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Amphibian Keeper Conservation Breeding Programs

R. K. Browne[1], P. Janzen[2], M. F. Bagaturov[3], D. K. van Houte[4]

[1] *Sustainability America. Belize, Corozal District, Sarteneja.*
[2]*Zoodirektoren. Germany, 47119 Duisburg, Landwehrstr, 32.*
[3]*IUCN/SSC/ Athens Institute for Education and Research/ Zoological Institute RAS, St.Petersburg. Russia, 199034 St. Petersburg, Universitetskaja emb., 1.*
[4]*Umea University. Sweden, 90736 Umeå, SE-901 87.*

***Corresponding Author:** R. K. Browne, Sustainability America. Belize, Corozal District, Sarteneja. robert.browne@gmail.com*

ABSTRACT

Nearly 200 amphibian species are in immediate need of conservation breeding programs (CBPs) to prevent their extinction, with up to another 950 species in need in the foreseeable future. In general official amphibian CBPs exclude private keepers from participating with their collections because an assumed inability for keepers to provide sufficient quarantine. Official amphibian CBPs must also have an exit strategy of eventual release thus neglecting the many species that suffer from irretrievable habitat loss. Because of their high cost and other restraints, official amphibian CBPs are mainly supported by zoos, aquaria, and other conservation institutions, and can only currently provide for about 50 species. Private KCBPs could fill the widening gap between the number of currently official CBPs and the number of species critically in need. To elucidate the potential of KCBPs we conducted a global internet survey with responses compared between nations, regions, and these pooled between western and other polities. Keepers showed the expertise and commitment needed to conduct CBPs and overwhelmingly supported KCBPs responsibly managed through their societies. Respondents overall wanted official recognition of KCBPs, and their inclusion in policy development, with a particularly strong feeling of dis-empowerment in other polities. There were also demographic differences in the age of first interest in amphibians, social interactions, information sources, and academic activities. A canvassing of keepers collections in western polities showed that they currently keep and breed a wide range of exotic species. We could find no conclusive evidence that keepers CBPs were more a quarantine security risk than many official CBPs. Therefore, KCBPs can provide a haven for the many species that are neglected by official CBPs, and where official CBPs could focus on their regional species, or in range institutional facilities for exotic species. All CBPs should provide high levels of public engagement.

***Keywords:** amphibian, threatened species, conservation breeding programs, policy, polities*

INTRODUCTION

The search for solutions to the amphibian conservation crisis is far from over with 30% of species threatened. More than ~200 species are in immediate need of conservation breeding programs (CBPs) to prevent their extinction and to provide for potential translocation, supplementation, head-starting and re-habitation projects (Johnson, 2016). Besides species in immediate need of CBPs there more than 750 species that may requiring CBPs in the foreseeable future (Ark, 2017*a*; IUCN, 2017; Zippel *et al*., 2011). Thirty percent of anurans (frogs and toads), 50% of caudata (salamanders and newts), and 3% of caecilians are listed as threatened (IUCN, 2017). However, the conservation status of many amphibian species, and particularly caecilians (Gower *et al*., 2013), cannot be ascertained due to a lack of data (IUCN, 2017). Hundreds of described species, and never described species may already be extinct ().

The Amphibian Ark (AArk, 2017*b*) was formed to implement official amphibian CBPs as defined by the Amphibian Conservation Action Plan (ACAP; Gascon *et al*., 2007) and detailed in Mendelson *et al*. (2007), and then presented as a revised web based document (Wren, 2015). Unfortunately, official CBPs only serve a few species in need (Bishop *et al*., 2012; Stuart *et al*., 2012). In 2017 there were only 122 species in official CBPs (AArk, 2017*c*). Few of these satisfied AArk mandates regarding founder numbers, studbook management, captive population size, reliable reproduction, or an exit strategy (AArk, 2017*d*). Between 2007 and

2014 there was widespread publicity concerning the amphibian conservation crisis and the need for CBPs. However, despite this effort the number of official CBPs only increased by ~60% (Harding *et al*., 2015), and some consider that the available resources for official CBPs are only capable of adequately supporting ~50 species (Bishop *et al*., 2012; Clulow *et al*., 2014).

Fazey *et al*. (2005) found that the sustainable management of biodiversity relies on collaboration that includes policy, management, project analysis, public relations and the media. The desirability of including private keepers in official CBPs has been known for over ten years (Beetz 2005). However, official policy regarding amphibian CBPs was drafted without the inclusion of private keepers. The resultant policies excluded KCBPs because of an assumed inability to provide sufficient quarantine (AArk, 2017*e*). However, although there are reviews supporting various approaches to the management of amphibian CBPs (Tapley et. al., 2015, 2017; Zippel *et al*., 2011), to our knowledge no data based information regarding keepers ability and willingness to conduct CBPs has been published.

METHODS

An Internet based survey of the potential of amphibian KCBPs was conducted through email networks, in English between January and October 2013, and between February and June 2013 using Survey Monkey™. Survey design conformed to Survey Monkey™ best practices (Survey Monkey, 2014) and questions included multiple choices, rating scales, Likert scales and demographic information, which were randomized in order to reduce bias.

Questions investigated the participant's interest in their societies managing CBPs, and keepers' facilities, current collections, and success in breeding amphibians. Social and cultural questions included nationality, age, age of first interest in amphibians, information sources, publications, and social networking. Management questions included the need for recognition as official CBPs, participation in policy making, and attitudes toward amphibian harvest, trade, and the sale of surplus amphibians from CBPs (Tabs. 1-11). The order of questions and the order of responses within questions were randomized to minimize bias.

Survey responses were categorized into polities as nations, regions, and pools of western versus other polities. Western polities were defined by a long history of industrialization, Greco-Roman philosophical traditions, and Judaeo-Christian theological backgrounds. Other polities included all other nations or regions. To provide a perspective of the current capacity of keepers' collections we canvassed experts, long familiar with keeper collections mainly in western polities and excluding Japan, and tabled the species in keepers collections, their numbers, and those successfully bred. We discuss survey results in respect to politics, policy and management, quarantine, release, harvest from nature, CITES regulations, and studbook management.

