Review

The future of keeping pet reptiles and amphibians: towards integrating animal welfare, human health and environmental sustainability

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Abstract

The keeping of exotic pets is currently under debate and governments of several countries are increasingly exploring the regulation, or even the banning, of exotic pet keeping. Major concerns are issues of public health and safety, animal welfare and biodiversity conservation. The keeping of reptiles and amphibians in captivity encompasses all the potential issues identified with keeping exotic pets, and many of those relating to traditional domestic pets. Within the context of risks posed by pets in general, we argue for the responsible and sustainable keeping of reptile and amphibian pets by private persons, based on scientific evidence and on our own expertise (veterinary medicine, captive husbandry, conservation biology).

Key words: reptile; amphibian; pet; welfare; health

Introduction

Humans sought the companionship of animals even before practicing agriculture. Dog and horse domestication are estimated to have occurred between 11,000-16,000 years and 5,500 years before present (Orlando and others 2013, Freedman and others 2014, Schubert and others 2014). The number of pet animals kept in the European Union is estimated at over 240 million (Schuppli and others 2014). Depending on the country, the number of exotic pets (here defined broadly as all animals kept as companion animals excluding dogs, cats and horses) now makes up between 34% to 64% of the pet population (Schuppli and others 2014). The keeping and trading of exotic companion animals is controversial due to issues concerning animal welfare, public health and conservation. Here we analyse arguments for and against the trade in - and keeping of - reptiles and amphibians, with suggestions to improve welfare and sustainability.

Benefits for human health and animal conservation

The keeping of companion animals provides clear benefits for human wellbeing. Indeed, keeping pets promotes psychological, physiological and social health and development (Wells 2007, 2009, Smith 2012). Beneficial effects are not limited to pets with high interactive value (e.g. dogs); even the keeping of non- or poorly- interactive animals, such as fish, has been shown to improve the keeper's overall health (Whiteford 1997, Langfield and James 2009). Nevertheless, other studies have failed to corroborate these positive effects, and in some cases even demonstrate a negative effect (Herzog 2011). A further positive aspect of keeping reptiles and amphibians lies in connecting people with these animals and the potential for public education, nurturing interest and dispelling prejudice. Interviews with prominent European herpetologists in academia or museums show that

keeping of herpetofauna during childhood fueled their interest in many cases (a.o. F. Andreone, W. Böhme, R. Griffiths, E. Lehr, S. Lötters, G. Nilson, M.O. Rödel, P. Uetz, M. Vences, W. Wüster, T. Ziegler; Li Vigni, 2013). Although IUCN ex situ management guidelines indicate that it is unlikely that animals from the private sector can be used for reintroduction, the expertise and capacity available from hobbyists is a potentially valuable resource to support ex situ captive breeding projects (identified as one of the few measures currently available to counteract the current global amphibian declines crisis) (Gascon and others 2007, Tapley and others 2015). Also, amphibians captive bred by hobbyists and made available for research purposes have greatly facilitated our understanding of the epidemiology of emerging diseases (Martel and others 2013, Martel and others 2014). Research led by hobbyists has on occasion led to pivotal contributions to the knowledge of reptiles and amphibians and even the publication of standard reference literature (e.g. Sparreboom 2014). Consequently, potential benefits of keeping reptiles and amphibians reach into broad areas relating to human health, science and education.

Human wellbeing and public health risk

Companion animals, including reptiles and amphibians, can potentially adversely affect human health by inflicting trauma, transmitting infectious diseases (zoonoses) or provoking allergic responses. The avoidance of medical treatment and any grief due to loss of a pet have also been shown to negatively impact human health and wellbeing (Smith 2012). In this section, we present an overview of the known health risks of keeping reptiles and amphibians.

Trauma: There are relatively few published reports of a pet reptile or amphibian inflicting trauma on the owner. Bites from large lizards have been reported most consistently, with the number of green iguana *(Iguana iguana)* bite injuries treated in emergency departments in the USA being estimated at 810 per year (Langley and others 2014). Green

iguanas are large lizards and one of the most widely kept pet reptiles in the USA and Europe. Traumatic injuries caused by other reptiles have been reported sporadically, including rare cases of death inflicted by large snakes such as pythons or large crocodilians (Wolf and Harding 2014).

