox below). Further enhanced networks and communication channels for managers have the potential to increase the effectiveness of programmes with timely problem solving and through sharing of lessons learnt, as well as discussing ideas and perceptions of the role and future of captive breeding programmes. As partners, an engagement in the debate and the sharing of knowledge and expertise is a significant contribution in itself.

Tools

AArk newsletter: The AArk newsletter is available in English and Spanish. See previous newsletters here: http://www.amphibianark.org/news/aark-newsletter/ or subscribe for free here: http://www.amphibianark.org/news/subscribe/

Amphibian husbandry workshops: The AArk run amphibian husbandry training workshops in priority areas. For more information see: http://www.amphibianark.org/about-us/workshops/husbandry-training/

Amphibian management school: AZA runs a range of training courses relevant to species management. Specifically, they run an amphibian management school at the beginning of the year. Keep an eye out on their calendar: https://www.aza.org/calendar, http://saveamphibians.org/2018-advanced-course/

AZA Guidelines for reintroduction of animals born or held in captivity: The Association for Zoos and Aquariums guidelines on reintroductions from 1992. Available at: https://www.speakcdn.com/assets/2332/aza_guidelines_for_reintroduction_of_animals.pdf

Amphibian Veterinary Outreach Programme: The AVOP WhatsApp group is available for assistance on veterinary issues in captive amphibian collections, for managers in Latin America who have limited access to veterinary expertise. See http://www.amphibianark.org/about-us/workshops/veterinary-program/

Tools continued

Directory of husbandry experts: The AArk has created an international directory of amphibian husbandry experts, with information including the experts' contact details, country and categories (nutrition, population management, enclosure design, developing new programmes, live food production and more). Find it at: www.amphibianark.org/amphibian-husbandry-experts/ or in Spanish at: www.amphibianark.org/es/amphibian-husbandry-experts/

Durrell Conservation Academy: Durrell Wildlife Conservation Trust does several training courses on practical conservation work. These include the Durrell Endangered Species Management Graduate Certificate, which provides students with a wide set of skills needed for implementing successful conservation interventions and a two-week endangered species recovery course. For more information see: http://wildlife.durrell.org/courses/

EAZA Academy Courses: EAZA occasionally run courses on ex situ programme management and funding for in situ conservation. See their calendar here https://www.eaza.net/academy/courses/

FrogLog: Produced by the IUCN SSC Amphibian Specialist Group, the FrogLog is a more general magazine on amphibian conservation. Read or subscribe here: http://www.amphibians.org/froglog/

Husbandry documents: A collection of husbandry documents relating to various aspects of amphibian husbandry, where you can search for words in the title, the author and the description fields, using the search field in the menu bar. These are available at: www.amphibianark.org/husbandry-documents/

Amphibian Husbandry Chat group: A WhatsApp group for amphibian experts to discuss husbandry issues: https://chat.whatsapp.com/59Ckh74mNxd78PVfU1xObp

IUCN guidelines for determining when and how ex situ management should be used in species conservation: Guidelines published by the IUCN in Conservation Letters found here: http://onlinelibrary.wiley.com/doi/10.1111/conl.12285/full

IUCN guidelines for reintroductions and other conservation translocations: The IUCN guidelines on planning and implementing reintroductions from 2016. Available here: https://portals.iucn.org/library/efiles/documents/2013-009.pdf

Field work in Yacuri, Ecuador
Berglind Karlsdóttir

3.9. In situ conservation

Habitat conditions

Suitable habitat must be available for the reintroduction of a species but is one of the three most common and critical barriers to programmes. Harding et al. (2016) found that the proportion of amphibian captive breeding programmes for conservation which carry out reintroductions as opposed to keeping assurance populations without possibility of reintroductions in the short-term reintroduction, has fallen significantly. This was likely due to the increase of threats in the wild which cannot currently be mitigated, such as chytrid fungus or climate change. It is debated whether species which do not currently have available habitat, or reversible threats, should be prioritised in these cases (discussed in the Introduction and under *Prioritisation of species*, Section 3.6). Reintroduction trials are carried out by some programmes and could offer insight into the feasibility of future reintroductions into habitat that may never become fully suitable. Ensuring suitable habitat can require a range of activities including habitat protection, management, restoration and/or identification and availability of alternative reintroduction sites. The barriers to providing suitable habitat are diverse and complex and include ecological and human factors. Examples include: reintroduction sites are privately owned with limited access and permission; agriculture and the impact of protection or restoration of habitats on local livelihoods; harvest and persecution of species can make suitable habitats unsafe for amphibians; habitat connectivity or climate change can have an impact on populations in otherwise suitable habitats and is often difficult to identify; development, mining and lack of legal or enforced protection; the presence of chytrid fungus.

