It’s not easy being green: Exploring the barriers to keeping more globally threatened amphibians in ex-situ collections

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Submitted for the MSc in Conservation Science
1 Front Materials

1.1 Declaration of Own work

I declare that this thesis, “It’s not easy being green: Exploring the barriers to keeping more globally threatened amphibians in ex-situ collections” is entirely my own work, and that where material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

Signature ______________________
Name of Student Leana Brady
Name of Supervisors Dr Richard Young, Mr Jeff Dawson
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1.3  List of Acronyms used
AArk – Amphibian Ark
ACAP – Amphibian Conservation Action Plan
ASG - Amphibian Specialist Group
Bd - *Batrachochytrium dendrobatidis*
CBSG - IUCN SSC Conservation Breeding Specialist Group
CITES - Convention on International Trade of Endangered Species of Wild Fauna and Flora
EAZA – European Association of Zoos and Aquariums
FET – Fisher’s Exact Test
GTA – Globally threatened amphibian
GTS – Globally threatened species
WAZA – World Association of Zoos and Aquariums
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1.6 Abstract & Word Count

This study aimed to identify the key barriers to holding more globally threatened amphibian species in ex-situ collections and potential strategies to mitigate these. Online surveys were completed by 107 institutions worldwide, asking about primary barriers to keeping globally threatened amphibians, solutions, and the facilities at each collection. Institutions with a collection plan which included amphibians held on average a significantly higher proportion of globally threatened amphibians (25.8%) than those without (12.4%) (F(1,96)=5.059, p=0.027). A lack of resources (including budget, staffing and space) was the most frequently identified barrier to holding more globally threatened amphibians (38% of responses), followed by disease/biosecurity concerns (10% of responses), and a lack of staff expertise/knowledge (9% of responses). 9 key priority action areas were identified, with increasing interest and budget allocation from zoo management the most important (49% of suggested solutions), followed by increased interest of externals/increased external funding (17% of suggested solutions), and training of staff (14% of suggested solutions). Innovative enclosure design and engaging guests differently were identified as a key mechanism to incentivise management investment by increasing financial return from, and visitor interest in, globally threatened amphibians. Space and staffing were primary resources which require further investment in order to hold more globally threatened amphibians (32% and 26% of resources identified as lacking respectively). For collections unable to mitigate the barriers to holding more globally threatened amphibians, partnerships with range country facilities was suggested as a meaningful way to contribute to amphibian conservation.

Word count: 15,360
1.7 Acknowledgements

I would like to thank Dr Richard Young and Jeff Dawson for their invaluable guidance and input, without which this project could never have been completed, and the staff at Durrell Wildlife Conservation Trust’s Herpetology team, particularly Matt Goetz, whose advice on the survey design was crucial.

I would also like to thank everyone who responded to my survey or took the time to take part in follow-up interviews.

Finally, a special thank you to my course mates and course leaders for their never-ending enthusiasm, and to my family for their consistent support, encouragement and a necessary ongoing supply of chocolate.
2 Introduction

2.1 Problem statement
Amphibians are currently the most threatened taxonomic group, with more than 40% of species threatened with extinction (IUCN, 2014), compared to 22% for mammals (IUCN, 2008), and 13% for birds (BirdLife International, 2014). Habitat loss is amphibians’ primary threat (Reid & Zippel, 2008) whilst the highly transmissible, virulent disease chytridiomycosis has contributed to the extinction or decline of 200 frog species (Skerrat et al., 2007). Concurrent changes in climate and land-use further threaten amphibians, and may lead to increased extinction rates throughout the 21st century (Hof et al., 2011). Research suggests we are experiencing or approaching the sixth mass extinction event – when the Earth loses more than 75% of species in a short geological interval (Wake & Vredenburg, 2008; Barnosky et al., 2011). Amphibians are experiencing extinction rates higher than any other vertebrate group (McCallum, 2007), and in 115 years have undergone extinctions that would have taken between 2,000 and 10,000 years at the background rate (Ceballos et al., 2015).

Amphibians play valuable roles to both humans and ecosystems and their extinction would represent a significant loss to global biodiversity (Halliday, 2008). Amphibians are valued for the pet trade and for human consumption (Carpenter et al., 2014; Hocking & Babbitt, 2014) and produce novel compounds on and within their skin, useful for medicinal drugs including antibiotics and analgesics (Tyler et al., 2007). They further function as model organisms for research in areas such as experimental embryology (Tyler et al., 2007), with 25% - 33% of research on invertebrates and lower vertebrates conducted on amphibians (Burggren & Warburton, 2007) and approximately 10% of Nobel Prizes for physiology and medicine resulted from research on amphibians (Tyler et al., 2007). Within their environments, amphibians play important roles, particularly in the humid tropics (Stebbins & Cohen, 1995; Whiles et al., 2006). These roles include contributing to ecosystem stability, helping regulate food webs (Davic & Welsh Jr., 2004), functioning as indicator species for environmental health (Martin & Hine, 2000; Böll et al., 2013) and, for predatory species, helping to regulate mosquito-borne diseases (Hocking & Babbitt, 2014).

An estimated 500 amphibian species currently face threats which cannot be mitigated quickly enough to prevent extinction (Conde et al., 2013) and focusing on habitat protection alone
cannot prevent mass extinctions (Reid & Zippel, 2008). Ex-situ conservation efforts – conservation efforts outside a species’ native habitat range - are therefore required to reduce this extinction risk, and captive breeding should be established before species reach critically low numbers (IUCN, 1987). In 2007, the Amphibian Conservation Action Plan (ACAP) was published following the 2005 IUCN/SSC Amphibian Conservation Summit, setting priority actions for amphibian conservation. The ACAP selected key thematic areas under which to set priorities, including captive programmes and reintroductions. As well as prioritising the establishment of captive operations within species’ native range countries, the ACAP also called for the creation of captive colonies within species’ native range countries, the ACAP also called for the creation of captive colonies with the intention of providing a safeguard population, individuals for reintroduction and the capacity and facilities for research (Gascon et al., 2007). To globally co-ordinate the ex-situ action prioritised by the ACAP, the Amphibian Ark (AArk) was formed. A key role of AArk is the Conservation Needs Assessments, which aim to prioritize species and immediate needs, given the limited resources available (Amphibian Ark, 2012). Although AArk’s primary focus is on captive breeding within a species’ native range they also ask that each zoo works to conserve at least 1 amphibian species, since hundreds of species require help from zoos until wild populations can be supported effectively (Amphibian Ark, 2014). AArk also stresses the importance of partnerships between organisations within and without the range country, to help distribute resources to where they are most required for conservation (Johnson et al., 2012).

As well as providing an insurance population and providing individuals for supplementing wild populations (Theodorou & Couvet, 2004), keeping globally threatened species (GTS) in ex-situ collections enables research on topics such as husbandry and nutrition (Browne et al., 2011). For example, the reproductive strategy of the Mountain Chicken, *Leptodactylus fallax*, was described based on captive individuals (Gibson & Buley, 2004). More than 700 million visitors attend zoos and aquariums which belong to the World Association of Zoos and Aquariums (WAZA) every year (Fa et al., 2014), and captive populations therefore also provide opportunities for raising awareness of the status of, and threats to, GTS (Pearson et al., 2014).

Reintroductions of captive-bred individuals to the wild have been criticised as expensive (Fischer & Lindenmayer, 2000), and for low success rates (Griffith et al., 1989; Armstrong & Seddon, 2008). For many amphibian species however, captive breeding may be the only viable way to prevent extinction (Bishop et al., 2012), and amphibians may be good
candidates for captive breeding and reintroductions (Griffiths & Pavajeau, 2008). Due to their small body size, low maintenance requirements and high fecundity (Bloxam & Tonge, 1995), amphibian populations require less financial investment than large vertebrate species to keep and breed in captivity (Balmford et al., 1996; Germano & Bishop, 2009). Captive populations of mammals and birds often lack appropriate learned skills (Peyton et al., 2014, Riedler et al., 2010), which can affect reintroduction success and require enrichment or pre-release training (Reading et al., 2013). Since much amphibian behaviour is innate rather than learned, reintroductions of amphibians may show higher success rates than reintroductions of mammals or birds (Griffiths & Pavajeau, 2008). A review of 58 amphibian captive breeding and reintroduction projects found that 13 reintroduced species had established self-sustaining populations, and a further 5 had successfully bred in the wild (Griffiths & Pavajeau, 2008). The Kihansi Spray Toad, *Nectophrynoides asperginis*, was classified as Extinct in the Wild in 2009 (IUCN, 2015), but had been conserved in captivity, and captive-bred individuals are now being released into the wild (Harding et al., in press). Similarly, 25% of wild Mallorcan midwife toads, *Alytes muletensis*, are the result of zoo breeding and reintroduction, showing the significant impact ex-situ breeding and reintroduction efforts can have (Reid & Zippel, 2008).

Despite their apparent suitability, and the clear need for ex-situ conservation (Balmford et al., 1996), amphibians made up only 6% of non-domestic terrestrial vertebrate species held in zoos in 2011 (Conde et al., 2013). As well as holding small numbers of amphibian species in general, in 2014 zoos held only 6.2% of globally threatened amphibian (GTA) species (Dawson et al., 2015). Many potential reasons have been suggested to explain why numbers of GTA species in zoos is low, however little research has been conducted to validate these barriers or to examine how barriers affect GTA collections in zoos. By researching these barriers, potential strategies can be devised to increase the number of GTA species in ex-situ collections.
2.2 Aims & objectives

The three primary aims of this study were:

- to identify key barriers to holding more GTA species, as perceived by zoo curators and collection managers,
- to identify associations between indirect indicators of particular barriers and the proportion of GTA species within a collection,
- to propose possible strategies to deal with the barriers to keeping more threatened amphibians within ex-situ collections.