USE OF STATISTICS

High respondent numbers provide statistical confidence in our survey results (Survey Monkey, 2014). Survey results were analyzed from two perspectives; general questions were by comparison within the total percentage of respondents, and in facilities and husbandry questions by comparison to the total numbers of amphibian keepers. Individual responses were averaged for national or regional polities, and these averages were the primary data for comparison between western and other polities. For the tables a two-sided difference between proportions tests, realized in STATISTICA (Statsoft Inc., Tulsa, OK, USA).

A difference of 5% between comparisons of general questions in Tables 1-5, 9, 10 and 11 provides a significant statistical difference ($P < 0.05$). Because of the lower number of keepers than respondents a difference of 10% between comparisons of keeper questions in Tables 6, 7 and 8, provides a significant statistical difference ($P < 0.05$). For readability in the text we have generally rounded percentages off to five in the tables and text.

RESULTS

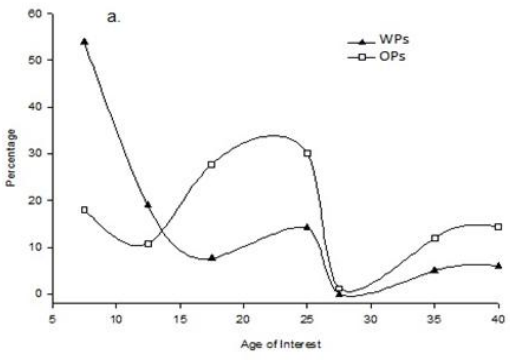
There were 350 responses in total with 296 in English and 54 in German. Responses that did not specify nationality and those that only answered the first few questions were excluded. The final analysis consisted of 313 survey responses with 230 from western and 83 from other polities. Half of all respondents were amphibian keepers, however, the percentage was much higher in western polities (61%) than other polities (18%; Tab. 1).

Table1. *The Age of First Interest of respondents from western (WP) or other (OP) polities as the mean (Mean) and percentages between 5-10 years (% 5-10), and the percentage that were a Society Member, or that had Close Friends or Best Friend interested in amphibians.*

Biopolity	No	Age	Age of First Interest		Society member	Friends
			Mean	% 5-10	%	% Close
*Australia	11	43	19	27	80	27
*Europe	60	43	16	47	76	37
*Germany	62	43	14	52	90	27
*Russia	11	49	14	64	100	64
*UK	28	48	14	57	78	32
*North America	52	47	14	56	76	44
#Asia/India	22	41	21	5	86	68
#Africa	11	46	22	18	82	60
#Latin America	49	44	19	24	71	76
*WP Mean	230	45	15	51	86	35
WP Range		43-49	14-19	27-64	76-100	27-64
#OP Mean	83	43	20	12	76	70
OP Range		41-46	19-22	5-24	71-86	60-76
Overall		45	16	41	83	44

Western polities included respondents from 18 countries: Australia, New Zealand, Spain, Sweden, Netherlands, Portugal, Romania, Germany, United States, Canada, United Kingdom, Russia, Hungary, Romania, Belarus, Azerbaijan, Georgia, and Finland. Other polities included respondents from 28 countries: South Africa, Argentina, Cameroon, Morocco, Madagascar, Vietnam, India, Indonesia, Sri Lanka, Thai, Toga, Singapore, Philippines, Republic of Korea, Salvador, Uruguay, Venezuela, Mexico, Panama, Paraguay, Peru, Puerto Rico, Argentina, Bolivia, Chili, Columbia, Costa Rico and Cuba. We had no respondents from Japan or South Korea countries known to support large numbers of private amphibian keepers.

The age of respondents averaged 44.6 years (range 15.0 to 89.0 years), with western polities averaging 42.5 years and other polities 43.3 years (Tab. 1). Curves of respondents ages were dissimilar between western and other polities, with a large peak in western polities between 35 to 44 years old (born 1970 to 1980), a trough between 44 to 49 years old (born 1964 to 1969), and then a peak between 50 to 55 years old (born 1960 to 1964; Fig. 1b).



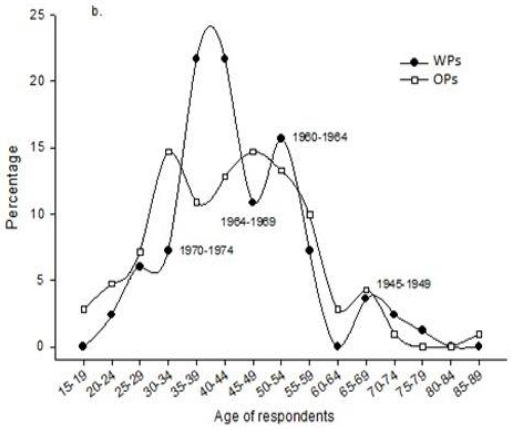


Figure1. *The percentage of respondents first age of interest (a) and the age (b), Curves were generated from the averages of the survey results; therefore an age data point 7.5 represents a response of age of interest of 5 to 10 years of age. a, the percentage of respondents in either WPs or OPs against their first age of interest in amphibians. b, the percentage of respondents for WPs and OPs against years of birth presented as 5 year ranges; peaks are specified by year of birth ranges. The date ranges on (b) are the years of births of respondents.*

Fig2. *Laotriton laoensis* (Stuart & Papenfuss, 2002) – one of the species of threatened caudated amphibians which was first captive bred by establishing CBP thanks to private keeper.

Fig3. *Scaphiophryne gottlebei* Busse and Böhme, 1992 is an iconic endangered species of Madagascar frog restricted for pet trade since 2014 and potentially is another object of amphibian CBP in joint of privates and zoo organizations.

Respondents first age of interest in amphibians averaged 16.6 years (range 5 to 40+), and was lower in western (14.7 years) than in other (20.0) polities. There was no overlap between the upper range of western polities and the lower range of other polities. Half of the respondents first age of interest in western polities was between 5-10 years but only 10% in other polities (Tab. 1) where it mainly occurred between 12.5 and 25 years (Fig. 1a). There are demographic peaks in western polities for respondents born 1964 to 1970, and with first ages of interest between 7.5 and 12.5 years (Fig. 1b). Respondents bonding to amphibians was first promoted by field trips (55%), vocations for natural history (50%), formal education (45%), documentaries (45%), amphibian pets (30%), play near home (30%), and other 10% (data not tabled).

