

# Increasing zoo's conservation potential through understanding barriers to holding globally threatened amphibians

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Received: 17 November 2016 / Revised: 1 June 2017 / Accepted: 6 June 2017 /  
Published online: 15 June 2017  
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**Abstract** The global amphibian crisis and current un-mitigatable threats make ex situ programmes a crucial complementary action for the conservation of many amphibians. Zoos and aquariums are some of the most important and influential groups of institutions to undertake this yet the proportion of globally threatened amphibians in zoos is just 23.9% compared to over 40% in the wild. To identify key barriers to holding globally threatened amphibian species in ex situ collections, as well as potential strategies to mitigate such barriers, we surveyed amphibian curators across 107 institutions worldwide. A lack of resources (including budget, staffing and space) was perceived as the most significant barrier (87% of respondents) and the barrier most frequently identified (119 responses), followed by disease/biosecurity concerns (31 responses), and a lack of staff expertise/knowledge (30 responses). Difficulty displaying amphibians due to cryptic behaviour or colouration (65% of respondents) and difficulty attracting visitor interest (60% of respondents) were seen as insignificant barriers. Nine key priority action areas were identified, with increasing interest from zoo leadership and budget allocation identified as the most important (49% of suggested solutions). Increasing visitor interest in amphibians to encourage increased investment and engaging with range country facilities were highlighted as two ways to address barriers. Careful collection planning considering both the

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Communicated by Dirk Sven Schmeller.

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This article belongs to the Topical Collection: Ex-situ conservation.

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**Electronic supplementary material** The online version of this article (doi:[10.1007/s10531-017-1384-y](https://doi.org/10.1007/s10531-017-1384-y)) contains supplementary material, which is available to authorized users.

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need and suitability of a species for captive breeding is also key, whilst critically assessing the role each species will play in a collection will enable a better assessment of the collection's conservation value rather than using global threat status alone.

**Keywords** Amphibians · Ex-situ conservation · Captive breeding · Threatened species

## Introduction

We are currently experiencing a sixth mass extinction (Barnosky et al. 2011) with global vertebrate populations declining by 52% since 1970 (McLellan 2014). At the forefront of these declines are amphibians, the most threatened vertebrate taxonomic group, with over 40% of species estimated to be threatened with extinction (IUCN 2015). As 2020 approaches, addressing these declines is crucial if we are to meet the Aichi Biodiversity Targets (<http://www.cbd.int/sp/targets/>).

Whilst addressing in situ threats, particularly habitat loss, degradation and fragmentation, is of primary importance; for many amphibian species in situ conservation alone will not be enough, especially in light of current un-mitigatable threats that can impact populations very rapidly such as chytridiomycosis (Woodhams et al. 2011; Scheele et al. 2014). Ex-situ programmes can complement in situ activities in a number of ways including maintaining genetically and demographically viable populations while threats are either better understood or mitigated in the wild (Wren et al. 2015). Amphibian Ark (AArk), established in 2006 to address and co-ordinate the ex situ components of the Amphibian Conservation Action Plan (ACAP), classified 801 species as ex situ rescue or research priority species through their Conservation Needs Assessments between 2006 and 2014 (Dawson et al. 2016). Although one of the most influential and important groups of institutions to undertake such programmes is the global zoo and aquarium community (hereafter zoos, Pritchard et al. 2011; Martin et al. 2014a), globally threatened amphibian species (GTAs; those assessed as Vulnerable, Endangered, Critically Endangered or Extinct in the Wild on the IUCN Red List of Threatened Species) are relatively poorly represented in the world's zoos.