To achieve these aims, the following objectives were met:

1. Invitations to online surveys were sent to more than 400 ex-situ collections, assuming a response rate of 25%, to identify collection statuses, and to investigate what zoo curators and collection managers see as key barriers to holding more GTAs

2. Survey responses were analysed to identify the primary barriers, whether barriers are seen as significant or insignificant and whether these vary regionally.

3. Further analysis investigated whether indirect indicators of particular barriers correlated with the proportion of GTA species within a collection.

4. Comparisons of the proportion of collection held which was considered threatened, and the perceived significance of various barriers, were made between groups and between regions

5. Respondents were invited to take part in a follow-up interview, to elaborate on perceived barriers and how they felt these should be addressed. Participants were also asked about barriers they felt were insignificant to identify any mitigating strategies they had used.

6. A literature survey was conducted and considered along with strategies suggested by respondents to identify potential strategies to deal with barriers to keeping more GTA species.
3 Background

An estimated 23% of terrestrial vertebrate species in zoos within the International Species Information System (ISIS) zoo network are categorised on the IUCN Red List as threatened (Conde et al., 2013), and so the low proportion of amphibian species in zoos reflects the wider trend. However, the proportion of species held which are considered threatened are higher for both mammals and reptiles held in zoos (27% and 40% respectively) than amphibians (25%), although estimates suggest that over 40% of amphibian species are threatened, compared to 26% of mammals (IUCN, 2014) and an estimated 19% of reptiles (Böhm et al., 2013). Given the rapid decline and widespread extinction of many amphibian species (Mendelson et al., 2006), the low proportion of amphibian species which are considered threatened held within zoo collections is particularly important.

Zoos portray themselves to visitors as contributing to conservation (Carr & Cohen, 2011) and therefore the low number of GTA species in zoos despite the current amphibian crisis is unexpected. Although the reasons are unclear, a number of potential barriers to keeping more GTA species within ex-situ collections have been suggested.

Extensive research has been conducted into visitor preferences of species held in zoos, and these preferences may be a barrier both to keeping more amphibian species in total, and to keeping GTA species. Research has identified a preference among visitors for larger, (Ward et al., 1998; Frynta et al., 2010), more attractive (Frynta et al., 2010; Frynta et al., 2013) species. Furthermore, the most significant predictor of visitor interest was taxonomic, with a strong preference for mammals (Moss & Esson, 2010). Although the return on investment is believed to be no higher for large animals than small (Balmford et al., 2000; Ward, 2000), perceived visitor preferences may select against keeping amphibians in general and zoos may focus on taxa that visitors are believed to prefer (Fa et al., 2014). These perceived visitor preferences may also result in zoos preferentially selecting traditionally attractive amphibian species such as poison arrow frogs, rather than threatened species, which are often small, plainly coloured and cryptic (Dawson et al., 2015), making them difficult to display (Conde et al., 2013).

Another potential barrier to keeping more threatened amphibians may be the inaccessibility of particular species, and difficulty obtaining individuals from the wild. Martin et al., (2013)
found that mammal and bird species held in zoos are less likely to be endemic or threatened than closely related species not held in zoos. This may be because the factors which threaten species act as barriers to keeping them in zoos; for example, species which have small native ranges are difficult to obtain or gain access to. Although Martin et al. (2013) considered mammal and bird species, the maps of endemic bird areas and endemic amphibian areas show considerable overlap, suggesting this may also be true of amphibian species (Price, 2005; IUCN, 2008).

Difficulty obtaining individuals may also be compounded by difficulty obtaining permits for export, import or movement of GTAs (New, 1994; Conde et al., 2013). It may be particularly difficult to obtain permit approval for species which are CITES listed (Banks et al., 2008), and obtaining such permits can be a time consuming process (Ginsberg, 1993).

An additional factor which may increase threat status in the wild but act as a barrier to keeping GTA species in ex-situ collections is disease (Zippel et al., 2011). A number of pathogens currently affect amphibians, including saprolegniasis, an infectious disease associated with egg mortality (Gomez-Mestre et al., 2006) and early hatching (Perotti et al., 2013). Ranaviruses are a group of viruses associated with significant mortality of tiger salamanders Ambystoma tigrinum (Jancovich et al., 2001; Daszak et al., 2003), common frogs, Rana temporaria, (Teacher et al., 2010), common toads, Bufo bufo, (Price et al., 2014) and a number of other amphibian species (Greer et al., 2005). Ranaviruses are poorly understood, increasingly prevalent and of increasing threat (Lesbarrères et al., 2012; Brunner et al., 2015).

The most well-described pathogen affecting amphibians is Batrachochytrium dendrobatidis (Bd), which causes chytridiomycosis, a disease associated with mass mortality of many anuran species (Berger et al., 1998; Rosenblum et al., 2010) and which also affects caecilians (Gower et al., 2013). A second chytrid fungus, Batrachochytrium salamandrivorans, affects salamanders and newts (Martel et al., 2014), making chytridiomycosis a threat to all three amphibian taxa.

For species being introduced to captivity from the wild, there is a risk of selecting individuals already infected, making disease control and quarantine procedures essential, requiring additional time, resource investment and expertise (Pessier, 2008). The risk of disease may reduce the desire for ex-situ collections to establish a captive population of a species which has not previously been kept in captivity, due to concerns of introducing infectious disease
into their collection. Even for individuals taken from other captive populations, disease and biosecurity concerns may increase the difficulty and costs of keeping threatened amphibians. To breed these threatened amphibians in zoos, with the intentions of eventual release into the wild, zoos would need to provide permanent biosecure facilities, to prevent exposure to other species within the collection (Pessier, 2008), putting a greater burden on space requirements. These risks, combined with the potential risk of introducing novel pathogens to local, native species, make disease surveillance and testing a necessary part of routine maintenance (Zippel et al., 2006; Tapley et al., 2015a). This places additional burdens on time and resources, and staff would need to be aware of control mechanisms for common diseases (Pessier, 2008). However, one study looked at individuals from nine amphibian species within a zoo, and found that although one species was positive for Bd, the biosecurity procedures at the zoo had prevented this spreading to other species, despite not having been aware of the presence of Bd (Winters et al., 2014), suggesting that disease risks can be successfully mitigated through biosecurity protocols.

Similarly, biosecurity concerns and the potential risk of introducing alien species due to escape or theft may also be of concern. Although the risk of introduction of invasive species from zoos in Australia is believed to be low for example, the number of releases has nonetheless increased dramatically between 1985 and 2010 (Cassey & Hogg, 2014). Disease and biosecurity concerns may affect both the desire to keep more GTA species, due to the potential associated risk, and also the ability to do so, due to the increased cost, resource and time investments required.

Another potential barrier may be due to difficulty meeting husbandry requirements. This may be due to a lack of knowledge regarding husbandry requirements (Gascon et al., 2007), particularly for species which have not previously been kept in captivity. Michaels et al., (2014) argue that there are publication biases away from both natural history and amphibian specific research, meaning little information on the native conditions of GTAs is available, giving little help to ex-situ collections wishing to keep species previously not held in captivity. This lack of knowledge may reduce a zoo’s desire to establish a population of species which has not previously been kept in captivity, both on a logistical and ethical basis due to the risk of mortality if husbandry requirements are not met (Bowkett, 2014). Determining correct husbandry requirements can be difficult and time consuming (Tapley et al., 2015b),
particularly since amphibians have complex, varied life history strategies (Pough, 2007). For example, UV-B is required for some amphibian species in captivity, but too much UV-B can also be detrimental, therefore for species previously not kept in captivity some trial and error may be required (Tapley et al., 2015b). Similarly, amphibian temperature preferences vary in response to variables such as age or social group (Hutchison & Dupré 1992; Pough, 2007). Research into conservation breeding of amphibians found that of 105 species identified as being held for captive breeding purposes, 55 had successfully bred, but only 19 had bred to the F2 level or beyond, and the study suggested this was due to poor species knowledge (Michaels et al., 2014).

Even for species with known ecological requirements, there may be an inability to meet their specific husbandry requirements (Martin et al., 2014b). A number of husbandry variables need to be controlled for animals in captivity, including lighting, humidity and temperature of the environment; size, furnishings, substrate and cleaning of an enclosure; food, water and any dietary supplements required as well as the social structure of a group and any seasonal variation in requirements (Fa et al., 2011). Threatened, endemic species may have very specific ecological niches, and may not be suited to captivity (Martin et al., 2014b). Replicating required conditions in captivity may be difficult (Martin et al., 2013). Nutritional needs are one area of husbandry which can be difficult to meet in captivity, since commercially available food species are limited (Tapley et al., 2015a). Crickets and mealworms are generally the most commonly available food species commercially and are often provided to amphibians in captivity, however these are low in calcium and vitamin A, meaning that captive amphibians require additional supplementation in order to meet their nutritional needs (Livingston et al., 2014). Therefore, two distinct barriers to keeping GTAs may be related to husbandry: a lack of husbandry knowledge or an inability to provide the husbandry required.

A further barrier may be a lack of staff expertise. Zoos potentially experience high staff turnover, and since amphibians often have very specific husbandry requirements, staff turnover could inhibit the time consuming creation of husbandry protocols (Tapley et al., 2015a).