Society membership was high in both western (85%) and other (80%) polities, and exceptionally high in Russia (100%), Germany (95%), and Asia/Africa (85%; Tab. 1). Most respondents from other polities had close friends (70%), and their best friend (60%), interested in amphibians, but these percentages of 35% and 40%, respectively, were much lower in western polities (Tab. 1). Approximately 70% of respondents from both western and other polities socially networked about amphibians through the Internet, and overwhelmingly (>80%) supported their societies managing KCBPs including studbook management, exchange of amphibians, and associated habitat protection (Tab. 2).

Table2. *The percentage of respondents from western (WP) or other (OP) polities that engage in social networking, desire their society to join a keepers CBP and to protect habitat of their chosen species, and willing to follow studbook recommendations including record keeping and exchange of individuals.*

Question	WP	OP	Overall
Do you socially network about amphibians through the Internet?	71	67	70
Society to join a keepers CBP	85	86	85
Society to protect habitat of a threatened amphibian species?	99	94	98
Willingness to follow studbook breeding recommendations.	94	87	92

The percentage of volunteering respondents was low in both western (40%) and other (25%) polities. The percentage of respondents that had donated money to amphibian conservation was higher from western polities (50%) than from other polities (35%), with Australia by far the highest nation at 75% (Tab. 3).

Table3. *The percentages of respondents from western (WP) or other (OP) polities contributing to amphibian conservation through publications, professional work, volunteering, or keeping threatened species and donations.*

Polity	Publications	Professional Work	Volunteering	Keeping Threatened Species	Donations
WP Mean	62	53	37	34	49
WP Range	52-92	27-91	18-54	18-58	27-73
OP Mean	95	89	25	19	36
OP Range	90-100	82-98	20-36	14-20	27-45
Overall Mean	71	62	34	30	45

A very high percentage (95%) of respondents from other polities had published articles about amphibians in comparison to 60% from western polities. The percentage (90%) of respondents in other polities having engaged in professional work was much higher than in western polities (55%, Tab. 3).

Books (70), Journals (75), and the Internet (75) had approximately equal use in western polities. However, other polities favored journals (90%), the Internet (70%) and then books (65%). Germany particularly favored books (90%) and journals (90%), Asia/India journals (95%), and Australia the Internet (90%, Tab. 4).

Table4. *The sources of information on amphibians as percentages of respondents from western (WP) or other (OP) polities. Metrics were often, sometimes, and not often. The percentage of often responses as a percentage of responding participants is shown.*

Polity	Books	Journals	Internet
WP Mean	71	73	76
WP Range	61-92	71-87	71-91
OP Mean	63	89	71
OP Range	45-77	82-95	69-77
Overall Mean	69	77	74

Respondents awareness of threats to amphibian survival corresponded with science based knowledge (Bishop *et al*., 2012; Amphibia web, 2017; Xenopoulos *et al*., 2005) as: habitat loss (100%), disease (90%), climate change (80%), illegal trade (60%), consumption (40%) and legal trade (20%). A greater concern for the effects on amphibians of climate change and both legal and illegal trade was shown by other polities compared with western polities (Tab. 5).

Table5. *Causes of amphibians declines as the mean percentages of overall respondents. The percentage of very high plus high responses as a percentage of responding participants is shown. Metrics were very high, high, moderate and low.*

Causes of amphibians declines	WP	OP	Overall
Habitat loss	100	89	99
Disease	90	86	89
Climate change	71	90	77
Illegal trade	53	84	61
Consumption	43	36	41
Legal trade	17	35	22

Respondents interests in amphibian species was highest for Anurans at 90%, 65% for Caudata 65%, and 35% for Caecilians. There was a high percentage (60%) of keepers in Germany keeping threatened species in contrast to the overall average of 35%. The percentage of Anuran keepers in western polities was lower (60%) than in other polities (75%), and of Caudata keepers in western polities higher (70%) than in other polities (20%). Of all amphibian keepers, 70% kept Anurans, 50% Caudata, and 2% Caecilians (Tab. 6). Most Anuran keepers 55% kept more than 5 individuals, 25% more than 5-15, and 30% more than 15. Half of Caudata keepers kept more than 5 individuals, 10% more than 5-15, and 40% more than 15. The vast majority (95%) of Caecilian keepers kept less than 5 individuals (Tab. 7). Overall 45% of keepers also kept reptiles, 25% fish, insects or mammals, and 10% spiders, scorpions, or birds.

Table 6. *Overall percentage of yes answers by respondents to keeping amphibians, the percentage of these that keep amphibians from different amphibian families, and the percentage of these that breed amphibians from these families.*

Question	WP	OP	Overall
Keeping - Amphibians	61	18	50
- Anurans	74	61	72
- Salamanders	69	17	52
- Caecilians	3	0	2
Breeding Anurans	75	92	77
- Salamanders	88	100	88
- Caecilians	30	0	15

Table7. *The percentage of keepers that kept anurans, salamanders, or caecilians. The number of respondents for each amphibian order are in brackets.*- values containing the lower case letter are not different in the row, and containing the same upper case letter are not different in the column (P> 0.05, two-sided difference between proportions test, realized in STATISTICA 12 Statsoft Inc., Tulsa, OK, USA).*

Question	% > 5	< 5 - >15	% < 15	% < 5	Answered/Skipped
Anurans	44^{aA*} (49)	24^{bA} (27)	$32a^{bA}$ (36)	56 (63)	112/182
Salamanders	51^{aA} (50)	12^{bAB} (12)	38^{aA} (38)	50 (50)	101/193
Caecilians	95^{aB} (83)	4^{bB} (3)	1^{bB} (1)	5 (4)	87/207

Anurans were bred by 60% of Anuran keepers, Caudata by 45% of Caudata keepers, and with very few keepers breeding caecilians and with 15% not breeding any species. A lower percentage of amphibian keepers from western polities bred Anurans and Caudata than from other polities (data not tabled).