Despite the global zoo community putting greater effort over the last 20 years into conserving GTAs, in 2014 only 6.2% (121 species) of all GTAs were held in zoos (Dawson et al. 2016), compared to 23, 22.1 and 15.6% of all globally threatened mammal, reptile and bird species respectively (Conde et al. 2013). Similarly, the proportion of all amphibian species held in zoos that were globally threatened was much smaller than the proportion of GTAs in the wild (23.9 vs. 40.4%). Whereas the proportion of species held in zoos that are threatened was greater than the proportion threatened in the wild for reptiles (40 vs. 21.9%) and mammals (26.8 vs. 26%) and only slightly less for birds (8.4 vs. 13%); (data from Conde et al. 2013; IUCN 2015; Dawson et al. 2016). For those 801 rescue and research species identified by AArk only 68 (8.5%) were represented in zoos in 2014 with an additional 13 (1.6%) held in non-traditional zoo AArk supported institutions (Dawson et al. 2016).

If the role of ex situ collections in amphibian conservation is to be increased, thus enabling zoos to fulfil their conservation potential (e.g. through conservation focussed research, breeding, education, training), the reasons for this underrepresentation of GTAs

in zoo collections need to be identified so that they can be addressed. Zoos must balance their constrained financial, staffing and space resources with the desire to provide entertainment, educate visitors, and contribute to in situ and ex situ conservation projects (Fa et al. 2014). A number of recent studies found that for mammals and birds, zoos tended to prefer bigger, more attractive examples (Frynta et al. 2010, 2013) and that species in collections tended to be less threatened and more widespread than related species in the wild (Martin et al. 2014a). Surveys of zoo visitors suggest they generally show a preference for mammals (Moss and Esson 2010) and as such amphibians may be seen as a lesser priority. Furthermore, zoos may not preferentially select GTAs over non-threatened species as they are often small, plainly coloured, cryptic and difficult to display (Dawson et al. 2016) and globally threatened species have been suggested as being more expensive to keep (Garnett et al. 2003). Species with restricted ranges, which many GTAs will have, may be difficult to obtain, either due to the remoteness of their location or difficulty obtaining permits (Conde et al. 2013; Martin et al. 2014a). Many GTAs may have very specific husbandry requirements which are difficult to replicate in captivity (Martin et al. 2014b). This lack of husbandry knowledge, combined with a lack of staff expertise in zoos, are further potential barriers to zoos holding GTAs (Tapley et al. 2015). Finally, disease transmission, especially amongst cosmopolitan collections, is of particular concern requiring adequate resources to mitigate against, including resource heavy permanent quarantine facilities for GTAs kept with the intention of reintroduction back into the wild (Pessier 2008).

In this study we undertake what we believe is to be the first survey of amphibian curators and collection managers at a global level to get their perceptions and insights on what the most significant barriers to zoos holding more and greater proportions of GTAs are. In addition we examined whether perceptions were correlated to geographical or institutional factors and collated potential solutions to addressing the barriers identified. This knowledge is vital in improving the status of global amphibian collections and their contribution to conservation efforts.

## Methods

### Framework

We used Ajzen's Theory of Planned Behaviour (Ajzen 1991) as the underlying framework for the survey. It states that 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 GTAs 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 the Association of Zoos and Aquariums (AZA) amphibian conservation action plan in 2007 (AZA 2015) and the formation of AArk by the World Association of Zoos and Aquariums (WAZA), the IUCN SSC Conservation Breeding Specialist Group, and the Amphibian Specialist Group 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.

## Survey design & data collection

An online survey questionnaire was developed using the Survey Monkey platform (<https://www.surveymonkey.com/>). It comprised of four core sections: basic information regarding the zoo; details on the zoos' amphibian collection; the barriers to the zoo holding further GTAs and the respondent's experience in holding or obtaining GTAs (see Supplementary Information 1 for full questionnaire details). The survey aimed to overcome potential social desirability bias (Grimm 2010) by informing participants at the start of the survey that information would be kept confidential; by providing the option to skip questions they felt uncomfortable answering and by phrasing questions in a neutral manner to avoid indicating desirable responses.