Finally, limited resources may be a significant barrier to keeping more threatened amphibians. Zoos need to balance their finite financial, staffing and space budgets with the desire to
provide entertainment, educate visitors, and contribute to *in-situ* and *ex-situ* conservation projects (Fa *et al.*, 2014). Threatened amphibians may be financially costly to obtain or to keep (Bowkett, 2014) and the need for permanent quarantine facilities for species which are intended for future release requires greater space requirements than for those which are kept for display purposes only (Pessier, 2008). GTAs may therefore require resources which collection managers are either unable or unwilling to commit, seeing GTAs as a lower priority compared to other taxa.
4 Methods

4.1 Framework
Ajzen’s Theory of Planned Behaviour states subjective norms, perceived behavioural control, and the individual’s attitude towards behaviour motivate an individual’s intention to act (or not act). The stronger an individual’s intention to act, the more likely an action is to occur, assuming an action is within the individual’s control (Ajzen, 1991). Following this theory, the intention by curators and collection managers to keep - or not - more GTA species is the result of three things: subjective norms, the perceived social pressure to perform an action; curators’ and collection managers’ perception of the importance of keeping threatened amphibians in ex-situ collections; and the perceived control of collection decisions from curators’ and collection managers’ point of view.

The creation of the ACAP, the development of AZA’s amphibian conservation action plan in 2007 (AZA, 2015) and the formation of Amphibian Ark by the World Association of Zoos and Aquariums, the IUCN SSC Conservation Breeding Specialist Group (CBSG), and the Amphibian Specialist Group (ASG) in 2007 (Amphibian Ark, 2015), are examples of an increasing focus on amphibians amongst the conservation community. It seems therefore that the inclusion of threatened amphibians within ex-situ collections is well supported, and that the subjective norms element of the theory of planned behaviour should encourage curators’ and collection managers’ intention to keep threatened amphibians. This study therefore focused on curators’ and collection managers’ perceived control – i.e. their ability to keep more threatened amphibians – and their attitude towards keeping more threatened amphibians.

Nine potential barriers to holding more threatened amphibians were identified through literature searches and discussions with the Durrell Herpetology Team [Table 4-1]. Of these, 5 barriers are related to perceived control (difficulty obtaining individuals, difficulty obtaining permits, difficulty meeting specific husbandry requirements, lack of staff knowledge/expertise and lack of resources). The remaining barriers could relate either to perceived control or attitudes, for example, disease/biosecurity concerns may impact the desire to hold threatened amphibians due to associated risk, but may also affect the ability to hold threatened amphibians in facilities which do not have the resources available for the necessary biosecurity procedures.
To investigate attitudes to keeping more GTA species, respondents were asked how they felt that chytridiomycosis had affected their desire to keep threatened amphibians, or impacted their collection strategy.

*Table 4—1: Potential barriers to holding more GTAs as identified through literature searches*

<table>
<thead>
<tr>
<th>Potential barrier to holding more threatened amphibians</th>
<th>Referred to in literature</th>
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<tbody>
<tr>
<td>Lack of resources (e.g. number of staff, adequate space and budget)</td>
<td>Ginsberg, 1993; New, 1994; Banks <em>et al.</em>, 2008; Conde <em>et al.</em>, 2013</td>
</tr>
<tr>
<td>Difficulty obtaining permits in order to move amphibians</td>
<td>Ginsberg, 1993; New, 1994; Banks <em>et al.</em>, 2008; Conde <em>et al.</em>, 2013</td>
</tr>
<tr>
<td>Difficulty obtaining individuals from the wild</td>
<td>Price, 2005; Martin <em>et al.</em>, 2014a</td>
</tr>
<tr>
<td>Difficulty displaying amphibians due to cryptic colours and behaviour</td>
<td>Conde <em>et al.</em>, 2013; Dawson <em>et al.</em>, 2015</td>
</tr>
<tr>
<td>Difficulty meeting specific husbandry requirements</td>
<td>Martin <em>et al.</em>, 2013; Tapley <em>et al.</em>, 2015a</td>
</tr>
<tr>
<td>Disease/biosecurity concerns</td>
<td>Pessier, 2008; Cassey &amp; Hogg, 2014</td>
</tr>
<tr>
<td>Cost concerns</td>
<td>Bowkett, 2014; Tapley <em>et al.</em>, 2015a</td>
</tr>
<tr>
<td>Lack of staff knowledge/expertise</td>
<td>Tapley <em>et al.</em>, 2015a</td>
</tr>
<tr>
<td>Difficulty attracting visitor interest</td>
<td>Moss &amp; Esson, 2010; Frynta <em>et al.</em>, 2013; Fa <em>et al.</em>, 2014</td>
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</table>
4.2 Choice of tools
An online survey was selected as the primary method of data collection, to reach a large number of ex-situ collections across a global scale.

The survey had two primary aims:

- To identify the most significant barriers as perceived by curators and collection managers.
- To identify any possible correlation between indicators of particular barriers and the number of threatened amphibians within a collection.

The online survey was developed through SurveyMonkey [Appendix A], with four key sections:

- Section 1 - Designed to obtain basic information about the collection where the individual worked, using closed-ended and primarily quantitative questions.
- Section 2 - Designed to gain information regarding the collection itself and collection plans using quantitative, closed-ended questions, and regarding guidance used to inform collection plans using an open-ended question.
- Section 3 – Designed to investigate perceived significance of potential barriers by using a Likert-Scale, and to identify top barriers and solutions using open-ended questions.
- Section 4 – Designed to obtain information from each collection which might act as indirect indicators for particular barriers, and about how they felt chytridiomycosis had affected their desire to keep GTA or impacted their collection strategy.

Email invitations to complete the survey were sent to a total of 465 ex-situ collections around the world. Emails were personally addressed to an individual by name wherever an individual could be identified, to increase response rates (Heerwegh, 2007).
4.3 Survey design
A number of potential survey biases were identified [Table 4-2] and attempted to address through survey design.

Table 4—2: Potential biases that could affect survey data

<table>
<thead>
<tr>
<th>Potential bias</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acquiescence</strong> – the tendency for some respondents to agree with a statement regardless of content (Tellis &amp; Chandrasekaran, 2010)</td>
</tr>
<tr>
<td><strong>Disacquiescence</strong> – the tendency for some respondents to answer all questions with disagreement (Greenleaf, 1992; Baumgartner &amp; Steenkamp, 2001; Tellis &amp; Chandrasekaran, 2010)</td>
</tr>
<tr>
<td><strong>Misresponse to reversed items</strong> – some individuals will respond to both the original item and reversed item the same way (Weijters et al., 2010)</td>
</tr>
<tr>
<td><strong>Central tendency bias</strong> – the chance that a neutral item will attract both respondents with genuinely neutral opinions but also potentially those with ambivalent opinions, as well as those who may be reluctant to share their true views, and will also offer respondents a way to respond without deciding on their opinion (Krosnick et al., 2002; Nowlis et al., 2002; Weijters et al., 2010).</td>
</tr>
<tr>
<td><strong>Social desirability bias</strong> – the chance that individuals will choose options which are socially desirable and avoid options which they feel will reflect poorly on them, regardless of their true opinion (Grimm, 2010)</td>
</tr>
</tbody>
</table>

Participants were not asked to state whether they Strongly Agreed, Agreed, Disagreed or Strongly Disagreed with statements such as “[Barrier] is a significant barrier to holding more threatened amphibians in ex-situ collections” but rather to select whether they felt each barrier was Highly Insignificant, Insignificant, Significant or Highly Significant in order to reduce acquiescence and disacquiescence. The use of balanced scales asking both the original question and a reversed question (i.e. asking participants to state how much they agree that barrier x is a significant barrier and later asking them to state how much they agree that barrier x is not a significant barrier) has been suggested as a way to combat acquiescence and disacquiescence (Paulhus, 1991), though research suggests that this can cause a misresponse.
to reversed items (Weijters et al., 2010). For these reasons, participants were not asked to agree or disagree with statements, but asked their perception of each barrier.

Participants were offered an even number of items to choose from in order to reduce central tendency bias, removing a neutral central value and forcing participants to classify each barrier as either significant or insignificant (Dawis, 1987).

To reduce social desirability bias, participants were informed at the start of the survey that information would be kept confidential and given the option to skip questions they felt uncomfortable answering. Questions were phrased in a neutral manner to avoid indicating desirable responses i.e. “How do you feel that chytridiomycosis has affected your desire to hold threatened amphibians?” rather than “Has chytridiomycosis increased your desire to hold threatened amphibians?”

4.3.1 Pilot testing
Before being sent to respondents, the survey was sent to Durrell Wildlife Conservation Trust’s herpetology team for testing. This highlighted a number of adjustments to be made, including giving respondents the option of leaving an answer blank in the case of unknown or sensitive information. Question wording was revised to make the meaning clearer, and additional terms were added to some questions to make questions more broadly accessible for non-native English speakers.

4.4 Follow-up interviews
As part of the survey, respondents were asked if they would be interested in taking part in a short follow-up interview. Each of the 71 respondents which indicated potential interest in a follow-up interview was contacted to invite their participation, either via email, skype or telephone. A total of 13 semi-structured interviews were conducted, with questions designed to raise further details regarding the perceived significant and insignificant barriers to holding more GTAs, ways to address barriers, the responsibility to address barriers, and the role of in-situ work for amphibian conservation [Appendix B].

4.5 Data Analysis
Before data analysis was conducted, duplicate records were identified, and one duplicate record was excluded from all analysis. For four zoos, two different individuals had responded. In order to avoid skewing the data, only one response from each of these zoos was included.
in all averages and correlations. One zoo which stated that 150% of amphibians held were threatened was excluded from all analysis which included proportion data. The four zoos without any amphibians were excluded from correlations and calculations of averages. Throughout data analysis, responses which were left blank, marked as NA or X were excluded. All responses were included in analysing perceived significance of barriers, solutions and regional differences, since the opinions of individuals rather than institutions were being considered.