Poisoning: The risk of being poisoned by a pet reptile or amphibian is a function of the presence of toxins and an effective delivery mechanism (e.g. fangs dedicated to envenomation). There is a large body of literature describing envenomation by snakes (including lethal incidents). Such cases tend to attract media attention. A lack of discrimination between reports of cases involving wild or pet animals sometimes hampers attribution to pet snakes (Langley and others 2014), but Schaper and others (2009) reported few cases of envenomation by pet snakes (approximately 16 across four European poison centers per year), although this may be an underestimate (Warrell 2005). We found no evidence of a significant health risk due to poisoning by amphibians kept as pets. Although three of the 185 known species of poison dart frogs (Dendrobatidae) are among the most toxic animals on earth, their skin toxins are mainly sequestered from arthropod food items in nature (Daly and others 2002). The frogs therefore lose much of their toxicity in captivity. Human deaths from amphibian poisoning have been reported occasionally, but these have followed ingestion of skin or skin extracts and have not been related to pet keeping (Bradley and Klika 1981, Hitt and Ettinger 1986, Gowda and others 2003).

Zoonoses and allergies: Pet reptiles and amphibians are potential reservoirs of several zoonotic (mainly viral, bacterial and parasitic) agents (reviewed in Johnson-Delaney 2006). Reptiles probably help maintaining infection cycles of West Nile Virus (crocodylians) and Eastern Equine Encephalitis virus (wild reptiles). Ecto- and endoparasites may directly affect human health or indirectly as vectors of, for example, Q fever and lyme disease, although reports confirming transmission to humans from reptile or amphibian parasites are lacking.

One of the most important zoonoses from amphibians is sparganosis, though this is typically associated with consumption of raw meat or use of raw parts in traditional medicine. Although a large number of potentially zoonotic bacteria haven been identified in reptiles and amphibians, the paucity of published reports on proven transmission to humans means that most bacterial zoonoses contracted from pet reptiles and amphibians represent rare cases, with a low overall disease burden for humans. The notable exceptions are *Salmonella* spp., which are well known to pose a significant health risk (Damborg and others 2016). Interestingly, the prevalence of *Salmonella* infection in wild-caught pet reptiles and amphibians appears to increase with time in captivity (Pfleger and others 2003). Some reptile- and amphibian-borne *Salmonella* spp. have the potential to cause severe infections, especially in young children. A significant number of cases of human salmonellosis are attributed to these pets: 0.95% of *Salmonella* cases in the UK (Aiken and others 2010) and 6% of sporadic *Salmonella* infections in the USA (i.e. not including outbreaks of salmonellosis) (Mermin and others 2004). However, this needs to be placed in context, as the vast majority of infections in humans are caused by foodborne *Salmonella*. To minimize infection from amphibians and reptiles, handling and hygiene guidelines for veterinarians and the public have been developed by the Association of Reptilian and Amphibian Veterinarians (ARAV 2017). Raising public awareness and applying basic personal and household hygiene (e.g. proper hand washing, keeping any reptile or material used for reptile care separate from food preparation areas) should prevent most cases of reptile associated salmonellosis. If children keep these animals, adult carers need to ensure high standards of husbandry and personal hygiene (Pierce 2017).

Allergic responses have been anecdotally reported for reptiles (Dutau and Rance 2009). Since insects are widely used as reptile and amphibian food items, keepers may be exposed to potential insect allergens (Jensen-Jarolim and others 2015).

Societal acceptance: The level of potential risk to human health that is acceptable requires a risk-benefit analysis. Keeping a pet is a lifestyle choice made by the owner with the aim of bringing benefits, and few owners are impacted negatively. Context can be provided by the domestic dog, which has had a relationship with humans for 11,000 - 16,000 years (Freedman and others 2014) and which numbers approximately 70 million in North America and 74 million in western Europe (Schuppli and others 2014). Attitudes to dogs could serve as a measure of the risk society is willing to accept for animal companionship. Estimates of the annual incidence of dog bites in western Europe and the USA are between 1.07 and 8.3 per 1000 population (Cornelissen and Hopster 2010, Quirk 2012) and up to 22 bites per 1000 children (De Keuster and others 2006). Although some of the most lethal infectious agents such as canine rabies have been successfully eliminated from the domestic dog populations in many countries, between 3% and 18% of dog bites become infected (Talan and others 1999) with bacteria, occasionally with lethal results (Butler 2015). Zoonotic infection from dogs (and cats) is of special concern, given their frequent and intimate contact with humans (Pierce 2017). Asthmatics who are allergic to dogs but continue to live with their pet result in an estimated additional 0.25 to 0.5 billion dollars to annual healthcare costs in the US alone (Ownby 2010). An estimated 86,629 tripping injuries have been associated with cats and dogs yearly in the USA, with the highest injury rates in persons 75 years and older (Steven and others 2010).