> *"I think it's important [to] hopefully see a little bit more of a shift in priority… towards in-situ stuff which I think tends to be a lot more long term beneficial for any you know taxa that are of special concern."*

Access to field sites

Many factors can affect a programme's ability to access their field sites for conducting research, monitoring, reintroductions or habitat restoration. Vehicles must be available to the managers, including in some cases boats. Permission to access the land is needed, and reintroductions and/or

restoration can often not take place on privately owned land. Weather conditions and species seasonality can also hinder expeditions, sometimes even when they have been organised and participants are ready to leave. In some cases, political unrest in certain areas can block access, or endanger the lives of the participants. Decisions must then be made to abort these expeditions indefinitely until conditions improve.

Allocation of resources

Research into the habitat threats, target solutions, and selection of sites is extremely time and resource intensive and increases with the number of species in a programme. Often, the resources required for this aspect of a programme have not been sufficiently secured and are not provided from the parent organisation (see *Internal support*, Section 3.7). Programmes then need to search for external partner institutions, researchers and funding. Programmes which have external partners leading the field work component of a programme are able to focus on the captive breeding and still achieve long term conservation objectives. Furthermore, some programmes consider outreach and engagement to be an essential part of the field work component.

Fear/apprehension of reintroductions

Due to the potential risks of reintroductions, fear or apprehension can occur both from the programme managers themselves and externally from governments or the public. Reintroductions should only be carried out after careful preparation and when everything is in place. It is a very real possibility that concerns regarding the potential consequences of reintroductions are blocking this advance, either because managers don't feel ready enough, or because government officials do not want to take a risk and possibly lose popularity as an outcome.

Partners and support

There is a huge gap between ex situ and in situ conservation efforts at the moment, and the resource constraints of most programmes means that this gap is most feasibly filled by external partners. The facilitation of in situ efforts needs to be coordinated with ex situ efforts to truly implement "captive breeding programmes as a complementary tool to in situ conservation" as planned by the Amphibian Conservation Action Plan (Gascon et al. 2007). Partners sometimes conduct parts or even all of the field work component of a programme, allowing captive breeding managers to focus on the captive breeding, whilst ensuring that suitable habitat is available for reintroductions. Useful contributions can include tagging and monitoring equipment, vehicles and salaries for field staff.

Tools

ASA Website: The Amphibian Survival Alliance is a global partnership for driving forward amphibian conservation. They assist with guidance and fundraising for in situ conservation projects. They also provide a suite of resources on their website, including the ACAP, action plans and guidelines. Have a look at: http://www.amphibians.org/

ASA Facebook forums: The ASA has established a range of Facebook forums for sharing of ideas and publications. The topics cover: captive breeding; climate change; communication and education; genome resources; ecotoxicology; habitat protection; infectious diseases; reintroductions; species conservation strategies; surveys and monitoring; taxonomy and systematics; and trade and policy. Access the groups here: http://www.amphibians.org/social/

Common frog
Berglind Karlsdóttir

3.10.Species and individuals

Availability of founding individuals

This is a point that really needs to be thought through before the collection of individuals. Will there be enough parental pairs to maintain the genetic diversity of the captive population? If not, are you willing to take the risk that the species might not persist after reintroduction? If there are not sufficient parental specimens in the wild, are there additional captive populations available at other institutions? The AArk recommends a minimum of twenty active breeding pairs of animals be used as founder animals, ideally including several different locations or populations. Their founder calculation tool and "PopFrog" – a tool for methodology and setting of goals for captive populations, can be found in the Tools box below.

Diseases

Some programmes experience diseases among their captive populations at the beginning of a breeding programme. This is a huge problem and has led to severe declines in captive populations. Diseases are often attributed to poor nutrition, insufficient lighting, unsuitable water and other husbandry issues. Transmission of diseases can also happen via individuals collected from the wild, or brought in from external captive collections. Detailed biosecurity protocols minimise the risk of disease transmission (see *Protocols* in Section 3.6 and the Tools box below). Veterinary expertise (see Section 3.8) is important for the identification of diseases and their causes. Managers are often open and honest about these losses, which contributes to the learning process.

Genetic diversity

Before bringing the individuals into captivity, and effectively lowering the wild genepool of the species, it is important to establish that the target species is taxonomically stable. Then, ensuring maintenance of genetic diversity within the collection is a concern for all programmes. The size of facilities and the availability of founding pairs are often limiting factors to breeding a sufficiently high number of unrelated individuals - especially for programmes that act reactively for species where dramatic

declines have already taken place and the founding population is small. Genetic uncertainty can pose big problems to programmes faced with hybridisation, species complexes or different populations that are genetically distinct from one another (Tapley et al. 2016). In some cases, populations have been collected and later been found to be genetically distinct from one another, reducing the set of founding pairs for each population to a point where long-term survival is highly compromised. This problem is exacerbated by the high cost of genetic testing, and such problems are often left unresolved for a long time. Studbooks are also pushed back, or poorly implemented (See Figure 4 in Section 2), partly due to the cost of genetic tests. Furthermore, for species kept in groups it can be difficult to identify the parents, and in one case inbreeding occurred when a female was mistaken for a male. One programme is resorting to importing individuals from international collections to increase the genetic diversity, which poses risks in terms of transmission of novel diseases. Other programmes have to continuously collect and introduce individuals from the wild to the captive population. If genetic problems are not resolved, the captive offspring might not be suitable for reintroduction, and potentially lower the evolutionary potential of the species (Tapley et al. 2016).