4.5.1 Correlation
To identify any possible associations between annual budget, annual visitors or zoo size with the amphibian collection within a zoo, bivariate correlations were used. Spearman’s rank correlation was used throughout the study as a number of variables were non-normally distributed even following transformation (Despara et al., 1995). Spearman’s rank correlation was also selected due to the highly kurtotic distribution of some variables, which past research has suggested is highly problematic for Pearson’s (Bishara & Hittner, 2012).

4.5.2 Group differences
To investigate indirect indicators of particular barriers, the mean proportion of a collection threatened was compared between the following groups:

- those with and without a collection plan that included amphibians;
- those with and without a collection plan for amphibians only;
- those with and without a strategy which determined the future of the amphibian collection plan;
- those who stated that they used global, regional or national assessments or priority lists to inform their collection plan and those who stated that they did not;
- those who did or did not take part in field conservation;
- those with and without an available quarantine space for newly arriving amphibian species;
- those with and without the facilities to keep and breed amphibians under permanent biosecure conditions;
- those with three or less keepers responsible for amphibians and those with four or more keepers responsible for amphibians.
ANOVA was conducted using SPSS v21 to identify any groups which showed statistically significant differences. Normal distribution was not assessed, as ANOVA is resistant to non-normal data (Khan & Rayner, 2003, Kao & Green, 2008), however for each group comparison, the homogeneity of variance was tested using Levene’s test, and for any groups which showed significant differences in variances, Welch’s ANOVA was used (Kao & Green, 2008; Field, 2013).

4.5.3 Significant barriers & solutions
In order to analyse the perceived significance of barriers based on the Highly Insignificant-Highly Significant matrix, responses were presented on a diverging stacked bar chart to allow a quick visual representation of the percentage of respondents who viewed a barrier as insignificant (to the left) and significant (to the right) (Bobbins and Heiberger, 2011). Descriptive statistics, such as identifying the barriers most frequently selected as significant, were conducted.

4.5.3.1 Significant barriers by region
Pearson’s Chi-Squared was conducted to investigate whether the proportion of individuals who felt a particular barrier was significant varied between regions. Due to the small sample sizes for Asia and South America, only European, North American and Australasian regions were compared. When Chi-Squared outputs showed that more than 20% of cells had expected values below 5, the Fisher’s exact test (FET) was used. All Pearson’s Chi-Squared results were reported using the exact p-value, since this is more accurate than the estimated asymptotic value (Mehta & Patel, 2012) particularly where small sample sizes are concerned (Meyer & Seaman, 2013).

4.5.3.2 Group differences in perceived significance of barriers
To see whether groups varied in terms of which barriers were perceived as significant, the same groups were compared as for mean proportion threatened, and those with and without GTA species were also compared. Pearson’s chi-squared was conducted as for regional variations.

4.5.4 Top three barriers to holding more threatened amphibians
In order to identify the barriers seen as most significant to holding more threatened amphibians, and to identify any potentially significant barriers which had not been included as part of the survey, participants were asked to freely identify the top three barriers and
solutions they felt significant to keeping more threatened amphibians. To identify common themes, responses were grouped into eleven barrier categories; nine matching the barriers asked about in the matrix [Table 4-1] and two additional: lack of management or institutional interest, and collection planning – a lack of collection planning, or the exclusion of species within the collection plan. The number of responses within each category were then tallied and plotted on a bar chart, showing the number of responses for each barrier category, broken down by whether these were ranked as the top, second, or third most significant barrier.

4.5.5 Desire to hold GTA
One question was specifically designed to investigate the desire of zoo curators and collection managers to holding GTAs in response to chytridiomycosis. Respondents were asked to state how they felt chytridiomycosis had affected their desire to keep GTAs or how chytridiomycosis had affected their collection plans. Responses were grouped into three categories: increased desire, no effect, and decreased desire/more cautious. As respondents were able to type text freely in response to this question, a number of responses were unclear; for example those that simply said “yes” or referred to increased difficulty in keeping amphibians due to chytridiomycosis without mentioning how the increased difficulty affected desire. These were not included in the analysis. Responses that said “no”, “very little” or similar were grouped into no effect, while any responses which mentioned “decreased desire” or “increased caution” were grouped into decreased desire/more cautious.

4.5.6 Solutions to the barriers to holding more threatened amphibians
Solutions were first grouped according to the barrier they had been designed to address, to identify any frequently suggested solutions for particular barriers. Due to several solutions appearing in response to multiple barriers, solutions were then grouped into nine broad priority areas (Increased interest and motivation of zoo management including budget, training of staff – e.g. on husbandry and disease protocols, increased interest of externals such as visitors and donors, collection planning at institutional, regional and wider levels, improved links between in-situ and ex-situ work, innovative design and increased investment in exhibits and enclosures, improved justification of ex-situ conservation and return on investment, increased collaborations and partnerships between institutions, increased in-situ research and fieldwork).
Follow-up interviews were audio-recorded as conducted and then transcribed in the case of phone and skype interviews, or emailed directly from respondents in the case of email interviews. Responses were analysed by using the cutting and sorting method used in Bernard & Ryan, (2010) and Bernard, (2011).
5 Results

A total of 111 survey responses were obtained, from 107 zoos and aquariums (two different individuals responded from four zoos), a response rate of 23.01%. Of these 111 responses, a total of 108 gave enough information to identify their region: 56 were located in Europe, 38 in North America and Canada, 11 in Australasia, 1 in Asia and 2 in South America. No amphibian species were held by 4 collections, and 2 did not provide information on their amphibian collection. For zoos which held at least one amphibian species, summary statistics were calculated for the number of amphibian species held, the number of threatened amphibian species held, zoo size in hectares, annual zoo budget, number of keepers working with amphibians, number of keepers working exclusively with amphibians, annual visitor numbers and the proportion of a collection considered threatened [Table 5-1].

Table 5—1: Summary statistics for ex-situ collections which held at least 1 amphibian species

<table>
<thead>
<tr>
<th></th>
<th>Number of valid responses</th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of amphibian species held</td>
<td>101</td>
<td>15.07</td>
<td>8</td>
<td>1-75</td>
</tr>
<tr>
<td>Number of threatened amphibian species held</td>
<td>100</td>
<td>3.48</td>
<td>2</td>
<td>0-19</td>
</tr>
<tr>
<td>Proportion of collection threatened</td>
<td>101</td>
<td>23.27%</td>
<td>21.42%</td>
<td>0-100%</td>
</tr>
<tr>
<td>Zoo size (hectares)</td>
<td>95</td>
<td>36.94</td>
<td>20</td>
<td>0.2-404.7</td>
</tr>
<tr>
<td>Annual budget in millions (USD)</td>
<td>54</td>
<td>11.13</td>
<td>3.51</td>
<td>0.12-60.0</td>
</tr>
<tr>
<td>Number of keepers working with amphibians</td>
<td>99</td>
<td>4.34</td>
<td>3</td>
<td>1-20</td>
</tr>
<tr>
<td>Number of keepers working only with amphibians</td>
<td>98</td>
<td>0.43</td>
<td>0</td>
<td>0-6</td>
</tr>
<tr>
<td>Annual visitors</td>
<td>90</td>
<td>646702</td>
<td>400000</td>
<td>2500-300000</td>
</tr>
</tbody>
</table>

5.1 Correlations

Correlations between zoo size, budget, annual visitors, number of threatened amphibian species held, total number of amphibian species held and the proportion of a collection which was considered threatened were considered using Spearman’s rank correlation [Table 5-2].

Zoo size was positively correlated with the number of amphibian species held ($\rho=0.226$, $p<0.05$) and the number of threatened amphibian species held ($\rho=0.796$, $p<0.01$) [Figure 5-1]. Annual visitor numbers were positively correlated with the number of amphibian species held ($\rho=0.395$, $p<0.01$) and the number of threatened amphibian species held ($\rho=0.473$, $p<0.01$) [Figure 5-2]. Zoo budget was positively correlated with the number of amphibian species held ($\rho=0.440$, $p<0.01$) and the number of threatened amphibian species held ($\rho=0.415$, $p<0.01$) [Figure 5-3], as well as the proportion of amphibian collection threatened ($\rho=0.299$, $p<0.05$) [Figure 5-4].
### Table 5—2: Spearman’s rank correlations of zoo budget, size, visitors and amphibian collection for zoos with at least 1 amphibian species

<table>
<thead>
<tr>
<th></th>
<th>Zoo Size</th>
<th>Zoo Budget</th>
<th>Annual visitors</th>
<th>Number of amphibian species</th>
<th>Number of Threatened amphibian species</th>
<th>Proportion of amphibian collection threatened</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoo Size</td>
<td>-</td>
<td>0.550**</td>
<td>0.301**</td>
<td>0.226*</td>
<td>0.221*</td>
<td>0.084</td>
</tr>
<tr>
<td>Zoo Budget</td>
<td>-</td>
<td></td>
<td>0.708**</td>
<td>0.440**</td>
<td>0.415**</td>
<td>0.299*</td>
</tr>
<tr>
<td>Annual visitors</td>
<td>-</td>
<td></td>
<td>0.473**</td>
<td>0.395**</td>
<td></td>
<td>0.103</td>
</tr>
<tr>
<td>Number of amphibian species</td>
<td>-</td>
<td></td>
<td></td>
<td>0.796**</td>
<td></td>
<td>0.186</td>
</tr>
<tr>
<td>Number of Threatened amphibian species</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>0.656**</td>
<td></td>
</tr>
</tbody>
</table>

* p<0.05, ** p<0.01
**Figure 5-1:** The number of total amphibian species and threatened species held in collections of varying sizes

**Figure 5-2:** The number of total amphibian species and threatened amphibian species held in relation to annual visitor numbers.
Figure 5-3: The number of total amphibian species and threatened amphibian species held for varying annual budgets.