For the third section, potential barriers to holding more GTAs were identified through searches of peer-reviewed literature using Google Scholar, Web of Knowledge, Wiley Online Library and Imperial College London's Online Library, using combinations of the words “amphibian(s)” “conservation” “ex situ” “zoo” “representation” “threatened” “distribution” “taxonomic” and “barriers” as well as similar words and synonyms. Potential barriers were then reviewed by the Herpetological Curator (M. Goetz) of a UK zoo (Durrell Wildlife Park), to consider their relevance, as well as possible overlap between barriers, resulting in a total of nine barriers identified (Table 1). These were

**Table 1** Potential barriers to holding more globally threatened amphibian species as identified through literature searches

Potential barrier to holding more globally threatened amphibians	Referred to in literature
Lack of resources (e.g. number of staff, adequate space and budget)	Ginsberg (1993), New (1994), Banks et al. (2008), Conde et al. (2013), Cikanek et al. (2014)
Difficulty obtaining permits in order to move amphibians	Ginsberg (1993), New (1994), Banks et al. (2008), Conde et al. (2013)
Difficulty obtaining individuals from the wild	Price (2005), Martin et al. (2014a)
Difficulty displaying amphibians due to cryptic colours and behaviour	Conde et al. (2013), Dawson et al. (2016)
Difficulty meeting specific husbandry requirements	Martin et al. (2014a), Tapley et al. (2015)
Disease/biosecurity concerns	Pessier (2008), Cassey and Hogg (2014), Tapley et al. (2015)
Cost concerns	Bowkett (2014), Tapley et al. (2015)
Lack of staff knowledge/expertise	Tapley et al. (2015)
Difficulty attracting visitor interest	Moss and Esson (2010), Frynta et al. (2013), Fa et al. (2014)

presented as a matrix in the survey and respondents asked to indicate how significant they thought each barrier was to their collection holding more GTAs on a four point scale (Highly Significant; Significant; Insignificant; Highly Insignificant). Asking for their perception to each barrier rather than asking to agree or disagree with a statement aimed to overcome the potential biases of acquiescence or disacquiescence (Tellis and Chandrasekaran 2010) and misresponse to reversed items (Weijters et al. 2010). Giving a four point scale aimed to overcome the potential bias of central tendency bias (Krosnick et al. 2002; Nowlis et al. 2002; Weijters et al. 2010). Following this, respondents were asked to rank their top three barriers, which could include barriers not provided in the prior list, and then provide suggested solutions to these top three barriers.

Prior to being sent out, the questionnaire was pilot tested by Durrell's Herpetological Curator and suggested adjustments and incorporations made. Email invitations to complete the survey were sent to a total of 465 ex situ collections around the world. Collections were identified from lists of WAZA members, AZA members and European Association of Zoos and Aquaria (EAZA) members. Contact points and email addresses for each institution were attempted to be identified either through the authors' address books or contacts, through the Zoological Information Management System (species360.org, formerly ISI-S.org) or on institutions' websites. To increase response rates emails were personally addressed to an individual by name wherever an individual could be identified (Heerwegh 2007).

## Data analysis

Prior to data analysis, nine duplicate records were identified. One was a true duplicate and discarded from all analysis. The others were from four separate zoos where two individuals from each had responded separately. In order to avoid skewing the data, only one response from each of these zoos was included in calculating institutional and collection averages. 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. 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. Throughout data analysis, responses which were left blank, marked as NA or X were excluded.

In order to analyse the perceived significance of barriers based on the Highly Insignificant-Highly Significant matrix, descriptive statistics, such as identifying the barriers most frequently selected as significant, were conducted. To investigate indirect indicators of particular barriers, the mean proportion of GTAs in a collection 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.

The percentage of respondents who perceived each of the nine barriers to be significant was also compared between the above groups. This was additionally compared between those zoos with an amphibian collection and those without.

Analysis of variance (ANOVA) was conducted on the average threatened percentage of an amphibian collection to identify any groups which showed statistically significant differences. 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 and Green 2008; Field 2013).