> *"A lot of these different taxa that suffer declines… we have these remnant populations that are still around obviously… that genotype is important in the population, because obviously they have been able to pass through the… you know the selective pressures would be different, the different pathogens that were affecting them, the chytrids. So I think it's kind of a shame that these small recuperating populations are… they're pulling these different individuals out of there which is you know just kind of shaving down the gene pool even more."*

Species with unusual husbandry requirements

Although amphibians appear to be ideal for recovery programmes due to their space requirements, it must not be forgotten that they can be very difficult to keep and breed. Amphibians are niche-specialists and often require very specific physical, chemical and biological parameters. The difficulty varies between species, and this should be taken into consideration when prioritising species for captive breeding programmes. If no information is available, an analogous species could be used (see *Analogous species*, Section 3.6). If a facility maintains multiple species, and if these species are from different regions and/or habitat types, catering to the environmental requirements of each species becomes increasingly complicated and a lot of time and resources will go into developing the keeping and breeding protocols. This can hinder a programme from entering the next stages of a project, and the long duration of captivity can lower the chances for success (see Tapley et al. 2015a).

Ethics

Ethics was not frequently brought up in this study, and overlaps somewhat with the animal welfare category, but is very likely something that subconsciously guides the management model of a programme. For example, one programme has hesitations to follow guidelines of culling surplus stock once breeding has become "too successful". Others have discussed the ethics of taking individuals from the wild gene pool of already threatened species and making the survival of that species dependent on human processes. The impact of a manager's values on decision making and ultimately the progress of the programme is something that is not well understood and needs further research.

> *"It's taken us you know [many] years to get to this point but now it's like - OK and now what - because now we're just finding that we have [loads] of frogs which is a fantastic. And so the first recommendation becomes cull which you know it just doesn't seem like that is a logical step for the reasons why we're even doing this."*

Animal welfare

Animal welfare was not frequently brought up in the interview study, but likely a major concern of programme managers. Welfare is considered before reintroductions with worries that captive bred individuals will not thrive and succeed in the wild. For example, concerns were raised that locomotive differences between captive bred and wild individuals had been observed, or that individuals bred in sterile facilities might not be resistant to wild diseases. This poses a trade-off between animal welfare and preparation for reintroduction (Harrington et al. 2013) but was not discussed much by managers in this study.

Ant infestations

Ant infestations can cause loss of individuals, and in some cases, they can be extremely difficult to prevent due to the small size of the perpetuators. Some possible solutions include improvement of facilities, keeping live food separated from amphibian collections and the use of ant poison. Building enclosures on shelving units, applying Vaseline to the legs of the shelves and then keeping the legs in buckets of water is an effective way of preventing ant infestations.

Partners and support

Partner institutions which hold a programme species in-house contribute significantly to the security of a species. This avoids the "keeping all the eggs in the same basket" scenario, ensuring that if one captive population is lost due to disease, fires, or other catastrophic events, parts of the captive population still remain. It is also an advantage when it comes to genetic management – the more individuals, the bigger the genetic makeup. Lastly, these partnerships are often important in knowledge sharing as institutions collaborate on the development of protocols and problem solving on diseases – an area where a lot of external advice and expertise is essential in solving problems. A network of experts with knowledge of a programme's species is important for all of the above.

Tools

Founder calculation tool: Advice on founding populations is available from the AArk's webpage at: www.amphibianark.org/founder-animals/ or in Spanish at: www.amphibianark.org/es/founder-animals/ A tool for calculating the needed founding population size, available online at: www.amphibianark.org/tools/Founder%20calculation%20tool.htm or in Spanish at: www.amphibianark.org/tools/Founder_calculation_tool_es.htm
Downloadable versions are available from: www.amphibianark.org/tools/AArk%20Founder%20calculation%20tool.xls Or in Spanish at: www.amphibianark.org/tools/Founder_calculation_tool_es.htm

PopFrog: This is a set of tools that assist in setting goals and management of ex situ populations. The tool was developed to provide guidance to managers, but now also includes analysis of species with a low reproductive rate. Find it here: http://www.popfrog.org/