Figure 5-4: The proportion of amphibian collection which is considered threatened for zoos of varying annual budgets.
5.2 Group differences in amphibian collection

Individuals were asked about their institution’s involvement in *in-situ* conservation, whether or not they had a collection plan for amphibians and how this was devised, and about particular facilities they had available. Summary statistics for this data were produced [Table 5-3].

**Table 5—3: Summary of zoo facility statistics for collections which hold at least 1 amphibian species**

<table>
<thead>
<tr>
<th>Question</th>
<th>Valid responses</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does your zoo/institution actively undertake any field conservation programmes? (not including small grants)</td>
<td>98</td>
<td>76</td>
<td>22</td>
</tr>
<tr>
<td>Do you have a collection plan which includes amphibians?</td>
<td>100</td>
<td>83</td>
<td>17</td>
</tr>
<tr>
<td>Do you have a collection plan for amphibians only? *</td>
<td>82</td>
<td>26</td>
<td>56</td>
</tr>
<tr>
<td>Do you have a strategy which informs the future of the amphibian collection? *</td>
<td>73</td>
<td>46</td>
<td>27</td>
</tr>
<tr>
<td>Do you use any national, regional, global assessments or priority lists to inform your amphibian collection strategy? *</td>
<td>73</td>
<td>46</td>
<td>27</td>
</tr>
<tr>
<td>Do you have an import quarantine space which would be available for newly arriving amphibian species?</td>
<td>101</td>
<td>54</td>
<td>47</td>
</tr>
<tr>
<td>Do you have the facilities to keep and breed amphibians under permanent biosecure conditions?</td>
<td>99</td>
<td>35</td>
<td>64</td>
</tr>
</tbody>
</table>

* Respondents which had stated they did not have a collection plan which included amphibians were excluded from analysis of these questions.
The mean proportion of a collection which was considered threatened was compared between groups for each of the factors in Table 5-3. Institutions which reported having a collection plan which included amphibians held on average a significantly higher proportion of threatened amphibians (25.8%) than those without (12.4%) ($F(1,96)=5.059$, $p=0.027$). No significant differences were observed between any of the other groups.

5.3 Significant barriers to holding more threatened amphibians

The barrier most frequently selected as significant was lack of resources. Disease/biosecurity concerns and difficulty meeting specific husbandry requirements were the next most frequently identified, with both identified as significant or highly significant 84 times, though a larger proportion felt that disease and biosecurity concerns were highly significant (32%) than husbandry requirements (15%). Only two of the nine barriers were selected as insignificant or highly insignificant more frequently than significant and highly significant: difficulty displaying due to cryptic colours or behaviour and difficulty attracting visitor interest [Figure 5-5].
Figure 5-5: A graph showing the percentage of responses for significance for each barrier.

5.3.1 Group differences in perceived significance of barriers

Those without a collection plan exclusively for amphibians were more likely to state that a lack of staff expertise/knowledge was highly significant than those with an amphibian exclusive collection plan ($p = 0.01$, FET). Those with a quarantine space were less likely state that a lack of resources was significant than those without ($p = 0.046$, FET). Those with biosecure facilities were more likely to state that difficulty meeting specific husbandry needs was insignificant than those without ($p = 0.047$, FET), and less likely to state that a lack of staff knowledge/expertise was highly significant than those without ($p = 0.021$, FET). No significant differences could be identified amongst any of the other groups.

Collections with at least one GTA were more likely to identify cost concerns as highly significant (28.8%) than those without (7.7%) ($p = 0.027$, FET), but less likely to identify a lack of staff knowledge/expertise as highly significant (13.5%) than those without GTS (33.3%) ($\chi^2 (3, N = 101) = 12.339, p = 0.06$). No other barriers varied significantly between those with GTA and those without.
5.3.2 Regional differences in perceived significance of barriers
Perceived significance of difficulty obtaining permits in order to import amphibians varied regionally, with Australasian respondents more likely to rate this as highly significant than European or North American respondents (p=0.02, FET). Australasian respondents were also more likely to state that difficulty meeting specific husbandry requirements was insignificant than European or North American respondents (p=0.02, FET). Finally, perceived significance of lack of resources varied regionally, with North American respondents more likely to state this was highly insignificant and Australasian respondents more likely to state this was insignificant than European respondents (p=0.01, FET). Perceived significance of other barriers did not vary regionally [Table 5-4].
## Table 5—4: FET results for regional perception of barrier significance

<table>
<thead>
<tr>
<th></th>
<th>Europe</th>
<th>North America &amp; Canada</th>
<th>Australasia</th>
<th>Total</th>
<th>N</th>
<th>%</th>
<th>N</th>
<th>%</th>
<th>N</th>
<th>%</th>
<th>N</th>
<th>%</th>
<th>df</th>
<th>Fisher’s p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Difficulty obtaining permits in order to import amphibians</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highly Insignificant</td>
<td>4</td>
<td>7.1</td>
<td>6</td>
<td>15.8</td>
<td>2</td>
<td>20.0</td>
<td>12</td>
<td>11.5</td>
<td>6</td>
<td>0.02*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insignificant</td>
<td>23</td>
<td>41.1</td>
<td>13</td>
<td>34.2</td>
<td>2</td>
<td>0.0</td>
<td>28</td>
<td>36</td>
<td>36</td>
<td>34.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant</td>
<td>21</td>
<td>37.5</td>
<td>17</td>
<td>44.7</td>
<td>4</td>
<td>40.0</td>
<td>12</td>
<td>40.4</td>
<td>12</td>
<td>34.0</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>8</td>
<td>14.3</td>
<td>2</td>
<td>5.3</td>
<td>4</td>
<td>40.0</td>
<td>14</td>
<td>13.5</td>
<td>14</td>
<td>11.5</td>
<td></td>
<td></td>
<td></td>
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<td><strong>Difficulty obtaining wild individuals</strong></td>
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<tr>
<td>Highly Insignificant</td>
<td>1</td>
<td>1.8</td>
<td>2</td>
<td>5.3</td>
<td>0</td>
<td>0.0</td>
<td>3</td>
<td>2.9</td>
<td>6</td>
<td>0.76</td>
<td></td>
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<tr>
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<td>18.2</td>
<td>32</td>
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<td>31.6</td>
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<td>36.4</td>
<td>31</td>
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<td>31</td>
<td>29.5</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Difficulty displaying due to cryptic colours or behaviour</strong></td>
<td></td>
<td></td>
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<tr>
<td>Highly Insignificant</td>
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<td>19.6</td>
<td>8</td>
<td>21.1</td>
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<td>21</td>
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<td>46.7</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Significant</td>
<td>17</td>
<td>30.4</td>
<td>7</td>
<td>18.4</td>
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<td>36.4</td>
<td>28</td>
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<td>5.3</td>
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<td>9.1</td>
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<td>7.6</td>
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<tr>
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<td>0.0</td>
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<td>7.9</td>
<td>1</td>
<td>9.1</td>
<td>4</td>
<td>3.8</td>
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<td>3.8</td>
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<tr>
<td>Insignificant</td>
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<td>18.2</td>
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<td>Lack of resources (e.g. number of staff, space, budget etc)</td>
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<tr>
<td></td>
<td>Insufficient</td>
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</tbody>
</table>

* p<0.05, ** p<0.01
5.4 Top three barriers
Respondents were asked to identify the top three barriers to holding more threatened amphibians from their perspective. Respondents were able to include any barriers they had previously been asked about or any of their own ideas and responses, which were then grouped into 11 categories. The most frequently identified barrier was lack of resources, followed by disease/biosecurity concerns and lack of staff knowledge/expertise [Figure 5-6].

![Top three barriers to holding more threatened amphibians](image)

**Figure 5-6: Top three barriers to holding more threatened amphibians as identified by curators and collection managers**

Since a lack of resources was by far the most frequently identified barrier, this was further categorised into subgroups. Of the 120 times lack of resources was identified as one of the three barriers, 93 respondents mentioned one type of resource in particular (77.5% of the time). Of these, space was the most frequently selected resource, followed by staff/staff time, and budget [Figure 5-7].
5.4.1 Top three barriers for collections without globally threatened amphibians

**Figure 5-7: Importance of lack of different resources to holding more threatened amphibians as identified by curators and collection managers**

**Figure 5-8: Top three barriers to holding more threatened amphibians as identified by curators and collection managers for collections without amphibians**
Figure 5-9: Percentage of responses which identified barriers as one of the top three barriers to holding more GTA for collections with GTA species and collections without GTA species

Amongst the 31 collections which do not currently hold GTA species, the most frequently identified top barriers to holding threatened amphibians were a lack of resources, difficulty meeting specific husbandry requirements and a lack of staff expertise or knowledge [Figure 5-8]. Disease or biosecurity concerns were perceived as a top barrier less, and difficulty meeting specific husbandry requirements more, often amongst those without threatened amphibian species [Figure 5-9].

5.5 Desire to hold threatened amphibians & indicators of difficulty obtaining

Of 63 responses which referred to changing desire to hold threatened amphibians in light of chytridiomycosis, 68% stated that chytridiomycosis had not affected their desire to hold threatened amphibians, whilst 24% stated their desire to hold threatened amphibians had increased [Figure 5-9].
Figure 5-10: Impact of chytridiomycosis on curators and collection managers’ desire to hold more threatened amphibians

Of the 94 respondents that answered the question with either a yes or no, as opposed to “I don’t know” or leaving it blank, 14 (15%) stated that there were amphibian species which they had previously considered keeping in the collection, but would have been unable to obtain due to permits or import/export regulations. Of the 100 that answered with either a yes or no to the question on difficulty obtaining individuals for any reason other than permits, 26 (26%) stated that there were amphibian species they had previously considered keeping in the collection, but would have been unable to obtain.
5.6 Solutions

After identifying the top three barriers to holding more threatened amphibians, respondents were asked to suggest possible solutions to deal with each barrier. Responses to these questions were mixed, with many respondents leaving the questions blank, however 38 potential solutions were identified with varying frequency [Table 5-5].