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.

To analyse the top three ranked barriers, responses were grouped into twelve barrier categories; nine matching the barriers asked about in the matrix (Table 1) and three additional ones. The number of responses within each category were then tallied and broken down by whether these were ranked as the top, second, or third most significant barrier.

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 subsequently grouped into nine broad priority areas (see Supplementary Information 2).

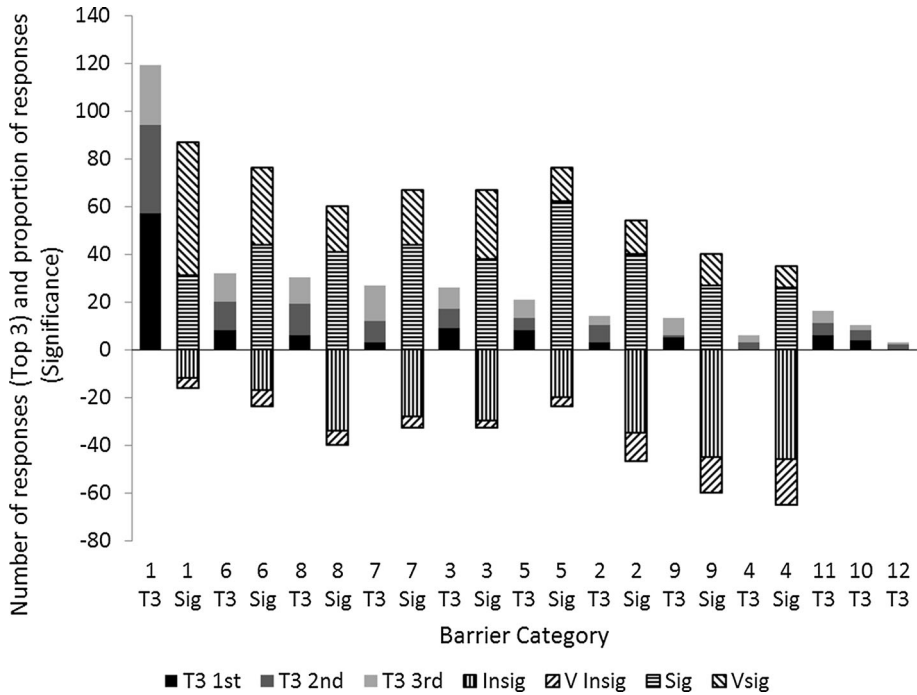
## Results

A total of 111 survey responses were obtained from 107 zoos and aquariums (four zoos had two different individuals respond on their behalf), a response rate of 23.9%. Of these survey responses, 108 gave enough information to identify their region: 56 were located in Europe, 38 in North America, 11 in Australasia, two in South America and one in Asia. Four zoos did not have an amphibian collection and two did not provide information on their amphibian collection.

### Barriers

A lack of resources was most frequently perceived as significant (87%) and most frequently identified as a top three barrier (119 times, 38% responses; see Fig. 1) by respondents. The next most frequently identified top three barrier was disease/biosecurity concerns (30 times, 10%; perceived as significant by 77% of respondent), followed by lack of staff knowledge/expertise (29 times, 9%; perceived as significant by 60%). Only two of the nine barriers were more frequently perceived as insignificant or highly insignificant: difficulty displaying due to cryptic colours or behaviour (65%) and difficulty attracting visitor interest (60%).