More than US$500 a year was spent a year on their collections by 35% of amphibian keepers in western and by 65% in other polities. Keepers in both western and other polities generally spent more than 30 minutes a day on amphibian husbandry (Tab. 8).

Table8. *The Spending per Year (US$) and Minutes per Day that keepers spent on their collections as percentages from western (WP) or other (OP) polities. For the Spending per Year (US$) amounts of 500+ and 1000+were derived from the survey question the range of amounts.*

Polity	Spending per Year (US$)					Minutes per Day		
	0-200	200-500	500-1000	500+	1000+	30	30-60	60+
WP	35	30	18	35	17	46	36	19
OP	36	7	14	56	42	50	21	29
Total %			27	57	30	18	52	30

The provision of internet portals was of higher priority to western (75%) than to other polities (65%). Desire by keepers for official recognition of their CBPs was higher in western (75%) than in other polities (65%). It was lowest in Australia (60%), UK (50%), and Latin America (60%), and highest in Germany (95%) and Russia (>80%). Being included in policy decision making was of lower priority in western (65%) than in other (80%) polities. Of nations, Germany and Russia are the highest (> 80%) priorities, with Australia, UK, and the USA - the lowest (<40%). Receiving financial support for KCBPs was less important to western (55%) than other polities (65%, Tab. 9).

Table9. *The percentage of keepers, from western (WP) or other (OP) polities, that considered that keepers CBPs would benefit by the provision of: Internet Portals and Financial Support, and the recognition of keepers CBPs as an "Official" Programs and a role in global decision making concerning amphibian CBPs.*

Polity	Internet Portal	Financial Support	Official Programs	Decision Making
WP Mean	72	54	75	63
WP Range	40-80	30-86	50-95	35-82
OP Mean	64	66	65	78
OP Range	64-65	61-73	59-86	64-86
Overall Mean	70	57	72	67

Respondents from western and other polities would chose species for their CBPs mainly through the managing organization and through personal contacts, with the species location being of particular importance to other polities (Tab. 10).

Table10. *The importance of influences on respondents choice of a target species for their CBP as Other People, Managing Organization, Location, Documentaries-News, Species, News/Reports, and Newsletters. Metrics were very high, high, moderate and low. The percentage of very high plus high responses is shown as a percentage of the number of respondents.*

Polity	Other People	Managing Organization	Location	Documentaries-News	Species	News/ Reports	Newsletters
WP Mean	62	62	55	37	45	33	32
OP Mean	62	63	71	59	36	60	52
Overall Mean	62	62	59	43	43	41	37

Respondents support for the sale of surplus amphibians from CBPs was much higher in western (70%) than in other polities (30%). Germany (95%) and Russia (100%) most favored sale of surplus amphibians, with Australia (30%) the least in favor. The legal harvest of amphibians was equally favored (65%) between western and other polities, however, was widely variable within western polities with a range from 40-90%. Participants in Germany (90%) and the UK (80%) were the most supportive and Australia the least (40%). Legal trade was supported more in western (80%) than in other polities (55%), with a high variability of responses in western polities from 30-95%, with Germany (95%) and Russia (90%) most supportive, and with Europe (40%) and Australia (30%) the least supportive (Tab. 11).

Table11. *Respondents support for the Sale of surplus amphibians from keepers CBPs, the Legal Harvest of amphibians, and the Legal Trade of amphibians, as a percentage.*

Polity	Sale	Legal Harvest	Legal Trade
WP Mean	70	65	77
WP Range	30-100	40-88	30-93
OP Mean	30	65	56
OP Range	23-36	55-76	55-56
Overall Mean	59	65	71

Limited canvassing of amphibian keepers showed that many threatened amphibian species are kept and bred by privates including, 15 Critically Endangered with 80% bred, 22 Endangered with 100% bred, and 28 Vulnerable with 95% bred. Large private collections of Critically Endangered, iconic, and easily bred Caudata include *Ambystoma spp*., the Chinese giant salamander (*Andrias davidianus*), and the Luristan newt (*Neurergus kaiseri*; IUCN, Appendix 1).

DISCUSSION

Confidence in our survey results is provided through the high number of respondents and through their global representation. Private amphibian keepers were shown to have the expertise, willingness, and facilities to conduct CBPs responsibly managed by their societies. Respondents overall showed a high commitment to amphibian conservation through professional work, volunteering, and donations. Our limited canvassing of species currently in keeper collections showed that keepers globally maintain and breed a wide range of species, and that some Critically Endangered species are already kept and bred in large numbers by private keepers.

Approximately half of amphibian CBPs are supported by zoos and aquaria with the rest mostly in specialist facilities run by governmental or nongovernmental agencies. Institutions in western polities generally prioritise for regional species and can only support a limited number of international CBPs (Harding *et al*., 2015; Conde *et al*., 2013). Zoo and aquarium based CBPs for endemic species provide high levels of public engagement, publicity, and co-operative research. Nevertheless, CBPs based in western polities for non-endemic species have also achieved remarkable success in co-operative research, public engagement, publicity, and breeding (Gibson & Buley, 2004; Lentini, 2007; CBSG, 2006; Edmonds *et al*., 2015). With zoos and aquaria focusing on regional species and supporting international projects, KCBPs in western polities could target the neglected species mostly from the highly biodiverse regions of other polities, Asia, Africa, and Central and South America.

Official policy excludes KCBPs because of keepers assumed inability to provide sufficient quarantine (AArk, 2017*e*). However, we found that KCBPs appear to have similar quarantine potential as institutional CBPs, and that quarantine risks exist in some institutional CBPs that are unlikely in KCBPs and vice versa. For example, institutions often house a number of species that could host amphibian pathogens, and rely on husbandry by different keepers, trainees and interns. In contrast, KCBPs can easily provide highly isolated housing and have the devoted care of one keeper thus providing excellent quarantine.