Table 5—5: Potential solutions for various barriers as suggested by zoo curators and collection managers

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Solution</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of resources</td>
<td>Increased interest from management (including increased budget allocation)</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Off-site storage / prioritising space / renovation</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Additional staffing</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Increase external interest - visitors, sponsors, donors</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Grants</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Prioritising species</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Design of enclosures</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Delivery of demonstrable conservation outcomes / return on investment</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Collaboration between institutions</td>
<td>1</td>
</tr>
<tr>
<td>Difficulty obtaining permits</td>
<td>Review/change legislation</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Improved justification for ex-situ work</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Continued fieldwork/more information</td>
<td>2</td>
</tr>
<tr>
<td>Difficulty obtaining individuals</td>
<td>Develop partnerships and improve coordination</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Improved communication between in-situ and captive collections</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Continued fieldwork</td>
<td>1</td>
</tr>
<tr>
<td>Difficulty obtaining individuals</td>
<td>Better enclosure design</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Invest in nocturnal enclosures</td>
<td>1</td>
</tr>
<tr>
<td>Difficulty displaying</td>
<td>Training/workshops to increase expertise in staff</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Increase in resources - space/staff/money</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Increased research including increased links between in-situ and ex-situ</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Educating management/funders to increase support for amphibian programmes</td>
<td>1</td>
</tr>
<tr>
<td>Disease / biosecurity concerns</td>
<td>Increasing resources for developing biosecurity</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Increased support from management level</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>No exotics - breed in range states or as close to as possible</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Improving knowledge - training, protocols, education</td>
<td>1</td>
</tr>
<tr>
<td>Cost issues of housing species</td>
<td>Sponsorship</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Direct more funds towards amphibians</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Grants</td>
<td>2</td>
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</tbody>
</table>
Since there was a great deal of overlap in suggested actions the solutions were then looked at more broadly, regardless of which barrier they had been proposed to address and categorised into 9 priority areas [Figure 5-11].

<table>
<thead>
<tr>
<th>Lack of staff knowledge/expertise</th>
<th>Training/workshops to increase expertise in staff</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increased funds to retain staff</td>
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<tr>
<td><strong>Difficulty attracting visitor attention</strong></td>
<td>Increase education and communication with visitors</td>
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<tr>
<td></td>
<td>Innovative enclosure design</td>
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<tr>
<td><strong>Lack of management / institutional interest</strong></td>
<td>Education of managers and directors</td>
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<tr>
<td></td>
<td>External awareness through conferences or by external agencies</td>
<td>3</td>
</tr>
<tr>
<td><strong>Lack of staff interest</strong></td>
<td>Having the correct resources</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Education</td>
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</table>

<table>
<thead>
<tr>
<th>Priority action areas for holding more threatened amphibians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased interest and motivation of zoo management...</td>
</tr>
<tr>
<td>Increased interest of externals such as visitors, donors...</td>
</tr>
<tr>
<td>Training of staff - husbandry, disease protocols etc</td>
</tr>
<tr>
<td>Increased collaborations and partnerships between...</td>
</tr>
<tr>
<td>Improve links between in situ and ex situ work</td>
</tr>
<tr>
<td>Collection planning - institutional, regional and wider</td>
</tr>
<tr>
<td>Design of exhibits and enclosures</td>
</tr>
<tr>
<td>Return on investment and improved justification...</td>
</tr>
<tr>
<td>Change legislation (for permits/import)</td>
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<tr>
<td>More in situ research and fieldwork</td>
</tr>
</tbody>
</table>

*Figure 5-11: Priority areas for required action in order to hold more threatened amphibians in ex-situ collections, as identified from solutions suggested by zoo curators and collection manage*
A number of additional themes were identified through follow-up interviews [Table 5-6].

**Table 5—6: Themes identified through follow-up interviews**

<table>
<thead>
<tr>
<th>Theme</th>
<th>No. of respondents</th>
<th>Example responses</th>
</tr>
</thead>
</table>
| Zoos have a responsibility to support in country facilities – where possible | 13                 | • “Ideally animals should be kept in their home range”  
• “It’s very important to focus efforts in the place they’re from”  
• “We have to keep the people within the home region of the animal involved in the conservation of that species”  
• “A capacity-building role should be at the heart of any zoo that is talking about conservation”  
• “The tricky part is that the area that are the most in need are the most difficult to work in and with” |
| Engaging the guest differently             | 7                  | • “If an animal is going extinct there’s a story that can be told that can be interesting to the average person”  
• “Difficulty attracting visitor interest – to be honest, it’s as hard as you want to make it... It’s about how you go about engaging with people”  
• “It’s about being clever – how do you attract people to these animals?”  
• “By appropriate signage (“Can you find me?” with a photo of the animal) even cryptic animals can be seen and/or appreciated.” |
| Husbandry challenges are not insurmountable | 5                  | • “I think people get excited about husbandry challenges – that can be motivational for your staff”  
• “If you don’t have experience it shouldn’t deter you if that species needs you”  
• “Just a matter of taking it one step at a time, being methodical, applying what you do know carefully, taking a risk when you think it’s responsible.” |
| Lack of separate amphibian departments or management support for amphibians | 5                  | • “There’s this mentality that “The reptile house is where the frogs are (even though that’s not what frogs are)”  
• “The problem is, with a lot of amphibian departments, they’re lumped in with reptile departments...keeping amphibians and keeping reptiles are two very different skill sets”  
• “A lot of [facilities] think of amphibians as filler species” |
| The importance of having an end goal       | 4                  | • “I don’t think conservation breeding should be a knee-jerk reaction.”  
• “What’s the plan for putting the animals back? That I think is the stumbling block with a lot of institutions.”  
• “What are we actually trying to do with it? Are we just looking to maintain a population or do releases?” |
6 Discussion

6.1 Most common barriers
The barrier identified most often as highly significant and most frequently cited as one of the top three barriers to holding more threatened amphibians was lack of resources. Space was the most frequently identified particular resource constraint and this was also supported by follow-up interviews, with 9 of 13 interviewees referencing a lack of space for amphibians. Threatened amphibians which are kept for conservation breeding programs and intended for future release should be kept under permanent quarantine, in separate rooms (Amphibian Ark, 2008), however this study suggests that implementing this in practice is difficult for ex-situ collections due to limited space availability. Only one third of respondents stated that they had the facilities to keep and breed amphibians under permanent biosecure facilities. This lack of resources may therefore result in zoos selecting not to keep species for conservation breeding. If a collection has decided to keep a species without intention of conservation breeding and future release, this may lead to the preferential selection of a non-threatened species over a threatened species, since threatened species may be harder to obtain (Martin et al., 2013). However, although physical zoo area was positively correlated with both the total number of amphibian species held and the number of threatened amphibian species held, zoo size was not correlated with the proportion of a collection which is threatened. Unlike zoo size, zoo budget was positively correlated with the proportion of a collection which is considered threatened. Although Balmford et al., (1999) suggest that amphibians require smaller financial investment than large vertebrates, the need for biosecure facilities, quarantine space and disease monitoring has no doubt increased these costs (Tapley et al., 2015a). This may explain why budget was positively correlated with proportion of collection threatened.

Disease and biosecurity concerns were the second most frequently cited barrier to holding more GTA species, and the third most often identified as significant or highly significant. While no significant difference in mean proportion of collection threatened, or in the perceived significance of disease/biosecurity concerns, could be identified between collections with or without a quarantine space or biosecure facilities, this does not necessarily mean that quarantine or biosecurity fail to reduce the risks associated with disease. For example, collections which have invested in such facilities may import more species, or import species suspected to be carriers of disease, increasing their risk of exposure, or it may be that collections with quarantine and biosecurity facilities are more conscious of disease due to their investment, or due to keeping
particularly critical species in their permanent biosecure facilities. It also may be that, although a significant barrier to holding more threatened amphibians, chytridiomycosis is perceived as an unavoidable barrier, which must be kept in mind and attempted to mitigate against, but which cannot at this point be eliminated as a barrier completely. Chytridiomycosis had only reduced the desire to hold threatened amphibians amongst 8% of respondents, suggesting that quarantine or permanent biosecure facilities may now be seen as inevitable costs associated with holding threatened amphibians.

The third most frequently identified barrier to holding threatened amphibians was lack of staff knowledge or expertise. Whilst this was identified as a potential barrier during literature surveys, it was not expected to rank so highly in terms of importance, as it ranked only sixth when respondents were asked to rate its significance. This apparent discrepancy may have been due to confusion in terminology as the barrier of difficulty meeting specific husbandry requirements had the opposite result. This was the second most frequently identified significant or highly significant barrier within the matrix but only sixth when respondents were asked to identify their top three most significant barriers. Each relates to different potential husbandry barriers – a lack of knowledge regarding husbandry requirements within the staff, and a difficulty meeting specific husbandry requirements even with the correct knowledge - but individuals selecting difficulty meeting specific husbandry requirements as part of the matrix may have identified the clarified the barrier as a lack of staff knowledge or expertise when given free choice. Alternatively, the absence of difficulty meeting husbandry needs from the top three barriers may suggest this is seen as a widespread problem, but of lesser consequence, since although 77% identified it as significant, only 15% of those identified it as highly significant.