Three further barriers to the nine previously presented were identified by respondents when asked to rank their top three barriers to holding more GTAs: a lack of management



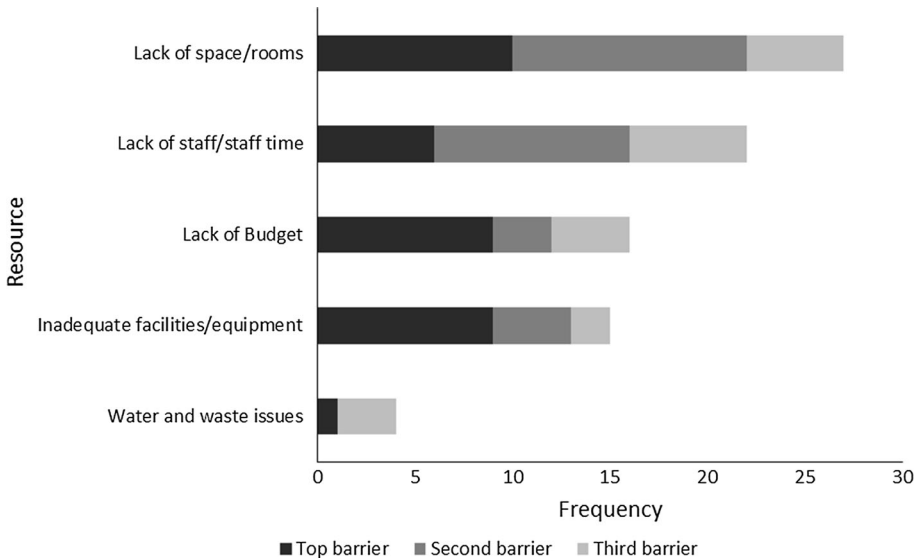
**Fig. 1** The number of times respondents listed each barrier as one of their Top 3 barriers (T3) to holding more threatened amphibians in their collection and the proportion of responses for perception of significance for each barrier (Sig). Barrier numbers: 1 lack of resources (inc. budget, space, staff), 2 difficulty obtaining permits; 3 difficulty obtaining individuals from the wild; 4 difficulty displaying species; 5 difficulty meeting specific husbandry requirements; 6 disease/biosecurity concerns; 7 cost concerns; 8 lack of staff knowledge/expertise; 9 difficulty attracting visitor interest; 10 lack of/not in the collection plan; 11 lack of management interest; 12 lack of staff interest

and/or institutional interest (15 times), a lack of staff interest (three times) and a lack of collection planning, or the exclusion of GTAs within the collection plan (ten times).

Since a lack of resources was by far the most frequently identified barrier, this was further categorised into five subgroups. Of the 119 times lack of resources was identified as one of the top three barriers, 84 respondents mentioned one type of resource in particular (70% of the time). Of these, space was the most frequently selected resource (27 times), followed by staff/staff time (22 times), and budget (16 times) (Fig. 2).

**Group differences in perceived significance of barriers**

Those respondents without an amphibian collection plan were more likely to state that a lack of staff expertise/knowledge was highly significant than those without such a plan ( $p < 0.02$ , FET). A lack of resources was less likely to be perceived as significant by those with quarantine space than those without ( $p < 0.05$ , FET). Respondents with biosecure facilities were more likely to state that difficulty meeting specific husbandry needs was insignificant ( $p < 0.05$ , FET), and less likely to state that a lack of staff knowledge/expertise was highly significant than those without ( $p < 0.05$ , FET). No significant differences could be identified amongst any of the other groups.



**Fig. 2** Importance of lack of different resources to holding more threatened amphibians as identified by curators and collection managers

Collections with at least one GTA were more likely to identify cost concerns as highly significant (28.8%) than those without (7.7%) ( $p < 0.05$ , FET). No other barriers varied significantly between those with GTAs and those without.

### 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 either European or North American respondents ( $p < 0.05$ , FET). Australasian respondents were also more likely than European or North American respondents to state that difficulty meeting specific husbandry requirements was insignificant ( $p < 0.05$ , FET). A lack of resources was more likely to be perceived as highly insignificant by North American respondents and insignificant by Australasian respondents than European respondents ( $p < 0.01$ , FET). Perceived significance of other barriers did not vary regionally.

### Solutions

Responses to questions on potential solutions to the top three barriers were mixed, with many respondents leaving the questions blank, however 39 potential solutions were identified with varying frequency (see Supplementary Information 2).