Biosecurity and permanent isolation of ex situ conservation populations: Biosecurity manual for amphibian survival assurance colonies and reintroduction programmes. http://www.amphibianark.org/wp-content/uploads/2018/07/Biosecurity-Manual-2017.pdf

Red-eyed tree frog
Berglind Karlsdóttir

3.11. Information

Species-specific information

Prior information on a species allows a programme to adopt a more evidence-based approach as opposed to trial-and-error. This is advantageous as it can reduce losses of individuals due to incorrect nutrition or environmental conditions from the onset. Information on the wild conditions including diet, temperature, humidity, water quality, substrate use, breeding behaviour etc. feeds into the development of husbandry practices. Meanwhile, information on species distribution, population size, ecology and behaviour is important in the process of prioritising species for programmes to ensure the highest chances of success - for the species with the highest needs (see Section 3.6). Additionally, information on a species is, in some cases, considered essential in developing education programmes in order to communicate a species' life history, its role in the ecosystem, threat status and overall importance.

> *"You try to look in some books and some papers and you don't have enough information… there was a lack of information how to start a breeding programme of this species. I remember in the [Zoo] in the first year that I was there all the [amphibians] died and they don't reproduce, so we tried to do many research and we started captive breeding. And as you know, both species are Critically Endangered."*

> *"we have very limited information about how to keep amphibians alive. And how to set the terrariums on what to put inside and how to manage the water systems. We have no information about that. So that was I think the first limitation when we started"*

Availability of information

Unfortunately, species-specific information is often not available in the literature as amphibians are usually highly understudied, especially in the regions of priority. This is an issue of low funding and

low capacity combined with a prioritisation of novel research by local scientists. The IUCN and the AArk's Conservation Needs Assessments (see Tools box) aim to fill some of these research gaps, but inaccuracy of species assessments, lack of assessment and lack of species descriptions still occurs. Sometimes this can prevent the inclusion of species onto formal lists.

Although a lack of information in the literature has been cited as a main barrier to many of these programmes, they can build this information over time through field studies and observations (especially in big research institutions). Existing information held by programmes and other keepers of amphibians should be disseminated to help fill husbandry knowledge gaps. Specifically, more information is needed on how to adjust captive conditions including diets and provision of UV lights.

> *"For example, for Endangered species, It's difficult here in [my country] to prioritise the species. It's difficult because we are in a huge country and a lot of species that we don't know the real status. So it's sometimes difficult to try to save the species that need more actions of conservation."*

> *"And it seems you know it doesn't seem like that's moved, that's really advanced what's going on […] last year I guess or we had an Amphibian Ark workshop here focused on salamanders and we had you know [redacted] here and kind of just talking and it doesn't seem like there's been a lot of advance, that really knows what's going on as far as the different issues that are with certain [species]."*

Partners and support

Partners can contribute to the information available to a programme, mainly by conducting research on species of interest. This is often carried out by field partners, student researchers or external researchers visiting the programme. If you are partnering with a programme, ask that manager what their research needs really are and think of ways in which you can build capacity for this work.

Tools

AArk newsletter: The AArk newsletter is available in English and Spanish. See previous newsletters here: http://www.amphibianark.org/news/aark-newsletter/ or subscribe for free here: http://www.amphibianark.org/news/subscribe/

Amphibian and reptile conservation: This is an open-access, peer-reviewed journal for publishing of amphibian related research: http://amphibian-reptile-conservation.org/

ASA Facebook forums: The ASA has established a range of Facebook forums for sharing of ideas and publications. The topics cover: captive breeding; climate change; communication and education; genome resources; ecotoxicology; habitat protection; infectious diseases; reintroductions; species conservation strategies; surveys and monitoring; taxonomy and systematics; and trade and policy. Access the groups here: http://www.amphibians.org/social/

Amphibian Conservation Needs Assessment: The Conservation Needs Assessment identifies priority amphibian species for ex situ research (such as analogous species) and conservation through an objective and consistent prioritisation process. The webpage is in English, Spanish or French, and can be found here: www.ConservationNeeds.org The full assessments can be seen here: www.ConservationNeeds.org/AssessmentSearch.aspx or you can read about their assessment process here: http://www.amphibianark.org/pdf/AArk-Conservation-Needs-Assessment-tool.pdf

FrogLog: Produced by the IUCN SSC Amphibian Specialist Group, the FrogLog is a more general magazine on amphibian conservation. Read or subscribe here: http://www.amphibians.org/froglog/

Captive European tree frog
Phil Jervis

3.12. Finance

Availability

This point refers to the funding options available to programme managers. Locally, internal funding, government funding, donor interest and grant options might be extremely limited, partly due to perceptions and low prioritisation of amphibians and conservation (see *Social relations*, Section 3.3)

Financial continuity

Programmes based in zoos and other institutions will usually have core funding from the onset, although this does not always cover equipment or fieldwork. Individual programmes often struggle to secure funding and to maintain a steady income but do have the advantage of increased flexibility of their funding options. Financial security, continuity and flexibility frees up a lot of a manager's time allowing them to focus and invest in priority tasks (ex situ and in situ) needed to achieve long term conservation goals.