Quarantine considerations also include the possibility of disease transmission between keepers CBPs and other amphibian populations through amphibian transfers, releases, or discharge of waste. In all CBPs amphibians should undergo full pathogen screening, along with appropriate treatment, when first taken into captivity and before transfer from the facility. The discharge of waste from keepers CBPs would normally be into domestic sewerage systems where pathogens would be eliminated. Amphibian pathogens can be also be naturally transmitted through aquatic vertebrates and invertebrates, water, and birds (Fisher *et al*., 2012; Garmyn *et al*., 2012; McMahon *et al*., 2013; Patricia *et al*., 2017). Therefore, the balance between saving of hundreds of species against that of species loss due to highly questionable quarantine issues favors the official endorsement and support of KCBPs. About half of all keepers kept fish which may provide high a quarantine risk; however, terrestrial animals provide no known transmission risk of virulent amphibian pathogens.

Recent publications reflecting official policy have considered that amphibian CBPs should not be undertaken for species where an exit strategy of re-habitation, translocation, or supplementation cannot be anticipated (Bishop *et al*., 2012; Carrillo *et al*., 2015; Tapley *et al*.,

2015). However, it is immoral to accept the loss of any species without considering all strategies for its conservation (Cafaro & Primack, 2013), and KCBPs can provide for many species with a view toward eventual but unanticipated re-habitation or translocation (Dodd & Seigel, 1991; Germano & Bishop, 2006). Harding (2015) considered that knowledge gained through KCBPs can provide imaginative solutions that enable amphibians to survive current, emerging, and future threats, and increase our knowledge of species biology.

Legal harvest and legal trade of amphibians in general were supported by the majority of respondents. The low levels of support for trade and the high donation levels in Australia suggest an emphasis on institutional CBPs. These may result from a history of invasive and destructive exotic species, including the cane toad (*Bufo marinus*), resulting its presence in few private collections only.

Amphibians in CBPs can produce hundreds to thousands of offspring from one female that are difficult to place (Carrillo *et al.*, 2015). Keepers CBPs could provide surplus amphibians for the pet trade. This would lower the price of threatened species and the demands on natural populations. The sale of surplus amphibians would also reduce pressure from illegal harvesting reduce pressure on threatened natural populations and generate financial benefits and incentives (Zipple et. al., 2011).

Literature and Internet searches found no species of amphibian has reached extinction through over-harvesting. However, over-harvesting of some species is considered an increasing threat especially when combined with the general decline in amphibian populations globally (Carpenter *et al.*, 2007; Rowley *et al*., 2016; Rowley *et al*., 2017). Therefore, the rescue of amphibians to establish KCBPs would seem little threat, and keepers can establish viable CBPs of increasingly threatened species before they reach a critical population in nature.

Unfortunately, 25% of amphibian species are found only in unprotected and mostly modified habitats (Nori *et al.*, 2015). The low support in other polities for legal trade may reflect the exploitation of local communities rather than the risk of species extinction. KCBPs could support the responsible harvesting of amphibians to both the benefit of local communities and biodiversity conservation. The provision of founders for KCBPs could include community education and training for habitat protection, and possibly eco- and scientific tourism. This is a far preferable scenario to current harvesting regimes where local suppliers are ruthlessly exploited in the supply chain. KCBPs could also work toward the protection and management of species´ habitats. Resources for amphibian CBPs are not equally divided globally and KCBPs may help address this deficiency through their international reach (Harding *et al*., 2015).

The recommended number of founders for CBPs is approximately 25 females and 25 males that must then establish populations of between 160 and 1000 to avoid loss of genetic variation (Schad, 2007). The use of cryopreserved sperm by storing the male genome, and particularly founders' genomes, can reduce the recommended CBP population to 25 or less females with most males being represented as cryopreserved sperm (Browne *et al*., 2011; Clulow & Clulow, 2016). The Amphibian Conservation Action Plan (Gascon et al., 2007) estimated the costs for a CBP for one amphibian species (without the benefit of sperm banking) as US$120,000 for two facilities, ongoing costs of US$70,000 a year, and a share in consultant fees and training workshops of US$200,000. Keeper expertise in amphibian CBPs, supported by their strong social networks, would negate the need for costly consultants and training workshops. The estimated cost of 5 keepers per species and 10 individuals per keeper are less than US$10,000 with many keepers willing to cover costs.

Examples of KCBPs exist for many other vertebrate orders, including CBPs within government co-operative breeding programs (AFA, 2015), and the Turtle Survival Alliance (TSA, 2015), and especially for birds with their extensive history in private collections such as those of the American Federation of Aviculture (AFA, 2017). KCBPs need to exchange individuals to comply with studbook requirements, and for importation of founders, and international trade agreements such as CITES must include regulations assisting the cross-border transport of amphibians for KCBPs (Conde *et al*., 2013).

Major differences between western and other polities were shown in respondent age of first interest and average age. A major peak in respondent age in western polities corresponded with those born in western polities from 1964 to 1970 a period of high environmental concern. The age of first interest of late childhood was much lower in western than in other polities

where the age corresponded to formative education. Other polities showed a greater awareness and concern for the threat of climate change, and almost doubled the percentage of respondents in western polities with a close and best friends interested in amphibians. Our survey analysis and literature searches did not rigorously compare the many possible relationship between respondent demographics and cultural factors. Further investigation of the cultural influences affecting public interest, and especially influential individual interest and motivation, is critical to the conservation of amphibians in the longer term (Mccallum & Bury, 2013, data base supplied for further analysis).

One of the greatest benefits of KCBPs may be in addressing the sharp decline in public interest in biodiversity conservation and the environment (Dalisay *et al*., 2012; Mccallum & Bury, 2013). KCBPs can increase public interest, encourage positive perspectives, and help achieve political goals and engagement through direct and indirect social contacts, based on media literacy expressed through news sources that show the value of KCBPs to the average citizen (Cooper, 2011). The decline in adolescent's interest in environmental activities (Wray-Lake *et al*., 2010) shows a need to focus on youth as the upcoming generation of environmentalists. The reasons chosen by our respondents for their first interest in amphibians, along with other surveys (Wray-Lake *et al*., 2010; Mccallum & Bury, 2013), provide a foundation for ongoing surveys to reveal current attitudes and trends over time.