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 ten priority areas (Fig. 3). Increasing interest and motivation of zoo management was the most frequently suggested solution (98 responses) and across six barriers.





**Fig. 3** 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

## Discussion

In this study we have undertaken what we believe to be the first investigation of potential barriers to holding globally threatened amphibians (GTAs) in zoological collections, and potential solutions, from the perspective of the zoo curators and managers.

### Barriers to holding more GTAs

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 GTAs. A lack of resources was perceived as the most significant barrier (87% of respondents). It was also the most frequently identified barrier when respondents were asked to identify their top three barriers (119 times), with space identified as the major resource barrier (27 times). A lack of space may make it more difficult for zoos to keep sufficient numbers of a species intended for future release as they would need to be under permanent quarantine conditions (Zippell et al. 2006). Subsequently this may lead to the preferential selection of non-threatened species which do not require such conditions. This is perhaps partly reflected in respondents from zoos with quarantine facilities being less likely to cite a lack of resources as being a significant barrier.

Currently, the majority of zoo amphibian collections consist of non-globally threatened species (76.1%; Dawson et al. 2016), which was reflected in this study (76.9%). Replacing some of these non-threatened species with GTAs could increase the conservation value of zoo collections (depending on the species' role within that), without requiring zoos to increase their total space availability. However, it is unlikely to be as simple as this, as in addition to requiring quarantine and biosecure facilities, other factors will likely act as compounding barriers; notably a lack of staff knowledge and/or a lack of management interest.

A lack of staff knowledge and expertise was the third most frequently identified barrier but placed sixth on the matrix of perceived significance of barriers. This is possibly due to confusion between this barrier and the difficulty in meeting husbandry requirements

barrier, with the latter referring specifically to the difficulty meeting a specific species' husbandry needs in captivity regardless of existing knowledge and expertise and ranked third on the perceived significance matrix. Amphibians are highly diverse with a range of captive requirements meaning that they are not necessarily easy to maintain (see Tapley et al. 2015). Keeping and breeding amphibians therefore requires determining the appropriate husbandry techniques, ideally through an evidence-based approach, and many zoos, as stated by respondents, lack the staff expertise and knowledge to do so.

One possible reason for this lack of amphibian husbandry knowledge is that within most zoos, keepers who look after amphibians are also responsible for the care of reptiles. Amphibians have vastly different husbandry needs including, in many species a dual lifecycle, which require different husbandry practices. This was reflected in our survey—only 21.6% of responses to the question stated they had at least one keeper dedicated exclusively to amphibians.

A lack of interest and motivation at zoo senior management level was identified as a top three barrier 15 times but increasing this interest/increasing investment from management was cited 98 times (49% of responses) as a potential solution, cutting across six top three barriers. This suggests that amphibians are not seen as a priority by zoo senior managers or seen as a lesser priority compared to other taxonomic groups held in the zoo. Having zoo senior managers interested and engaged in amphibian conservation is important if sufficient investment is to be given to improve facilities for keeping, breeding and displaying species; provide enough trained staff and importantly retain those staff.

Our results reflect the importance of collection planning at an institutional level with the mean proportion of GTAs held in zoos with an institutional collection plan including amphibians (25.8%) significantly higher than those without (12.4%). This may suggest that although subjective norms seem to promote holding GTAs in zoos, individual attitudes still vary, with the presence of a collection plan indicative of institutions which value keeping GTAs more highly. The presence of an exclusive amphibian collection plan was also associated with a reduced perceived significance of lack of staff knowledge as a barrier, perhaps because the collection plan signifies increased management interest and therefore investment in staffing or training.

Regional zoo associations can also play an important role by providing direction into what species member zoos should focus conservation efforts on and in influencing member institutions' collections plans. Fifteen years ago for example, members of Australasia's Zoo and Aquarium Association (ZAA) agreed to focus on threatened native amphibian species whilst phasing out exotic species (K. Johnson pers. comm., Dawson et al. 2016). As a result, Australasian species showed the highest proportional increases in the number of GTAs held of any region between 2004 and 2014 (Dawson et al. 2016).