Allocation of funding internally

For programmes in parent institutions, limited funding often has to be shared with other activities of that institution. Internal support and prioritisation of amphibians plays a big part in the way funding is allocated. Furthermore, parent institutions may only fund activities of priority to them such husbandry and breeding, or ex situ research (see Section 3.7). This often leaves managers unable to conduct much field work or to buy specialised equipment (see Sections 3.2 and 3.9)

"Making do", financial discipline

There is no link between the budget of a programme, their ability to successfully keep and breed species, and to reach the reintroduction stage. While finance is an important aspect of a programme, it is just one component to its successful implementation. Some programmes highlight the importance of financial discipline and making do with few resources. For example, enclosures can be built using

in-country materials, and similarly, equivalents to imported nutrient supplements can sometimes be found in-country. One programme in has had to completely reinvent their keeping protocols, after political instability blocked access to the facilities for days at a time. An article was published in the AArk Newsletter (available on page 15 here, or in Spanish here), highlighting how the programme made use of natural light, and kept live food cultures inside the enclosures. It is often independent programmes which show innovative financial initiatives, as they have to source the funding themselves.

> *"Depending on the scale of your idea or your project… at a later stage it is a problem, but if you work I'm sure you'll work and if you are like a little bit lucky, you do have good results. I think it's easier and easier to get some funds… now for example it's a little easier… because people know us outside and it's easier to get funds because everybody wants to support us […] I don't want to see it as a limitation because at different stages you can work here with the things that you have."*

Different funding sources

Donors and external fundraisers can contribute significantly to the financial security and flexibility of programmes. One important component for developing such relationships is trust. A programme leader's ability to demonstrate their capabilities or the value of the project is an important driver in developing good relationships and access to a good funding network. Examples of donors in country and internationally include zoos, mining companies, amphibian hobbyists and schools.

Some programmes start with no funding and must search for donors and grant opportunities. This can be extremely time consuming and restricting. Even after decades of running, programmes can struggle to secure a stable income. The AArk allocates seed grants and has been instrumental in the development of many programmes at a time when other funding options have been limited. For more information on the seed grants, see the Tools box below.

Some programmes have been able to secure continuous, long-term funding from corporations such as mining companies or airport authorities, who wish to offset their impact on the local amphibians. Most programmes see this as a necessary collaboration for ensuring the survival of the focal species, and the funding provided from these companies is often a substantial contribution.

One programme included in this study was trialling biocommerce as a new model for the conservation of species threatened by the pet trade. Endangered, charismatic species were bred and exported to buyers, mainly located in the U.S. Future plans included an employment scheme, paying local women for replanting the species' habitat. The programme experienced success in awareness raising of the pet trade and building support amongst hobbyists in the U.S. Unfortunately, severe delays in export permits and a multitude of problems collaborating with the local and national government limited the programme which was not financially viable.

Partners and support

Funding is always needed by programmes, and if this is your preferred method of support, that's great! However, be careful to provide the money for what the programme really needs. Some programmes struggle from restrictions in what external funding can be used for. Sometimes, programmes might apply for funding for one aspect of a programme, but then need to spend money on other aspects such as broken equipment. Some programmes especially struggle with the lack of funding opportunities for staff salaries. Long term funding frees up a lot of management time from fundraising, and allows them to plan for the future, while fluctuations in income can cause managers to triage and drop aspects of a programme that are critical to their long-term success. Also, keep in mind that grant applications, follow-up reporting and evidence of expenditure can be time-consuming for managers. Lastly, some partners can provide access to a good network with potential funders such as supporting zoos and institutions.

Tools

AArk seed grants: The AArk seed grants have historically funded the set-up of programmes, but have been revised to include multi-year programmes and other types of amphibian conservation projects. Read more at: http://www.amphibianark.org/about-us/aark-activities/conservation-grants/

Mohamed bin Zayed Species Conservation Fund: provide grants between $5,000 and 25,000 to species conservation, and are looking for proposals on amphibians: https://www.speciesconservation.org/grants/

EDGE Fellowship: Grants available for the establishment of programmes for EDGE species in priority regions, including 6 weeks of training and $10,000 total for two years. Apply here: https://www.edgeofexistence.org/apply-now/

Columbus Zoo: Continuously accept proposals for grants and emergency grants, often supporting amphibian initiatives. Contact Rebecca Rose at: Rebecca.Rose@columbuszoo.org