To reverse cultural alienation from environmental causes (Gruenewald, 2004; Young *et al*., 2014), KCBPs present inclusive strategies that are effective, self-motivated, satisfying, and therefore welcoming to public understanding and support (Cooper, 2011; Mccallum & Bury, 2013). The dominating interests of many lobby groups and elites are increasingly excluding average citizens from decision making and therefore the benefits of official policies (Matthes *et al*., 2010; Gillens & Page, 2014). Conservation initiatives have to be careful that they work with a democratic and inclusive framework. Many organizations including the AArk and Amphibian Survival Alliance are moving toward this direction and is adopting increasingly cost effective and democratic Internet portals for program management. These portals could easily be extended to support KCBPs managed by their societies as affiliated but independent entities.

A recognition of dis-empowerment was overwhelmingly voiced by most respondents from the generally highly biodiverse non-English speaking other countries, perhaps due to most amphibian conservation policy makers being based in English speaking countries. Disempowerment of non-English speaking countries also included Europe in general, and particularly Germany and Russia, as globally recognized pioneers and achievers in amphibian conservation husbandry and breeding (Zeigler, 2011; Bagaturov *et al*., 2014; Zeigler *et al*., 2016). To help address this deficiency, globally directed media including internet sites that concern concerning KCBPs should at least be published in the major global languages.

Dicks *et al*. (2014) recommend a transparent process for incorporating evidence into policy decisions, where the process of evidence synopsis with expert evaluation provides a clear evidence audit trail, allows rapid response to new policy contexts, and clarifies sources of uncertainty (Guston, 2000). These are currently missing in the formation of some conservation policy where decisions are often underlain by the attitudes and interests of a few peer groups (Campbell, 2012). Any policies concerning KCBPs should embrace keepers globally and democratically in decision making (Carrillo *et al*., 2015) and include the official recognition of KCBPs.

Conclusion

A global network of KCBPs, managed by their societies could economically save many hundreds of amphibian species from extinction and reduce harvesting pressures on natural populations. Social networks of keepers along with public engagement will help address the declining public interest in conservation and environmental issues and provide a wide range of expertise for policy development. The facilitation of KCBPs must be included into CITES regulations to enable the transport and exchange of listed amphibians. Policies and management plans for KCBPs should be canvassed through the amphibian conservation community for discussion and review to encourage innovative and entrepreneurial approaches to amphibian conservation.

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Appendix1. *Some amphibian species in private keepers collections, their IUCN Redlist category as Critically Endangered (CR) Endangered (EN) Vulnerable (VU) Near Threatened (NT) Locally Common (LC) and Not Assessed (NA), approximate number in captivity, whether captive bred, domestic strains, and comments. Species sorted by Redlist category, the order as anuran (frogs and toads) or caudata (salamander sand newts). * = caudata. Note. "No. captivity" means the estimated stable quantity of adult specimens of each species in known collections (via scientific publications and press, Internet (forums, social networks etc). Species once entered hobby and then was lost as well as very common species with no protection status didn't covered.*

Scientific name	CITES, Appendix No.	No captivity	Captive bred	Domestic strains	Comments
Critically Endangered					
Agalychnis lemur [aka *Hylomantis* [was previously described in the genus *Phyllomedusa*]		50+	Y	Y	Privates mostly in Europe and few zoos in Americas. Ex-situ CBP established. Species is urgent need of high level protection but erroneously no CITES listed unlike some

					other un-threatened species.
Agalychnis spurrelli	II	20+	Y	N	Likely privates only
Mantella aurantiaca	II	?	Y	N	Privates and some zoos
Mantella madagascariensis	II	?	Y	N	Privates mostly
Mantella milotympanum	II	?	?		Privates and zoos
Minyobates steyermarki	II	?	Y	N	Privates
Oophaga lehmanni	II	?	?	N	Likely privates only. Several morphs readily available.
Peltophryne lemur		10+	Y	N	Privates and zoos
Xenopus longipes		30+	N	N	Zoos
**Ambystoma mexicanum*	II	100+	Y	Y	CBP at many private collections and scientific organizations mostly as neothenic form (Axolotl) – possibly the most successful caudated captive culture used as laboratory animal. Strains and genetic of captive populations are not maintained, possibly hybridized.
**Ambystoma andersoni*			F1 and F2	Y	Axolotl Suisse
**Andrias davidianus*	I	12,000,000	Y	Y	Large scale aquaculture program in Peoples Republic of China. Only sole breeding case known by private (Germany) and СИЗ created by EAZA (Bagaturov, in prep.)
**Neurergus kaiseri*	I	3000	Y	N	Mostly kept and bred by privates and some zoos. One of the most successful caudated amphibian species in captivity. Quite popular pet trade object. It is erroneously included in CITES due to that fact possibly disappeared from captivity and sooner became extinct (Bagaturov, in prep.).
**N. derjugini*		10	Y	N	Both subspecies by privates
* *Paradactylodon (Afghanodon) mustersi*		Less than 10	Y	N	Privates only, possibly not in captivity at a time
Endangered					
Agalychnis annae	II	100+	Y	Y	Privates
Bombina pachypus		20+	Y	N	Privates
Epipedobates tricolor	II	100+	Y	Y	Privates mostly
Excidobates mysteriosus	II	?	Y	N	Privates and a very few zoos
Hyloxalus azureiventris	II	?	Y	N	Offered by Understory Enterprises (based Canada). **Note**. Cites record is under name *Cryptophyllobates azureiventris* (syn.)
Gastrotheca riobambae		20+	Y	N	Privates
Hyperolius puncticulatus		200+	Y	Y	Privates, Kiev zoo, some other zoos
Leptopelis vermiculatus		50+	Y	N	Privates and a very few zoos
Phyllobates terribilis	II	500+	Y	Y	Privates, zoos. Very successful