A lack of separate amphibian departments and management support for amphibians was a theme among follow-up interviews, with one interviewee referring to amphibian departments as “lumped in with the reptile departments”, and two referring to keepers being responsible for both amphibians and reptiles. A lack of staff knowledge or expertise may therefore be due to keepers being responsible species with vastly different requirements, and in some cases due to little keeper interest in amphibians, referred to by two interviewees.

It is interesting to note that collections which had a collection plan exclusively for amphibians were less likely to feel that lack of staff knowledge was a significant barrier. This may be because the
presence of an amphibian exclusive collection plan represents increased management interest, and therefore investment in terms of staffing, staff training, or through increased staff interest.

6.1.1 Most common barriers for collections without GTA species
The top three barriers according to collections which do not currently hold GTA species seemed to reflect the overall trend in barriers, with lack of resources also being the most frequently identified barrier, and lack of staff knowledge/expertise also the third most frequently identified amongst those without threatened amphibians. A lack of staff expertise or knowledge was more often identified as one of the top three barriers for collections which do not hold threatened amphibians than for *ex-situ collections* in general, amongst whom it was the sixth most frequently identified barrier. While this may mean that a lack of staff knowledge or expertise is perceived as a more significant barrier amongst collections which do not hold threatened amphibians, this may be due to the small sample size of zoos which do not hold threatened amphibians. It may also reflect a differing perception of the significance of disease/biosecurity concerns, the second most frequently identified barrier amongst collections as a whole, but the fifth amongst collections which do not currently hold threatened amphibians. Further research would need to be conducted to identify the top barriers amongst collections which do not hold amphibians, and whether these vary from collections which do.

The presence or absence of threatened amphibians within a collection, based on Ajzen’s theory of planned behaviour (1991), is the result of intentions and perceived control. A fundamental assumption of this investigation of barriers is that zoos wish to keep threatened amphibians within their collection. This is supported by the fact that zoos with a collection plan which included amphibians held, on average, a higher proportion of threatened amphibians within their collections than those without a collection plan which included amphibians. Keeping threatened species for conservation breeding may be seen as of lesser importance than providing educational benefits, since educating visitors is believed to be the highest priority activity for zoos, according to both zoos and zoo visitors (Roe *et al.*, 2014). Although this does not necessarily select against keeping threatened amphibians, since threatened species can be kept for a number of other important reasons not related to conservation breeding (Harding *et al.*, *in press*), the selection of threatened amphibians may be compounded by the finding that zoo visitors highly value being informed about conservation actions they can take at home (Roe *et al.*, 2014) – in the case of amphibian declines due to disease, zoos may find it difficult to suggest conservation actions visitors can undertake at
home and feel empowered to implement. It may therefore be that one of the primary barriers to keeping more threatened amphibians is a lack of desire to do so, rather than an inability to do so. Although only 15 respondents selected lack of management interest or support as a barrier, approximately 50% of suggested solutions were related to increasing management interest and budget allocation. A lack of desire to keep threatened amphibians seems therefore relevant for some collections, and although many did not outright suggest this to be a barrier, the high number who selected lack of resources may mean that institutional focus on other taxa may impact the budget and resources available for amphibians. The lack of resources as a barrier to holding more threatened species may therefore be due to both a genuine lack of resources available, but also due to the low prioritisation of amphibians.

6.2 Insignificant barriers
Contrary to previous research (Ward et al., 1998; Frynta et al., 2010), difficulty attracting visitor interest and difficulty displaying due to cryptic colours or behaviour were perceived by respondents in this survey to be insignificant barriers to keeping more threatened amphibians. Larger annual visitor numbers was correlated with higher numbers of amphibian species in total, and higher numbers of threatened amphibian species, however there was no correlation with the proportion of a collection threatened, suggesting that as zoos focus on increasing exhibit numbers, they are not preferentially selecting threatened species. It has been suggested that since threat statuses may change over time, zoos may decide not to distinguish between threat categories, as currently unthreatened species may suffer declines in the future (Bowkett, 2014), and given the rapid decline of amphibian species, this may be an important consideration (Lips et al., 2006). This potential for rapid, unpredictable changes in threat status may mean that although the proportion of an amphibian collection which is threatened is low, zoos are nonetheless safeguarding species which may become threatened. No causation could be identified between factors however, and based on this study, it is impossible to say whether zoos focus on increasing number of exhibits as visitor numbers increase, or whether increasing number of amphibian species and threatened amphibian species result in higher visitor numbers annually.

6.3 Limitations of research
One key limitation of this study is the geographic distribution of respondents. Zoos are likely to focus effort within their own regions, for a number of reasons, including lower financial costs, easier
access, reduced import restrictions and similar climatic conditions (Dawson et al., 2015). The barriers seen as most significant may vary between regions with large numbers of zoos (Western Europe, North America and Australasia) and those with lower numbers of zoos (South America, Asia and Africa) (Martin et al., 2014b), unfortunately due to the small numbers of respondents from South America, Asia and Africa, this was not something that could be compared as part of this study.

One key consideration is that ex-situ collections may choose to keep globally threatened species for a number of reasons which may not be related to conservation breeding. For example, research has been identified as the primary reason for establishing amphibian captive breeding programmes (Harding et al., in press). Similarly, species which are least concern or near threatened may be kept for purposes related to conservation breeding, where a species is locally but not globally threatened, such as the agile frog, *Rana dalmatina*, in Jersey (Buley et al., 2001; Racca, 2003), or because husbandry protocols can be practiced on a less threatened species, such as using the roseate frog, *Geocrinia rosea*, as a model for closely-related threatened *Geocrinia* species (Mantellato et al., 2013). The proportion of amphibians held which are threatened therefore may provide an ‘at a glance’ view of threatened species kept in zoos, but not necessarily a clear view of the zoo’s contribution to conservation. In order to fully assess the contribution of a collection to conservation, the purpose of a species within a collection must therefore be ascertained, but was outside the scope of this project. This information would allow more meaningful analysis of the conservation benefit of a collection, and for recommendations to be made for increasing the conservation efficacy of collections.

### 6.4 Regional variations

Between North America, Europe and Australasia, three barriers varied in perceived significance: difficulty meeting specific husbandry requirements, which was seen as less significant among respondents from Australasia than Europe and North America; difficulty obtaining permits in order to import amphibians which was seen as highly significant more often from Australasian zoos, and lack of resources, which was seen as highly insignificant by North American zoos and insignificant by Australasian zoos more often than European zoos. Australasian zoos may have felt husbandry requirements were of less significance due to their informal commitment to focus on local species rather than importing exotic amphibians (Zippel et al., 2011), since local species are less likely to have extreme variation in husbandry requirements than species from other regions. Given the informal agreement not to import exotic amphibian species (Zippel et al., 2011), difficulty obtaining
permits was not expected to be a significant barrier for Australasian respondents, however, respondents may have selected “difficulty obtaining permits” due to the agreement not to import exotic amphibians. The variation in perceived significance of lack of resources is not clear, however among collections which held at least one amphibian species annual mean budget was $13,972,615 amongst North American zoos, $14,947,666 among Australasian zoos and $5,841,047 amongst European zoos. Although the number of respondents who provided budget information was low, this seems to suggest that budgets amongst European zoos is lower than North American and Australasian and this may help to explain the regional variation.

6.5 Solutions
Nine priority action areas were identified by respondents in this study, with the most frequently identified solutions falling into one of three categories: increased interest and motivation from management including improved budget allocation; increased interest and funding from externals such as donors and visitors, and training of staff.

Increased management interest and budget, as well as increased interest from externals such as donors and visitors have the potential to reduce the most frequently identified significant barrier to holding more threatened amphibians: a lack of resources. Staff training on husbandry and biosecurity have the potential to reduce the impact of disease and biosecurity concerns (the second most frequently identified significant barrier), and increase staff knowledge and expertise (the third most frequently identified barrier).

Mechanisms to increase management, donor or visitor interest were not frequently suggested, however some respondents suggested innovative enclosure design as a solution, and this could potentially increase both management and visitor interest. Innovative displays can result in increased visitor interest in typically less favoured groups such as insects (Yajima, 1991), potentially increasing return on investment to zoo management. Enclosure design, particularly combined with careful selection of species has the potential to increase visitor enjoyment in amphibian exhibits substantially, since although the attraction power of amphibians (the number of individuals who stopped to look at an exhibit) was higher than expected, the holding power (the time spent looking at an exhibit) was lower than expected (Moss & Esson, 2010). Mechanisms to increase time looking at an exhibit may therefore prove beneficial to increasing the profile of amphibian exhibits. Although some exhibit design features, such as reducing distance (Johnston, 1998) may not be practical for
small amphibian species, it may be possible to use innovative design or unusual perspectives, such as overhead exhibits as have been used for elephants (AZA, 2012).

Fa et al., (2014) raised the question of whether visitor preferences were immovable, or whether zoos could “strive to change the way the public engage”. This was a common theme amongst follow-up interviews, with 7 of 13 interviewees talking about “telling the story” and “engaging the guest differently”. Suggestions on ways to draw more attention included the use of volunteers, or ‘gamifying’ exhibits by putting the number of individuals, or tips for spotting individuals, on exhibit signage. It is also important to consider that although zoo’s focus primarily on entertainment for their public image, conservation is strongly emphasised (Carr & Cohen, 2011), but despite this 58% of UK zoo visitors felt they were not well enough informed about zoos’ contribution to conservation (Shaw, 2011). An increasing focus on threatened species may therefore increase visitor satisfaction, even if species are not typically attractive.

6.5.1 Future research
South American, Asian and African zoos, which hold the highest numbers of threatened amphibians (IUCN, 2008), were very poorly represented in this study. Future research into identifying key barriers in these areas, particularly those which differ from those identified here for North American, European and Australasian zoos could identify clear priorities for action by ex-situ institutions from outside a species’ native range country to effectively partner with in country facilities, as prioritised by the AArk (Johnson et al., 2012).