Emergency funds: are available from the following institutions: the rapid response facility http://www.rapid-response.org/; and Memphis Zoo akouba@memphiszoo.org

ASA seed grants: provide small seed grants between $500 and $1,000 for starting conservation, education and research projects. Read more here: http://terravivagrants.org/amphibian-survival-alliance-seed-grants/

4. USEFUL RESOURCES

Amphibian Husbandry Chat group: A WhatsApp group for amphibian experts to discuss husbandry issues: https://chat.whatsapp.com/59Ckh74mNxd78PVfU1xObp

AArk newsletter: The AArk newsletter is available in English and Spanish. See previous newsletters here: http://www.amphibianark.org/news/aark-newsletter/ or subscribe for free here: http://www.amphibianark.org/news/subscribe/

AArk programme implementation tool: This tool helps determine when a programme should be initiated, and what components to ensure before the initiation: http://www.amphibianark.org/adequate-resources/ it can be downloaded and used offline at: http://www.amphibianark.org/Tools/AArk%20Program%20Implementation%20tool.xls

AArk Seed grants: The AArk seed grants have historically funded the set-up of programmes, but are being revised to include multi-year programmes and other types of amphibian conservation projects. Read more at: http://www.amphibianark.org/about-us/aark-activities/conservation-grants/

Amphibian and reptile conservation: This is an open-access, peer-reviewed journal for publishing of amphibian related research: http://amphibian-reptile-conservation.org/

Amphibian Conservation Needs Assessment: The Conservation Needs Assessment identifies priority amphibian species for ex situ research (such as analogous species) and conservation through an objective and consistent prioritisation process. The webpage is in English, Spanish or French, and can be found here: www.ConservationNeeds.org The full assessments can be seen here: www.ConservationNeeds.org/AssessmentSearch.aspx or you can read about their assessment process here: http://www.amphibianark.org/pdf/AArk-Conservation-Needs-Assessment-tool.pdf

Amphibian husbandry resource guide: These guidelines, developed by AZA, are longer and more detailed than the guidelines above, covering a wide range of husbandry topics including a short paragraph on enrichment: http://www.amphibianark.org/wp-content/uploads/2018/07/AZA-Amphibian-Husbandry-Resource-Guide.pdf

Amphibian husbandry workshops: The AArk run amphibian husbandry training workshops in priority areas. For more information see: http://www.amphibianark.org/about-us/workshops/husbandry-training/

Amphibian management school: AZA runs a range of training courses relevant to species management. Specifically, they run an amphibian management school at the beginning of the year. Keep an eye out on their calendar: https://www.aza.org/calendar, http://saveamphibians.org/2018-advanced-course/

Amphibian Veterinary Outreach Programme: The AVOP WhatsApp group is available for assistance on veterinary issues in captive amphibian collections, for managers in Latin America who have limited access to veterinary expertise. See http://www.amphibianark.org/about-us/workshops/veterinary-program/

ASA seed grants: provide small seed grants between $500 and $1,000 for starting conservation, education and research projects. Read more here: http://terravivagrants.org/amphibian-survival-alliance-seed-grants/

ASA Facebook forums: The ASA has established a range of Facebook forums for sharing of ideas and publications. The topics cover: captive breeding; climate change; communication and education; genome resources; ecotoxicology; habitat protection; infectious diseases; reintroductions; species conservation strategies; surveys and monitoring; taxonomy and systematics; and trade and policy. Access the groups here: http://www.amphibians.org/social/

ASA Website: The Amphibian Survival Alliance is a global partnership for driving forward amphibian conservation. They assist with guidance and fundraising for in situ conservation projects. They also provide a suite of resources on their website, including the ACAP, Action plans and guidelines. Have a look at: http://www.amphibians.org/

AZA Guidelines for reintroduction of animals born or held in captivity: The Association for Zoos and Aquariums guidelines on reintroductions from 1992. Available at: https://www.speakcdn.com/assets/2332/aza_guidelines_for_reintroduction_of_animals.pdf

Biosecurity and permanent isolation of ex situ conservation populations: Biosecurity manual for amphibian survival assurance colonies and reintroduction programmes. http://www.amphibianark.org/wp-content/uploads/2018/07/Biosecurity-Manual-2017.pdf

Captive programmes pages: This AArk page provide access to a set of pages on amphibian husbandry skills and standards, establishment of new programmes, species knowledge, programme resources, population management and founder animals: http://www.amphibianark.org/conservation-programs/captive-programs

Chytrid test sets: A new, cheap method of testing for chytrid is currently being developed by researchers at Exeter University and the Whitley Wildlife Conservation Trust. The method is less precise than current methods, but is more convenient and comes a lower cost. The product is not currently available commercially. Read more in: Dillon MJ, Bowkett AE, Bungard MJ, Beckman KM, O'brien MF, Bates K, Fisher MC, Stevens JR, Thornton CR. 2017. Tracking the amphibian pathogens Batrachochytrium dendrobatidis and Batrachochytrium salamandrivorans using a highly specific monoclonal antibody and lateral-flow technology. Microbial biotechnology, 10(2), pp.381-394.