					captive established species. CITES inclusion may cause a negative impact within some time.
Phyllobates vittatus	II	100+	Y	N	Privates mostly. Very successful captive established species. CITES inclusion may cause a negative impact within some time.
Ranitomeya summersi	II	30+	Y	N	CITES treated as subpopulations of *Dendrobates fantasticus*
Mantella crocea	II	20+	Y	N	Privates mostly. Offered by Understory Enterprises (based Canada)
Mantella expectata	II	20+	Y	N	Privates mostly. Offered by Understory Enterprises (based Canada)
Mantella viridis	II	20+	Y	N	Privates mostly. Offered by Understory Enterprises (based Canada)
Theloderma bicolor		30+	Y	Y	Mostly Privates
**Cynop ensicauda*		?	Y	N	Privates mostly. Both subspecies are available, both bred
**Paramesotriton guangxiensis*		20+	Y	N	Likely privates only
**Ranodon sibiricus*		10	N	N	CBP maintains with participation of Moscow zoo
		20+	Y	N	Likely privates only
**Hynobius dunni*		10+	Y	N	Likely privates only
**Hynobius tokyoensis*		30+	Y	N	Likely privates only
**Echinotriton andersoni*		20+	Y	N	Likely privates only
Vulnerable					
Alytes muletensis		100+	Y	Y	In zoos and Privates
Atelopus flavescens		20+	Y	N	Privates and zoos
Atelopus spumarius		30+	Y	N	Privates and zoos. A few successful breedings reported but unlikely offspring rose to adulthood successfully (for both subspecies (or forms): *A. s. hoogmoedi and A.s. barbotini*.)
Calyptocephalella gayi		50+ (1000+)	Y	N	Privates
Ceratophrys stolzmanni		20+	Y	N	Privates mostly, originated from farm bred specimens exported by WIKIRI Selva Viva (Ecuador)
Oophaga granulifera		?	Y	N	Privates
Ranitomeya benedicta	II	?	Y	N	Privates mostly. Offered by Understory Enterprises (based Canada)
Mantella pulchra		20+	Y	N	Privates, Zoos?
Rhacophorus annamensis		10+	Y	N	Privates, Riga zoo, Leningrad zoo (past)
Bombina microdeladigitora/ maxima		20+	Y	N	Privates and zoos
**Mertensiella*		Less than 10	N	N	Raised from larvae, CBP with

caucasica					participation of Moscow Zoo together with Tbilisi zoo (Rep of Georgia)
**Neurergus crocatus*		Circa 10	Y	N	Privates, originated from Iranian population
**Neurergus strauchii*		Circa 10	Y	N	Privates, both subspecies bred
**Pachyhynobius shangchengensis*		10+	Y	N	Kept and bred (several cases known) by privates mostly
**Paramesotriton deloustali*		?	Y	N	Privates
**Tylototriton wenxianensis*		20+	Y	N	Privates
**Tylototriton kweichowensis*		50+	Y	N	Privates only
**Salamandra algira*		10+	Y	N	Privates only
**Salamandra lanzai*		10	Y	N	Privates only
**Pleurodeles nebulosus*		10+	Y	N	Privates only
Scaphiophryne marmorata		50+	Y	N	Likely privates mostly. Regularly exported from Madagascar
Near Threatened					
Bufo verrucosissimus		20+	Y	N	Likely privates only
Ceratophrys ornata		1000+	Y	Y	Traditional object of zoo trade and display
Dyscophus antongilii	I	30-40	Y	Y	Bred for decades, CBP by Moscow zoo
Epipedobates anthonyi	II	50+	Y	Y	Privates mostly
Phyllobates bicolor	II	50+	Y	Y	Privates and zoos
Ranitomeya fantastica	II	?	Y	?	Offered by Understory Enterprises (based Canada) farm bred juveniles. CITES listed as *Dendrobates fantasticus*
Ameerega bassleri	II	?	Y	N	Offered by Understory Enterprises (based Canada)
Oophaga sylvatica		30+	Y	N	Privates mostly, originated from farm bred specimens exported by WIKIRI Selva Viva (Ecuador)
Hyalinobatrachium aureoguttatum		20+	Y	N	Privates mostly, originated from farm bred specimens exported by WIKIRI Selva Viva (Ecuador)
Pseudepidalea brongersmai		100+	Y	N	Zoos and privates
**Paramesotriton hongkongensis*		20+	Y	N	Privates only
Rhacophoru sreinwardtii		?	Y	Y	Privates and zoos, Object of active zoo-trade
Theloderma (Nyctixalus) pictum		60+	Y	Y	Privates, Chester Zoo, Cologne zoo, Moscow University
Theloderma stellatum		100+	Y	Y	Privates mostly
Theloderma vietnamensis		100	Y	N	Privates and zoos
**Triturus dobrogicus*		50+	Y	N	Privates only
* *Tylototriton (Liangshantriton) taliangensis*		20+	Y	N	Privates only
**Tylototriton*		20+	Y	N	Privates only

asperrimus					
**Tylototriton shanjing*		30+	Y	N	Privates only
**Ommatotriton ophryticus*		20+	Y	N	Likely privates only
**Triturus pygmaeus*		50+	Y	N	Likely privates only
**Salamandra infraimmaculata*		10+	Y	N	Likely privates only
**Bolitoglossa platydactyla*		10	N	N	Kept in few private collections
**Pleurodeles waltl*		500+	Y	Y	Privates and zoos. Common laboratory animal, enter the captivity long ago.
**Pleurodeles poireti*		50+	Y	N	Privates and zoos. Previously not recognized and used to kept and bred under "*P. waltl*" name
**Calotriton asper*		29	Y	N	Likely privates only
**Speleomantes strinatii*		10+	Y	N	Likely privates only
Scaphiophryne madagascariensis		50+	Y	N	Likely privates mostly. Regularly exported from Madagascar.
Least Concern					
Agalychnis callidryas	II	100+	Y	Y	Privates and zoos. Quite popular pet trade object (erroneously included in CITES).
Agalychnis (Pachymedusa) dacnicolor		30+	N	N	Last time available WC subadult-adult specimens
Cruziohyla calcarifer		20+	Y	N	Likely privates only. originated from farm bred specimens exported by Costa Rican Amphibian Research Center
Cruziohyla craspedopus		20^{+}	Y	N	Likely privates only
Cochranella granulosa		30+	Y	N	Likely privates only
Hypsiboas picturatus		?	Y	N	Likely privates only. Originated from farm bred specimens exported by WIKIRI Selva Viva (Ecuador)
Adelphobates galactonotus	II	100+	Y	N	Privates and zoos. Several morphs readily available.
Ameerega hahneli	II	?	Y	N	Privates mostly. Offered by Understory Enterprises (based Canada)
Ameerega trivittata	II	?	Y	N	Privates mostly. Offered by Understory Enterprises (based Canada)
Dendrobates auratus	II	100+	Y	N	Privates and zoos. Several morphs readily available.
Dendrobates tinctorius	II	100+	Y	Y	Privates and zoos. Several morphs readily available.
Dendrobates truncatus	II	40+	Y	N	Privates
Dendrobates leucomelas	II	100+	Y	N	Privates and zoos
Oophaga pumilio	II	100+	Y	Y	Privates and zoos. Quite popular pet trade object (erroneously included in CITES). Several morphs readily available.
Oophaga histrionica	II	100+	Y	N	Privates mostly. Different