Thus, the keeping of conventional pets such as dogs results in a significant health burden on society, yet, it is deemed acceptable, and indeed, beneficial.

Animal health and welfare risk

Keeping a companion animal should ideally enhance – and certainly not jeopardize - its welfare (Schuppli and Fraser 2000). Here, we consider welfare in terms of the "five

freedoms" (Farm Animal Welfare Council 1979): 1) freedom from hunger and thirst, 2) freedom from discomfort 3) freedom from pain, injury or disease 4) freedom to express normal behaviour and 5) freedom from fear and distress. These freedoms can be assured if conditions for optimal nutrition, environment, health and behaviour are provided to assure optimal physical and mental state (Mellor and Stafford 2001); principles that can be widely applied to any animal under human care. However, in contrast to many well-recognized pets, the physical, mental and behavioural demands of amphibians and reptiles usually do not depend on interactions with the owner, but are met by providing an optimal environment, nutrition and, if relevant, compatible cage mates. This would imply that taxon-specific husbandry standards should be adopted to ensure optimal welfare (Michaels and others 2014).

Husbandry and nutrition: Although enforceable husbandry standards for reptiles and amphibians (and most pets!) are largely lacking in most countries (in contrast to animals used for research purposes or, in some countries, zoo animals), an easily accessible, extensive and ever-increasing body of literature is available with regard to husbandry of most species kept as pets. For example, an extensive database of husbandry standards is available from the German society (Deutsche Gesellschaft für Herpetologie und Terrarienkunde, DGHT 1997). This has resulted in many very knowledgeable reptile / amphibian keepers who are capable of successfully keeping and breeding a wide variety of species. Indeed, a complete industry, estimated to be worth between $56.5 – $70.5 million in the USA in 2009, has been built around reptile and amphibian nutrition and husbandry to meet the needs of most species regularly kept in captivity (Collis and Fenili 2011). Nevertheless, this same industry may still occasionally misinform customers, an example being the dried crustaceans (*Gammarus*) that are widely advocated as staple food for terrapins.

Nevertheless, there remain considerable welfare problems associated with captive reptiles and amphibians, particularly among novice keepers. Any veterinarian with a

substantial reptile keeper clientele will probably confirm that husbandry and nutrition related problems are common. For example, 142 out of 671 (21%) lizards and chelonians presented for examination at the clinic for exotic pets at Ghent University in 2013 exhibited clinical signs of metabolic bone disease (MBD, T. Hellebuyck, F. Pasmans, A. Martel, unpublished results). MBD is a calcification disorder, most often resulting from an imbalanced diet and/or lack of proper UV lighting and illustrates a lack of basic knowledge concerning nutrition and husbandry. Advances in knowledge and animal welfare, however, are being made in this area (e.g. Baines and others 2016). Species vary in their "suitability" as pets (as defined by Schuppli and Fraser 2000), with some species requiring highly-specific nutritional and/or husbandry methods (e.g. the largely ant-eating lizards of the genus *Phrynosoma*). Many herpetological societies (such as the DGHT in Germany) offer training in captive husbandry and even provide certificates of aptitude (SKN 1995). Unfortunately, an increasing number of keepers are not affiliated with such organizations and rely on self-education, often based on questionable information obtained from the internet and social media. Another growing trend is the breeding of unusual colour morphs, which are being produced for an increasing number of species, often with high commercial value (Tapley and others 2011). The breeding of these morphological variants increases the risk of inbreeding depression and possible disease risks, an example being the susceptibility of 'designer' leopard geckoes (*Eublepharis macularius*) to cryptosporidiosis (Deming and others 2008). The need for enriched and stimulating environments is often underestimated (reviewed in Burghardt 2013). One important aspect that sets aside reptiles, amphibians and many other pets from, for example, free-roaming dogs, is the burden of captivity and confinement. Amphibians and reptiles have pronounced abilities to learn, show (socially) complex and (for reptiles) even playing behaviour and the potential of emotional experience. The use of barren, yet functional cages as often used for example in snake or gecko breeding facilities, should not be advocated, and efforts to produce an

"ethologically informed design" encouraged. Proper enrichment should facilitate expression of normal behavioural repertoire (including hunting, although the feeding of live mammals is controversial in itself), reproduction and development of normal phenotypes. Since important aspects such as predator avoidance are absent, at best, enrichment will result in "controlled deprivation" (Burghardt 2013).