Focusing on native species may help to mitigate some of the barriers to holding GTAs by reducing costs associated with obtaining species, reducing permit requirements and reducing biosecurity concerns. For species being captive bred for reintroduction this will also align with the recommendations of the Amphibian Specialist Groups Captive Breeding Working Group (<http://www.amphibians.org/asg/workinggroups/captive-breeding/>). Similarly, native species may be less likely to show such extreme variations in husbandry requirements as multiple exotic species, helping to alleviate difficulty meeting husbandry requirements as a barrier. Indeed, zoos within Australasia, which focus on native threatened species, were more likely to state that difficulty meeting husbandry requirements was an insignificant barrier to holding GTAs than European or North American zoos.

It is key, however, to consider that the distribution of zoos does not accurately reflect the distribution of threatened amphibians. The Caribbean, Mexico, Central and South

America and Sri Lanka have high percentages of threatened amphibians (Stuart et al. 2008), but the majority of zoos are located in Australasia, Western Europe and North America. Therefore regional collection planning in these areas which focuses only on native species is unlikely to be able to provide for all GTAs requiring ex situ intervention.

### Addressing the barriers to zoos holding GTAs

Having identified the primary barriers to holding GTAs in zoos, potential solutions and mitigation actions need to be identified in order to address these barriers. The most commonly proposed solutions were: increasing the interest and motivation of zoo managers including improved budget allocation; increasing interest and funding from externals such as donors and visitors; and staff training.

Few methods to increase management and budget allocation were identified; however increasing interest in amphibians from visitors may encourage investment. Innovative display design can increase visitor interest in less favoured taxonomic groups (Yajima 1991) and enclosure design, particularly combined with careful selection of species, has the potential to increase visitor enjoyment in amphibian exhibits substantially. Past research into exhibits found that the attraction power of amphibians (the number of individuals who stopped to look at an exhibit) was higher than expected, though the holding power (the time spent looking at an exhibit) was lower than expected (Moss and Esson 2010). Mechanisms to increase time looking at an exhibit may therefore prove beneficial to increasing the profile of amphibian exhibits. Innovative design or the use of unusual perspectives, such as overhead exhibits as have been used for elephants (AZA 2012); ‘gamifying’ exhibits by putting the number of individuals, or tips for spotting individuals, on exhibit signage may provide a novel way to engage visitors differently.

It is also important to consider that although zoos focus primarily on entertainment for their public image, conservation is strongly emphasised (Carr and Cohen 2011). Despite this 58% of UK zoo visitors felt they were not well enough informed about zoos’ contribution to conservation (Shaw 2011) and increasing focus on threatened species or those of conservation value may therefore increase visitor satisfaction, even if species are not typically attractive. Rarity may also drive interest; a slideshow of ‘rare’ species photographs attracted more visitors, and visitors spent more time waiting for it, than a slideshow of ‘common’ species photographs (Angulo and Courchamp 2009).

Increased staff training to address both disease/biosecurity concerns and a lack of staff knowledge/expertise will require additional investment from zoos. This was recognised as an essential component of the regional amphibian collection plan developed by the ZAA (Gillespie et al. 2007). Although a lack of resources is likely the main barrier to achieving this, WAZA recommends that its members allocate at least 3% of their operational budget to supporting conservation (Barongi et al. 2015) which could help overcome this. Additionally, agreeing on a regional or associational focus on staff training and pooling expertise to provide training on a wide regional scale may help streamline resources.

Increasing partnerships between zoos and facilities working with GTAs within range countries could be an additional important way to overcome some of the barriers. As well as helping to avoid the issue of limited space, this would reduce costs associated with obtaining and movement of species, as well as reducing biosecurity concerns arising from having cosmopolitan collections. Such partnerships are supported strongly by AArk, in order to help distribute resources to where they are most needed (Johnson et al. 2012). 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).