CMP Open Standards: The open standards developed by the Conservation Measures Partnership provide a guide for conservation planning based on the newest industry standards. It follows a cycle of conceptualizing, planning, Implementing and monitoring, analysing and adapting, and learning. The use of the Open Standards is accompanied by the Moradi software. See the newest version in English, Indonesian, Portuguese, French, Albanian or Spanish here: http://cmp-openstandards.org/download-os/

Columbus Zoo: Continuously accept proposals for grants and emergency grants, often supporting amphibian initiatives. Contact Rebecca Rose at: Rebecca.Rose@columbuszoo.org

Directory of husbandry experts: The AArk has created an international directory of amphibian husbandry experts, with information including the experts' contact details, country and categories (nutrition, population management, enclosure design, developing new programmes, live food production and more). Find it at: www.amphibianark.org/amphibian-husbandry-experts/ or in Spanish at: www.amphibianark.org/es/amphibian-husbandry-experts/

Durrell Conservation Academy: Durrell Wildlife Conservation Trust does several training courses on practical conservation work. These include the Durrell Endangered Species Management Graduate Certificate, which provides students with a wide set of skills needed for implementing successful

conservation interventions and a two-week endangered species recovery course. For more information see: http://wildlife.durrell.org/courses/

EAZA Academy Courses: EAZA occasionally run courses on ex situ programme management and funding for in situ conservation. See their calendar here https://www.eaza.net/academy/courses/

EDGE Fellowship: Grants available for the establishment of programmes for EDGE species in priority regions, including 6 weeks of training and $10,000 total for two years. Apply here: https://www.edgeofexistence.org/apply-now/

Education activities and materials: This list of suggestions and materials for educational activities is provided by AZA: https://www.aza.org/amphibian-education-resources

Emergency funds: are available from the following institutions: the rapid response facility http://www.rapid-response.org/; and Memphis Zoo akouba@memphiszoo.org

Ex situ management of amphibians: Shorter but more recent guidelines than the AZA *Amphibian husbandry resource guide*: http://www.amphibianark.org/wp-content/uploads/2018/07/Ex-situ-management-of-amphibians-Gupta-et-al.pdf

Facility design guidelines: These brief guidelines on *Facility design and associated services for the study of amphibians* include general information on enclosures, light, water, substrate, quarantine facilities and more: http://www.amphibianark.org/wp-content/uploads/2018/07/Facility-design-and-associated-services-for-the-study-of-amphibians.pdf

Founder calculation tool: Advice on founding populations is available from the AArk's webpage at: www.amphibianark.org/founder-animals/ or in Spanish at: www.amphibianark.org/es/founder-animals/ A tool for calculating the needed founding population size, available online at: www.amphibianark.org/Tools/Founder%20calculation%20tool.htm or in Spanish at: www.amphibianark.org/Tools/Founder_calculation_tool_es.htm
Downloadable versions are available from: www.amphibianark.org/tools/AArk%20Founder%20calculation%20tool.xls Or in Spanish at: www.amphibianark.org/tools/Founder_calculation_tool_es.htm

FrogLog: Produced by the IUCN SSC Amphibian Specialist Group, the FrogLog is a more general magazine on amphibian conservation. Read or subscribe here: http://www.amphibians.org/froglog/

Global Species Management Plans: A resource template for developing a species management plan with globally agreed goals, through an inter-regional approach. Produced and made available by WAZA here: http://www.waza.org/files/webcontent/1.public_site/5.conservation/conservation_breeding_programme/resource_manual/GSMP%20Resource%20Manual_10Sep2015.pdf

How much UV-B does my reptile need? The UV-Tool, a guide to the selection of UV lighting for reptiles and amphibians in captivity: The UV-Tool is a working document that seeks to address the lack of guidance on UV lighting for herpetofauna, by considering the range of UV experienced by each species in the wild: http://www.amphibianark.org/wp-content/uploads/2018/07/How-much-UV-B.pdf

Information on equipment and enclosures: The AArk's husbandry documents page provides numerous resources on how to design your captive environment: http://www.amphibianark.org/husbandry-documents/

IUCN guidelines for determining when and how ex situ management should be used in species conservation: Guidelines published by the IUCN in Conservation Letters found here: http://onlinelibrary.wiley.com/doi/10.1111/conl.12285/full

IUCN guidelines for reintroductions and other conservation translocations: The IUCN guidelines on planning and implementing reintroductions from 2013. Available here: https://portals.iucn.org/library/efiles/documents/2013-009.pdf