Veterinary care: Arguments that veterinary care for reptiles and amphibians lags behind that for other companion animal species are losing currency. Exotic pet medicine is now included in the curricula of most Western veterinary schools and "herpetology" veterinary specialisms are being increasingly developed and recognized; e.g. the European College of Zoological Medicine's (ECZM) herpetology specialty. Veterinary postgraduate training is offered in several countries (e.g. in Germany: Zusatzqualifikation Reptilien und Amphibien) and specialist training in herpetological medicine is provided by the ECZM. Unfortunately, many amphibian and reptile keepers do not consult the veterinary profession. This is possibly because of difficulties in locating a veterinarian with the appropriate expertise, and/or the perceived high costs of veterinary treatment.

Trade: Many species lead healthy lives in captivity if provided with the right conditions (including proper veterinary care; Pasmans and others 2008), and mortality rates in the home may be relatively low (Robinson and others 2015). Nevertheless, poor treatment and animal cruelty do occur in the animal trade (e.g. Ashley and others 2014). Reports of such incidents are rare in relation to the total numbers transported around the world (Robinson and others 2015). However, wild-caught reptiles and amphibians often are transported in bulk and may endure crowding and stress prior to and during transit; conditions which also are conducive to the transmission of infectious diseases and trauma. High standards of animal welfare are therefore needed throughout the commercial chain (Baker and others 2013). For some species of wild-caught reptile and amphibian, high volumes of animals are traded and

this practice can negatively affect both animal welfare and conservation. For example, there has been a large international trade in Chinese fire-bellied newts (*Hypselotriton orientalis*) with more than 2 million imported into the USA over a 10 year period (Herrel and van der Meijden 2014). These newts are sold at low prices, ranging from 5-15 Euros and often destined for tropical aquaria (or, worse, garden ponds), which are unsuitable for this species. Due to the mass availability and low price of such species, few hobbyists breed them, thus sustaining a wildlife trade which may negatively impact wild populations. The wide variety of species currently kept and successfully bred in captivity should render the importation of wild-caught specimens largely redundant. Commercial availability of wild-caught specimens is justified only if they are procured from a sustainable and legal source, preferably with conservation benefits for their wild populations and habitats. Equally, there should be a tangible benefit to local communities (Hutton and Leader-Williams 2003, Roe 2008). Consumers therefore need to understand the potential implications for conservation, welfare and animal health of purchasing wildcaught animals (Moorhouse and others, 2017).

To put the issue in perspective, inadequate husbandry and nutrition underlie a plethora of highly prevalent diseases in many taxonomic groups of companion animals. According to the Association for Pet Obesity Prevention, more than half of all dogs and cats in US households are obese (Pierce 2017). An estimated 25-50 percent of cats and dogs in the USA never visit a veterinarian in their entire life (Pierce 2017). Emotional neglect is a widespread concern for dogs (Pierce 2017), which by the very process of domestication have come to accept humans as companions, requiring intensive interaction especially in the absence of conspecifics. There is no evidence that reptiles or amphibians are disproportionately affected by health and welfare issues compared to other species kept as pets.

Ecological health risk

The keeping of reptiles and amphibians can potentially impact ecological health through the reduction of wild populations collected for the pet trade, the introduction and establishment of invasive alien species from escaped or deliberately released animals and/or by the introduction of diseases to new geographic regions and, hence, to native wildlife.