Responses regarding responsibility for addressing barriers to holding more threatened amphibians were very mixed, with institutional, regional, associational and governmental levels all identified as responsible during follow-up interviews. Although this study has identified key priority areas for keeping more threatened amphibians, identifying group differences in perceived responsibility may help to select the most appropriate actions for each organizational level.

6.6 Conclusions
Given the threats to amphibian species in the wild, ex-situ conservation is vital to prevent widespread extinctions, particularly as extinctions through chytridiomycosis may increase with climate change (Pounds et al., 2006). The perceived barriers – identified by this study as lack of resources, disease and biosecurity concerns, and a lack of staff knowledge or expertise – must be urgently addressed.
Further research could investigate whether the lack of resources is institutional, or departmental, requiring increased management interest in amphibians, however identified solutions may be able to address both. For example, solutions which focus on increasing income, perhaps through innovative ways of encouraging interest in amphibian exhibits (e.g. Zoo Victoria’s ‘Love Your Locals’ campaign (Harley, 2012; Zoos Victoria, 2012; Skibins, 2014) could increase visitor numbers resulting in increased financial resources, and potentially incentivising investment in amphibian exhibits. Zoos with a collection plan which included amphibians held significantly more GTA species on average than zoos without, highlighting the importance of collection planning to holding GTA species. Careful collection planning and selection of species can help to balance a zoo’s contribution to conservation, limited resources and the desire to provide entertainment. While zoos should focus on species which have been prioritised for ex-situ conservation, within this category, further prioritisation could focus on species which are also good candidates for captive breeding (Tapley et al., 2015a).

Zoos could contribute to conservation despite the barriers to holding more GTA through partnership with a facility within the range country. For example, the Amphibian Rescue and Conservation Project in Panama is supported by a number of ex-situ collections from outside Panama, including Zoo New England, Houston Zoo and Smithsonian’s National Zoological Park. These ex-situ partners support the in-country operations in a number of ways including providing training and veterinary support (Gratwicke et al., 2012), or by maintaining assurance colonies, as for Panamanian golden frogs, *Atelopus zeteki*, of which more than 1500 adult individuals are now held in the US (Estrada et al., 2014). All follow-up interviewees felt that ex-situ collections had a responsibility to work within country, with financial support, staff support and training on husbandry and food culture suggested as ways to do this. International partnerships such as these would allow zoos to contribute to amphibian conservation, whilst requiring less space than maintaining an entire population of a species. Additionally, zoos and aquariums provide crucial financial support to in-situ conservation efforts (Gusset & Dick, 2011; Conde et al., 2013). Even where barriers such as lack of staff expertise impact their ability to hold more GTA species, zoos therefore can contribute substantially to amphibian conservation.
7 References


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Appendices

Appendix A – Online Survey

Amphibian Survey

Welcome

My name is Leana Brady, and I am an MSc student at Imperial College London. I'm conducting this survey in collaboration with Durrell Wildlife Conservation Trust as part of my dissertation.

This survey aims to identify potential restrictions/contraints/barriers which prevent keeping more globally threatened amphibians in ex-situ collections, and to rank these barriers in order of importance from the viewpoint of curators/collection managers.

Information provided will be kept confidential and used for analysis only, with no identifying information used in the write up of the results.

If you could complete the survey by 30 June 2015 I would be most grateful.

If you have any queries, please contact Leana Brady at Leana.brady14@imperial.ac.uk.

My supervisor, Jeff Dawson, can also be reached at jeff.dawson@durrell.org

Please note, this survey requires an answer to all questions - if you do not know the answer to a question, please put 'x'.
Amphibian Survey

Basic information

1. Which zoo or collection do you currently work at?

2. What is the size of the zoo you work at? (please specify whether this is in acres, hectares or square km)

3. How many visitors does the zoo receive each year? (To the nearest thousand)

4. What is the annual operational budget of the zoo? (To the nearest thousand)

5. Does your zoo/institution actively undertake any field conservation programmes? (not including small grants)
   - Yes
   - No
   - I don't know
6. How many amphibian species does the collection currently hold?

7. What is the approximate total room space available for amphibians? (Please specify whether this is in square metres or square feet)

8. Of the amphibian species currently held within the collection, how many are identified by the IUCN Red List as vulnerable?

9. Of the amphibian species currently held within the collection, how many are identified by the IUCN Red List as endangered?

10. Of the amphibian species currently held within the collection, how many are identified by the IUCN Red List as Critically Endangered?

11. Of the amphibian species currently held within the collection, how many are identified by the IUCN Red List as Extinct in the Wild?

12. Do you have a collection plan which includes amphibians?
   - Yes
   - No
   - I don't know

13. Do you have a collection plan for amphibians only?
   - Yes
   - No
   - I don't know
14. Do you have a strategy which informs the future of the amphibian collection?
   - Yes
   - No
   - I don't know

15. Do you use any national, regional, global assessments or priority lists to inform your amphibian collection strategy? If so, which ones?

16. How many keepers are currently working with amphibians in the collection?

17. How many keepers are currently working with only amphibians?
18. In your opinion, what do you feel is the most significant restriction/constraint/barrier to keeping globally threatened amphibians in your collection?

19. The following have been suggested as potential constraints/restrictions/barriers to keeping more globally threatened amphibians in *ex-situ* collections. Please select for each barrier whether you feel that this barrier is Highly Insignificant, Insignificant, Significant or Highly Significant for your collection.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Highly Insignificant</th>
<th>Insignificant</th>
<th>Significant</th>
<th>Highly Significant</th>
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</thead>
<tbody>
<tr>
<td>Difficulty obtaining permits in order to import amphibians</td>
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<td></td>
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<tr>
<td>Difficulty obtaining wild individuals</td>
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<td>Difficulty displaying due to cryptic colours or behaviour</td>
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<tr>
<td>Difficulty meeting specific husbandry requirements</td>
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<tr>
<td>Disease/biosecurity concerns</td>
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<td>Cost concerns</td>
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<tr>
<td>Lack of staff knowledge/expertise</td>
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<tr>
<td>Difficulty attracting visitor interest</td>
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<tr>
<td>Lack of resources (e.g., number of staff, space, budget etc.)</td>
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20. In your opinion, what are the three most significant constraints/restrictions/barriers to keeping more globally threatened amphibians in your collection? [This can include any of the potential barriers identified in Q19 or any of your own suggestions]

<table>
<thead>
<tr>
<th>Most significant barrier:</th>
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<tr>
<td>Second most significant barrier:</td>
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<td>Third most significant barrier:</td>
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21. For the top 3 barriers/constraints you have listed in question 20, how do you think they could be addressed/overcome/resolved?

<table>
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<tr>
<th>Most significant barrier:</th>
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<tbody>
<tr>
<td>Second most significant barrier:</td>
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<td>Third most significant barrier:</td>
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22. Please use the space below to list any other barriers which you feel are significant to keeping more globally threatened amphibians which have not been mentioned. [This question is optional]

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23. Do you have an import quarantine space which would be available for newly arriving amphibian species?

- Yes
- No
- I don't know

If yes, what is the approximate total room space? (Please specify whether this is in square metres or square feet)

24. Are there amphibian species which you have previously considered keeping in the collection, but would have been unable to obtain due to permits or import/export regulations?

- Yes (please specify below)
- No
- I don't know

Species which are difficult to obtain due to import/export regulations or permits

25. Are there amphibian species which you have previously considered keeping in the collection, but found difficult to obtain (for any reason other than obtaining permits)?

- Yes (please specify below)
- No
- I don't know

Species which are difficult to obtain

26. Do you have the facilities to keep and breed amphibians under permanent biosecure conditions?

- Yes
- No
- I don't know

If yes, what is the approximate total room space? (Please specify whether this is in square metres or square feet)
27. Which one amphibian species would you most like to keep in the collection if you had the opportunity, and why?


28. How do you feel that chytridiomycosis has affected your desire to keep globally threatened amphibians or impacted your collection strategy?


Thank you very much for participating in this survey.

29. Would you be interested in being informed about the results of this study in the future?
   - Yes
   - No

30. Would you be willing to participate in a short follow up interview via phone/skype or in person if required?
   - Yes
   - No
   - Maybe

If you are happy to participate in a short follow up interview, please provide the best email address or other contact details to reach you on.
Appendix B – Follow up interview questions

Thank you very much for filling in the survey and agreeing to this follow up interview. Please be assured that all answers will be treated anonymously.

1. You identified [Top barrier], [Second barrier], and [Third barrier] as the top barriers to holding more threatened amphibians in *ex situ* collections. Please could you expand on those, particularly why you picked those as the most significant (e.g. personal experience, due to discussion groups)?
   a. If respondent mentioned a lack of resources: Please can you confirm whether you would also include [lack of staff or space] when you refer to a lack of resources?

2. You mentioned in the survey that you think the solution to [Top barrier] is [Solution if identified in survey] – how do you think that could be implemented?

3. Where do you think the responsibility for addressing the barriers to keeping more globally threatened amphibians lies? Do you feel this lies at the institutional level, with curators or zoo management, or at a regional or associational level?

4. You highlighted that [barriers identified as insignificant in the survey] were insignificant barriers to keeping more globally threatened amphibians in your collection – please can you expand on why you felt that way? (e.g. personal experience, discussion groups)

5. Do you think that the barriers affecting keeping globally threatened amphibians in *ex situ* collections would also apply to other taxonomic groups, such as birds or mammals? Why or why not?

6. Do you think that the conservation breeding of globally threatened species should be concentrated in facilities within the species indigenous range counties? If so, do you think overseas zoos have a responsibility to support these, particularly in developing countries which might be lacking the infrastructure or expertise?