Where zoos do have available space and capacity to keep amphibians, careful consideration of which species to keep should be given. Not all GTAs are suitable for captive breeding programmes for various reasons and individual suitability needs to be assessed on a species by species basis (see Tapley et al. 2015 for review of considerations). Additionally the role each species will play within the collection and, if members of WAZA, how they will fit into the One Plan Approach of integrating ex situ and in situ conservation initiatives for a species need to be considered. This latter point, highlighted by ten respondents as a solution, is particularly important as captive breeding itself is not a conservation end-point and requires complementary in situ conservation effort.

### Study limitations and future research

Despite making every reasonable effort to ensure we obtained a globally representative sample of zoo curator's views, South American, Asian and African zoos were very poorly represented in this study due to a lack of questionnaire responses. The barriers seen as most significant within these regions may vary with those identified here for North American, European and Australasian zoos. Therefore, we urge caution in applying the results reported here to zoos in South America, Asia and Africa. Identifying key barriers for zoos in these regions, particularly those which differ, could identify clear priorities for action including those for ex situ institutions from outside a species' native range country to more effectively partner with in-country facilities, as prioritised by the AArk (Johnson et al. 2012).

Using the IUCN Red List of Threatened Species to assess a zoo's collection provides an 'at a glance' view of globally threatened species kept in zoos, but not necessarily a clear view of the zoo's contribution to conservation. Whilst the proportion of GTAs within a collection may act as a rough proxy for its conservation value, assessing individual species' roles within a collection would provide a much more accurate assessment. Conservation breeding for reintroduction is often promoted as the primary reason for captive breeding (Balmford et al. 1995) but since 2007 the relative number of amphibian species programmes involving reintroductions has fallen from 41 to 16% (Harding et al. 2016). Conservation research is the main reason given for establishing captive programmes followed by captive assurance and conservation education (Harding et al. 2016). Similarly, species which are Least Concern or Near Threatened globally may be kept for conservation breeding purposes for example, if the species is threatened locally (Racca 2003), or as an analogue for a globally threatened species on which husbandry protocols can be practiced (Mantellato et al. 2013). As species roles within collections are not yet systematically classified globally this is not yet possible to do but would allow more meaningful analysis of the conservation efficacy of a collection, and for making recommendations to increase this.

### Conclusions

Given the complex threats such as disease and climate change facing amphibian species in the wild, ex situ conservation remains a vital component in preventing widespread extinctions. To improve ex situ conservation for amphibians however, the perceived

barriers identified in this study including lack of resources, biosecurity concerns and a lack of staff knowledge or expertise must be urgently addressed. These must be done at the various levels influencing a collection from institutional through to regional and global association level. Increasing management interest and awareness to incentivise increased levels of investment in amphibian ex situ programmes appears key, perhaps through increasing visitor engagement and stronger strategic support at the regional and association level.

Careful collection planning and selection of species can help balance a zoo's contribution to conservation, limited resources and the desire to provide a public attraction. However, this needs to better take into account those species prioritised for ex situ conservation e.g. AArk Conservation Needs Assessments, with further prioritisation on those species suitable for captive breeding (Tapley et al. 2015). Captive breeding in itself is not a conservation goal so it is important that zoos critically assess the role of each species within their collection to enable a clearer assessment of their conservation value than species global threat status alone. Developing a universal method for assessing species roles within collections would enable more detailed assessments of the contribution global animal collections are making to amphibian conservation and highlight gaps and opportunities.

**Acknowledgements** We would like to thank everyone who responded to the questionnaire or took the time to take part in follow-up interviews. Further thanks to Kevin Johnson, Dianne Barber and Amy Hall for assistance with identifying contacts and to Benjamin Tapley for pre-submission feedback and comments.

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