Overexploitation: Bush and others (2014) demonstrated that reptile species threatened with extinction (according to the International Union for Conservation of Nature) are more likely to be traded as pets than common species. The European Union imported over 20 million reptiles between 2004 – 2014, many of which have been illegally traded and most probably suffer from severe overexploitation (Auliya and others 2016a). There are several examples where the capture of reptiles and amphibians from the wild for the pet market is known to compromise the survival of wild populations. Collection from populations of newly discovered and attractive species has even led to calls no longer to provide locality details in scientific publications (Stuart and others 2014, Lindenmayer and Scheele 2017). For many species, reliable estimates of natural population sizes do not exist, yet they are exploited in large numbers. Striking examples are species that appear in the pet trade even before they have been described scientifically, such as several species of monitor lizard (e.g. *Varanus melinus* (Böhme and Ziegler 1997)). An additional problem is that many species (for example, several newt species of the genus *Tylototriton*) are illegally exported from their country of origin (e.g. People's Republic of China) despite national or regional protection (Auliya and others 2016b). Once they have entered pet markets in the EU or the USA, these species are no longer protected by any legislation. The "laundering" of wild-caught specimens by fraudulently listing them as captive-bred or farm-bred is commonly deployed to circumvent both national and international (i.e. CITES) regulations and is a growing concern for species conservation (Lyons and Natusch 2011, Auliya and others 2016b).

Invasive alien species: Invasive alien species (IAS) pose a major threat to biodiversity. An estimated 480,000 species have been translocated by people to regions outside their natural ranges (Pimentel 2002), with over 12,000 alien species having been introduced to one or more European countries according to the project "Delivering Alien Invasive Species Inventories Europe" (DAISIE 2008). For herpetofauna, the pet trade provides the primary platform for invasions, with over 9 million reptiles imported in the USA between 2000 – 2004, belonging to at least 799 species, of which 89% were alien (Perry and Farmer 2011). Negative impacts of invasive species include: predation, competition, hybridization and pathogen pollution (Pilliod and others 2012). Although not all alien species cause harm, and many have been beneficial to humans, some may become agents of human-accelerated environmental change (Simberloff and others 2013). In the inventory of European alien species (DAISIE 2008), 13 amphibian and 32 reptile species are listed as introduced to Europe, although not all of these have become established with successfully reproducing populations. Notorious examples of invasive alien reptile and amphibian species in Europe arising from the international pet trade are the red-eared terrapin (*Trachemys scripta elegans*) and the North American bullfrog (*Lithobates catesbeianus*), both of which are on the "100 of the worst" list of DAISIE. The introduction of species that hybridize with native species may cause "genetic pollution" through introgression (e.g. hybridization of different species of green frog (*Pelophylax* sp.); Holsbeek and others 2010). The establishment success of invasive chelonians has recently been shown to be more associated with the number of release events, rather than the number of animals traded (Garcia-Diaz and others 2015). Accidental escapes may account for some of these cases, but deliberate releases, such as the release of red-eared terrapins when owners lose interest or when animals outgrow the aquarium and introduction into garden ponds (e.g. North American bullfrogs), are the most likely routes for escape into the wild. Attempts to mitigate the risk of IAS have included restrictions on the

importation of high risk species, e.g. through the banning by the European Union and Switzerland of the importation of red-eared terrapins and North American bullfrogs.

Pathogen pollution: Pathogen pollution occurs when there is anthropogenic spread of a pathogen across an ecological or geographical boundary into an area or species in which it has not naturally evolved (Cunningham and others 2003). The pet trade is an important source of pathogen pollution (Kolby and others 2014), including the introduction of ranavirus from North America to the UK (Hyatt and others 2000), the introduction of *Batrachochytrium salamandrivorans* to Europe (Martel and others 2014) and the introduction of *B. dendrobatidis* globally (Garner and others 2006). *B. dendrobatidis* has been identified as one of the most important causes of amphibian population declines and extinctions globally (Amphibian Conservation Summit 2005). Two amphibian species implicated in the global spread of *B. dendrobatidis* are the African clawed frog (*Xenopus laevis*) and the North American bullfrog; these species have been historically traded in huge numbers globally, mostly as food or laboratory animals. Both ranaviruses and *B. dendrobatidis* are listed by the World Organisation for Animal Health (OIE) and measures should be taken to ensure that amphibians are free of these agents prior to international trade. Veterinary expertise is required to help ensure captive amphibians are free of these and other infectious agents and that biosecurity measures are in place to minimize disease threats to captive and wild animals (Amphibian Disease Alert 1995). For reptiles, spillover of bacterial pathogens from captive animals to wild populations has been demonstrated for *Mycoplasma* associated upper respiratory tract disease in tortoises (*Gopherus* sp.) and turtles (*Terrapene* sp.) (Jacobson and others 1991, Brown and others 2001, Feldman and others 2006) and, very recently, *Devriesea agamarum* infections in threatened iguanids (Hellebuyck and others 2017). Captive reptiles constitute a large potential reservoir of pathogen pollution for many fungal (e.g. snake fungal

disease) and viral (e.g. arenaviruses) infections (Hetzel and others 2013, McBride and others 2015). However, the epidemiology of many of these diseases is poorly understood.