					geographical morphs are available.
Ranitomeya flavovittata		30+	Y	N	Privates mostly. Offered by Understory Enterprises (based Canada)
Ranitomeya imitator		60+	Y	N	Privates mostly. Several morphs readily available. Offered by Understory Enterprises (based Canada)
Ranitomeya lamasi	II	50+	Y	N	Privates mostly. CITES listed as *Ranitomeya sirensis* (which has *En* status)
Ranitomeya reticulata		50+	Y	N	Privates mostly. Offered by Understory Enterprises (based Canada)
Ranitomeya uakarii		30+	Y	N	Privates mostly. Offered by Understory Enterprises (based Canada)
Mantella betsileo	II	20+	Y	N	Likely privates only. Offered by Understory Enterprises (based Canada)
**Ambystoma maculatum*		10+	N	N	Privates
**A. opacum*		10+	N	Y	Privates
**Laotriton laoensis*		6-7	Y	N	Privates
Megophrys nasuta		30+	Y	N	Privates and some zoos
**Paramesotriton chinensis*		100+	Y	N	Privates mostly
**Salamandrella keyserlingii*		50-60	Y	N	Mostly F1, Likely only privates
**Salamandra salamandra*		100+	Y	Y	Privates and zoos
**Theloderma asperum*		100+	Y	N	Privates and few zoos
**Triturus cristatus*		50+	Y	N	Mostly privates
**Triturus karelini*		50+	Y	N	Mostly privates
**Tylototriton verrucosus*		100+	Y	N	Privates and zoos. Shall be noted that under the name "*T. verrucosus*" several recognized species are presented in captivity (at least *T. shanorum*, *T. verrucosus* and *T. uyenoi*)
**Ichthyosaura alpestris*		100+	Y	Y	Several subspecies bred and kept mostly by privates
**Triturus marmoratus*		100+	Y	N	Likely privates only
**Triturus carnifex*		50+	Y	Y	Likely privates only
**Ommatotriton vittatus*		30+	Y	N	Likely privates only
**Paramesotriton (Pachytriton) labiatus*		50+	Y	N	Likely privates only
**Cynops pyrrhogaster* (incl. *C. sasayamae*)		100+	Y	N	Likely privates only
**Hypselotriton orientalis*		100+	Y	Y	Traditionally most popular caudated amphibian species at pet market
**Amphiuma tridactylum*		30+	N	N	Mostly privates
**Siren lacertian*		10+	N	N	Privates and zoos
**Siren intermedia*		10+	Y	N	Privates and zoos
**Lissotriton montandoni*		50+	Y	N	Likely privates only
**Hynobius retardatus*		20+	Y	N	Likely privates only
**Hynobius tsuensis*		10+	Y	N	Likely privates only
**Hynobius naevius*		20+	Y	N	Likely privates only
**Lissotriton helveticus*		50+	Y	N	Likely privates only

**Euproctus montanus*		30+	Y	N	Likely privates only
**Taricha granulosa*		30+	Y	N	Likely privates only
**Taricha rivularis*		10+	Y	N	Likely privates only
**Necturus maculosus*		30+	Y	N	Likely privates only, possibly zoos in Americas (USA, Canada)
**Pseudotriton ruber*		30+	Y	N	Likely privates only
**Gyrinophilus porphyriticus*		20+	Y	N	Likely privates only
**Eurycea bislineata*		20+	Y	N	Likely privates only
**Eurycea longicauda*		20+	Y	N	Likely privates only
**Plethodon cinereus*		20+	Y	N	Likely privates only
**Aneides lugubris*		20+	Y	N	Likely privates only
**Desmognathus carolinensis*		20+	Y	N	Likely privates only
Anotheca spinosa		40+	Y	N	Privates and zoos
Triprion petasatus		30+	Y	N	Privates and zoos
Lepidobatrachus laevis		50+	Y	N	Privates and zoos
Peltophryne peltocephala		10+	Y	N	Privates and zoos in Russia
Hyalinobatrachium valerioi		?	Y	N	Offered by Understory Enterprises (based Canada)
Melanophryniscus stelzneri		?	Y	N	Privates and some zoos
Melanophryniscus klappenbachi		?	Y	N	Privates mostly
Not Assessed					
Polypedates dennysii		50-60	Y	N	Privates, zoos
Polypedates feae		30-40	Y	N	Privates, Leningrad zoo (past)
**Ambystoma marvortium*		10	Y	N	Privates
Theloderma ryabovi		10+	Y	N	Privates only
**Tylototriton yangi*		50+	Y	N	Privates
**Hypselotriton cyanurus* (incl. *H. yunnanensis*)		20+	Y	N	Likely privates only
**Notophtalmus viridescens*		200+	Y	N	At least 1 subspecies (nominotypical) kept and bred by privates
**Onychodactylus koreanus*		10+	Y	N	Likely privates only
** Hynobius quelpaertensis*		40+	Y	N	Likely privates only
**Hynobius hirosei*		10	Y	N	Likely privates only
**Tylototriton lizhenchangi*		Less than 10	N	N	Privates only. Note. It was presented in captivity before under the name "*T. asperrimus*" or "*T. wenxianensis*"
Ranitomeya vanzolini		50+	Y	N	Likely privates only. Offered by Understory Enterprises (based Canada)
Ranitomeya variabilis	II	50+	Y	N	Listed as Data Deficient by IUCN although reason for the inclusion into CITES is unknown. Several morphs readily available.
Anitomeya ventrimaculata		100+	Y	N	Mostly privates.

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