IUCN guidelines for species conservation planning: Written by the SSC Species Conservation Planning sub-committee, these guidelines follow a planning, implementation, learning and adaptation cycle. It also emphasises the One Plan Approach which promotes collaboration between all relevant stakeholders and streamlining of goals and vision. Available here: https://portals.iucn.org/library/sites/library/files/documents/2017-065.pdf

IUCN guidelines for wildlife disease risk analysis: Detailed guidelines for assessing disease risks. https://portals.iucn.org/library/sites/library/files/documents/2014-006.pdf

Managing water quality for amphibians in captivity: An in-depth guide to water quality: http://www.amphibianark.org/wp-content/uploads/2018/07/Managing-water-quality-for-amphibians-in-captivity.pdf

Mohamed bin Zayed Species Conservation Fund: Provide grants between $5,000 and 25,000 to species conservation, and are looking for proposals on amphibians: https://www.speciesconservation.org/grants/

Monitoring and evaluation: The following papers provide a good overview of the importance and use of monitoring and evaluation in conservation:
Kleiman DG, Reading RP, Miller BJ, Clark TW, Scott JM, Robinson J, Wallace RL, Cabin RJ, Felleman F. 2000. Improving the evaluation of conservation programmes. Conservation Biology. 14(2):356-65.
Mascia MB, Pailler S, Thieme ML, Rowe A, Bottrill MC, Danielsen F, Geldmann J, Naidoo R, Pullin AS, Burgess ND. 2014. Commonalities and complementarities among approaches to conservation monitoring and evaluation. Biological Conservation. 169:258-67.
Stem C, Margoluis R, Salafsky N, Brown M. 2005. Monitoring and evaluation in conservation: a review of trends and approaches. Conservation Biology. 19(2):295-309.
Kapos V, Balmford A, Aveling R, Bubb P, Carey P, Entwistle A, Hopkins J, Mulliken T, Safford R, Stattersfield A, Walpole M. 2008. Calibrating conservation: new tools for measuring success. Conservation Letters 1(4):155-64.

Nutrition and health in amphibian husbandry: This commentary provides an overview of amphibian nutrition and other captive factors to improve population health: http://www.amphibianark.org/wp-content/uploads/2018/07/Leaping-forward-in-amphibian-health-and-nutrition.pdf

Open Standards for the Practice of Conservation: The open standards developed by the Conservation Measures Partnership provide a guide for conservation planning based on the newest industry standards. It follows a cycle of conceptualizing, planning, Implementing and monitoring, analysing and adapting, and learning. The use of the Open Standards is accompanied by the Moradi software. See the newest version in English, Indonesian, Portuguese, French, Albanian or Spanish here: http://cmp-openstandards.org/download-os/

PopFrog: This is a set of tools that assist in setting goals and management of ex situ populations. The tool was developed to provide guidance to managers, but now also includes analysis of species with a low reproductive rate. Find it here: http://www.popfrog.org/

Species for ex situ research programmes: All species recommended for captive research programmes, as identified by the Conservation Needs Assessment can be found here www.amphibianark.org/species-for-ex-situ-research/ and in Spanish here: www.amphibianark.org/es/species-for-ex-situ-research/

Species for rescue programmes: All species urgently in need of captive breeding rescue programmes as identified by the Conservation Needs Assessment can be found here: www.amphibianark.org/rescue-species/ and in Spanish here: www.amphibianark.org/es/rescue-species/

Stakeholder engagement handbook: This handbook developed by Biodiversa in 2014 is a pratitioner's guide to identifying and engaging stakeholders: http://www.biodiversa.org/stakeholderengagement

Swabbing protocols for chytrid: This simple website with videos outlines what you need and shows how to swab an amphibian for chytrid: https://amphibiaweb.org/chytrid/swab_protocol.html

Template and guidelines for developing a Species Action/Recovery Plan: The following template by the AArk guides the development of the taxon management plan for in situ, ex situ and education and awareness information and strategies: http://www.amphibianark.org/pdf/Species-Action-Plan-template-EN.docx or in Spanish at: http://www.amphibianark.org/pdf/Species-Action-Plan-template-ES.docx

Template for developing husbandry guidelines: The AArk has also produced a template for developing the husbandry guidelines of your project, in English: http://www.amphibianark.org/pdf/AArk-WAZA-Husbandry-Guidelines-template-English.doc, Spanish: http://www.amphibianark.org/pdf/AArk-Husbandry-Guidelines-template-Espanol.doc and French: http://www.amphibianark.org/pdf/AArk-WAZA-Husbandry-Guidelines-template-French.docx

ZIMS for studbooks: Studbooks are managed through the Species 360 ZIMS tool. It is designed to make the job of the studbook keeper easier. Read more and access the tool at: https://www.species360.org/products-services/zims-for-studbooks/

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