Livestock diseases: The introduction of wild-caught reptiles may carry risks of disease transmission to livestock, with potential impacts on animal production, through the introduction of ticks. Reptiles imported from Africa may import the tick reservoirs of pathogens such as *Cowdria ruminantium*, which causes heartwater disease in ruminants. This led to the US Department of Agriculture imposing a ban on the importation of several reptile species from Africa in 2000 (Burridge 2001). So far, however, there is no evidence that the importation of reptiles or amphibians into Europe has had any negative ramifications for livestock production.

Once again, the negative ecological impacts of keeping pet amphibians and reptiles should be placed in context, as the keeping of living creatures (and many plants) in human households poses many ecological risks. For example, domestic cats kill an estimated 1.3 - 4 billion birds and 6.3 – 22.3 billion mammals per year in the USA alone (Loss and others 2013). The sheer quantity of faeces produced by domestic dogs poses a significant environmental concern (Pierce 2017). An estimated 2.5 million tonnes of the 39 million tonnes of wild caught fish (a limited biological resource for overall human benefit) was used for cat food production in 2006 (De Silva and Turchini, 2008). Minimizing ecological risks associated with the keeping of reptiles, amphibians and other species should be included in national threat abatement plans based on thorough risk analysis.

Current measures in Europe

To mitigate the negative impacts of the keeping of reptiles and amphibians, several European states have legislation in place to regulate the keeping of exotic pets, often with emphasis on dangerous species (for an overview, see ENDCAP 2012). Some countries, such as France,

require proof of aptitude of the keeper (Arrête du 10 août 2004). A voluntary certificate of aptitude can be obtained in Germany (Sachkundenachweis, DGHT). Very recently, Switzerland, Canada and the USA temporarily suspended the importation of salamanders and newts to reduce the risk of *B. salamandrivorans* introduction. Most legislation either restricts importation of species (e.g. CITES legislation), imposes minimum requirements (e.g. requirements for pet shops selling reptiles and amphibians in Belgium, Royal Decree 27/4/2007) or prohibits the keeping of certain taxa, either formulated as a list of species that is allowed ("positive list", under consideration in Belgium) or as a list of prohibited species ("negative list", e.g. Norway). Current restrictions, however, are often poorly designed and based on reactions to single-issue lobby groups rather than evidence-based approaches. If restrictions on the keeping of specific taxa are put in place, these should be based on a risk assessment, considering cost-benefits for human health and wellbeing, animal welfare and ecological sustainability. The level of risk tolerated needs to be proportionate and comparable across different taxa. For example, the risks associated with dangerous dogs should not be down-played relative to dangerous snakes, simply because of public perceptions about the different taxa and the strength of lobbying by different interest groups. The assessment should therefore be based on scientific evidence, allowing objective classification of species and rigorous risk analyses (Schuppli and Fraser 2000, Schuppli and others 2014). This should preferentially be done at transnational level with adaptations to account for country specific threats because most issues related to animal and human health and wellbeing and to biodiversity conservation are similar in all countries. Such risk analyses should involve representatives of all stakeholders. For the veterinary profession, this would mean the involvement of organisations, such as the ECZM, which is approved by the European Board of Veterinary Specialisation and which includes recognised veterinary specialists in the matters of exotic pet and wildlife population health. Only then, decisions to implement taxon-

specific restrictions would justify the compilation of, for example, a list of species that cannot be kept privately unless specific requirements are met. The current lack of consistent risk analyses argues against such a course of action at this time. In Europe, the implementation of such lists will only be meaningful if this is done at the EU level, and only if sufficient resources are in place to allow monitoring and enforcement. Periodic evaluation of such a system is required in order to demonstrate effectiveness and beneficial outcomes.

Conclusions and recommendations

As with the keeping of other, more "traditional" pets, the keeping of reptiles and amphibians benefits society but brings with it concerns about animal welfare, human health and ecological sustainability (Table 1). Despite the wide availability of specialist information, care products and expert advice and veterinary care, inappropriate management and nutrition by inexperienced keepers remains a concern, particularly because of potentially misleading information available online. We do not, however, believe that keeping reptiles and amphibians presents a disproportionate burden on public health or animal welfare compared to that posed by the keeping of other companion animals. We therefore do not see any valid reasons to selectively restrict the keeping of reptiles and amphibians for these reasons. Since such concerns pertain to the keeping of companion animals as a whole, regulatory measures need to be based on risk assessment criteria that are evidence-based and independent of public perceptions and pressure. Nevertheless, such regulations may need to account for the levels of risk that the public is willing to bear. Health, welfare and conservation risks from the pet trade can be mitigated by:

1) the development and maintenance of species-specific minimal husbandry requirements, based on evidence, throughout the commercial chain. For the species that are allowed to the trade, these requirements should have been established. Even in the case of limited resources

for enforcement, guidelines for minimal requirements can easily be made more widely available, including at the time of purchase of a pet.

2) pet keeper education (e.g. the implementation of a system of certification of competence). Informed pet keepers and herpetological societies are an important key to improved animal welfare, public health and environmental sustainability. Keeping both exotic and non-exotic pets should require a demonstrable minimum level of knowledge and expertise.

3) the implementation of sanitary measures (quarantine, entry controls) to prevent the risk of pathogen pollution in a broader framework of improving public health and animal welfare and reducing ecological risks of pet keeping.

4) increasing sustainability of the pet trade by promoting trade in captive bred animals and those from which sustainable harvesting has been demonstrated, as well as closing legal loopholes that allow wild animals to be passed off as captive-bred or that do not take the species' legal status in the country of origin into account.

5) promoting high standards of veterinary care for any pet. For herpetofauna, access to veterinary care may be improved by further diversifying herpetological medicine in veterinary curricula and promoting specialist training. Increasing access to appropriate veterinary care by promoting public awareness of any lists of specialist veterinarians, such as the one held by the Royal College of Veterinary Surgeons in the UK.

Advantages	Disadvantages
Human health and wellbeing	
May promote psychological, physiological and social health of the keeper.	Significant source of zoonotic diseases. Some species pose risks of traumatic injuries or intoxication.
Animal conservation and environmental health	
Helps nurture interest and dispel prejudice. Fosters expertise for *ex situ* conservation. Offers opportunities for research. Conservation programs may benefit from sustainable trade. The wide variety of species currently kept and bred successfully may render the importation of wild-caught specimens redundant.	Risk of overexploitation of natural populations. Significant illegal trade in threatened species. Source of pathogen pollution. Source of introduction of invasive alien species. Risk of introduction of diseases affecting domestic animal species.
Animal health and welfare	
Easily accessible information and infrastructure allow proper management of many species of reptiles and amphibians. Captive bred offspring of many species are undemanding pets in the hands of a knowledgeable keeper. Well-being does not require interaction with the keeper.	Husbandry and nutrition-related problems remain common problems and are mostly due to lack of knowledge of the keeper. Health and welfare issues associated with trade. Some species require highly specialist care that is difficult to provide. Proper veterinary care may not be easily accessible everywhere. No immediate benefit for the individual animal: one directional relationship.

Table 1. Summary of advantages and disadvantages of keeping of pet reptiles and amphibians

Conflict of interest statement

All authors are deeply involved in matters discussed in this paper, which reflects their professional opinion. This manuscript is not expected to yield any commercial benefits to the authors.

Frank Pasmans is professor and director of the Laboratory of Veterinary Bacteriology and Mycology (UGent) and a member without commercial profits of a number of organisations concerned with microbiology (American Society for Microbiology), veterinary medicine (European Association of Zoo and Wildlife Veterinarians, European College of Zoological Medicine, Association of Reptilian and Amphibian Veterinarians) and herpetological societies (DGHT, SEH) and several scientific committees (CITES Belgium, Amphibian Survival Alliance, advisor to Flemish, Dutch, Belgian, European and US authorities with regard to amphibian infectious diseases).

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