

Review

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

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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, the authors argue for the responsible and sustainable keeping of reptile and amphibian pets by private persons, based on scientific evidence and on the authors' own expertise (veterinary medicine, captive husbandry, conservation biology).

Introduction

Human beings sought the companionship of animals even before practising agriculture. Dog and horse domestication are estimated to have occurred between 11,000–16,000 years and 5500 years before the present.^{1–3} The number of pet animals kept in the EU is estimated at over 240 million.⁴ 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 per cent to 64 per cent of the pet population.⁴ The keeping and trading of exotic companion animals is controversial due to issues concerning animal welfare, public health and conservation. Here the authors 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.^{5–7} Beneficial effects are not limited to pets with high interactive value (eg, dogs); even the keeping of non-interactive or poorly interactive animals, such as fish, has been shown to improve the keeper's overall health.^{8,9} Nevertheless, other studies have failed to corroborate these positive effects, and in some cases even demonstrate a negative effect.¹⁰ 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. Several prominent European herpetologists in academia or museums have declared that the keeping of herpetofauna during childhood fuelled their lifelong interest in herpetology 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).¹¹ Although IUCN (International Union for Conservation of Nature) 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).^{12–13} Also, amphibians captive-bred by hobbyists and made available for research purposes have greatly facilitated the authors' understanding of the epidemiology of emerging diseases.^{14–15} 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.¹⁶ 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

Veterinary Record (2017)

doi: 10.1136/vr.104296

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Provenance and peer review Not commissioned; externally peer reviewed.

Received January 5, 2017

Revised August 12, 2017

Accepted August 18, 2017

human health and wellbeing.⁷ In this section, the authors 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.¹⁷ 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.¹⁸

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 (eg, 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,¹⁷ but Schaper and others¹⁹ reported few cases of envenomation by pet snakes (approximately 16 across four European poison centres per year), although this may be an underestimate.²⁰ The authors found no evidence of a significant health risk due to poisoning by amphibians kept as pets. Although 3 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.²¹ 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.^{22–24}

Zoonoses and allergies

Pet reptiles and amphibians are potential reservoirs of several zoonotic (mainly viral, bacterial and parasitic) agents (reviewed in Johnson-Delaney 2006²⁵). Reptiles probably help maintaining infection cycles of West Nile virus (crocodilians) and Eastern equine encephalitis virus (wild reptiles). Ectoparasites and endoparasites may directly affect human health or indirectly as vectors of, for example, Q fever and Lyme disease, although reports confirming transmission to human beings 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 have been identified in reptiles and amphibians, the paucity of published reports on proven transmission to human beings means that most bacterial zoonoses contracted from pet reptiles and amphibians represent rare cases, with a low overall disease burden for human beings. The notable exceptions are *Salmonella* species, which are well known to pose a significant health risk.²⁶ Interestingly, the prevalence of *Salmonella* infection in wild-caught pet reptiles and amphibians appears to increase with time in captivity.²⁷ Some reptile-borne and amphibian-borne *Salmonella* species have the potential to cause severe infections, especially in young children. A significant number of cases of human salmonellosis is attributed to these pets: 0.95 per cent of *Salmonella* cases in the UK²⁸ and 6 per cent of sporadic *Salmonella* infections in the USA (ie, not including outbreaks of salmonellosis).²⁹ However, this needs to be placed in context, as the vast majority of infections in human beings is caused by foodborne *Salmonella*. To minimise 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.³⁰ Raising public awareness and applying basic personal and household hygiene (eg, 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.³¹

Allergic responses have been anecdotally reported for reptiles.³² Since insects are widely used as reptile and amphibian food items, keepers may be exposed to potential insect allergens.³³

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 human beings for 11,000–16,000 years² and which numbers approximately 70 million in North America and 74 million in western Europe.⁴ 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^{34 35} and up to 22 bites per 1000 children.³⁶ 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 per cent and 18 per cent of dog bites become infected³⁷ with bacteria, occasionally with lethal results.³⁸ Zoonotic infection from dogs (and cats) is of special concern, given their frequent and intimate contact with human beings.³¹ Asthmatics who are allergic to dogs but continue to live with their pet result in an estimated additional \$0.25–0.5 billion to annual healthcare costs in the USA alone.³⁹ 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.⁴⁰

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 jeopardise – its welfare.⁴¹ Here, the authors 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;⁴² principles that can be widely applied to any animal under human care. However, in contrast to many well recognised 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.⁴³

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 ⁴⁴Herpetologie

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 million and \$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.⁴⁵ 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.⁴⁶ Species vary in their 'suitability' as pets (as defined by Schuppli and Fraser 2000⁴¹), with some species requiring highly specific nutritional and/or husbandry methods (eg, 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.⁴⁷ Unfortunately, an increasing number of keepers are not affiliated with such organisations 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.⁴⁸ 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.⁴⁹ The need for enriched and stimulating environments is often underestimated (reviewed in Burghardt 2013⁵⁰). 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'.⁵⁰

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 recognised; for example, the European College of Zoological Medicine's (ECZM) herpetology specialty. Veterinary postgraduate training is offered in several countries (eg, in Germany: Zusatzqualifikation Reptilien und Amphibien) and specialist training in herpetological medicine is provided by 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)⁵¹ and mortality rates in the home may be relatively low.⁵² Nevertheless, poor treatment and animal cruelty do occur in the animal trade.⁵³ Reports of such incidents are rare in relation to the total numbers transported around the world.⁵² However, wild-caught reptiles and amphibians often are transported in bulk and may endure crowding and stress before and during transit; conditions which are also conducive to the transmission of infectious diseases and trauma. High standards of animal welfare are therefore needed throughout the commercial chain.⁵⁴ For some species of wild-caught reptiles and amphibians, 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.⁵⁵ These newts are sold at low prices, ranging from €5 to €15 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.⁵⁶ Consumers therefore need to understand the potential implications for conservation, welfare and animal health of purchasing wild-caught animals.⁵⁸

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.³¹ An estimated 25–50 per cent of cats and dogs in the USA never visit a veterinarian in their entire life.³¹ Emotional neglect is a widespread concern for dogs,³¹ which by the very process of domestication have come to accept human beings 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 with 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 (IAS) from escaped or deliberately released animals, and/or by the introduction of diseases to new geographical regions and, hence, to native wildlife.

Overexploitation

Bush and others⁵⁹ 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 EU imported over 20 million reptiles between 2004 and 2014, many of which have been illegally traded and most probably suffer from severe overexploitation.⁶⁰ 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. Overexploitation of certain populations of newly discovered and attractive species

has been associated with the availability of locality details in scientific publications and led to calls aiming to prevent the distribution of such details in future publications.^{61–63} 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 (eg, *Varanus melinus*).⁶⁴ An additional problem is that many species (eg, several newt species of the genus *Tylosotriton*) are illegally exported from their country of origin (eg, People's Republic of China) despite national or regional protection.⁶⁵ 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 (ie, Convention on International Trade in Endangered Species of Wild Fauna and Flora; CITES) regulations and is a growing concern for species conservation.^{65,66}

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,⁶⁷ 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).⁶⁸ For herpetofauna, the pet trade provides the primary platform for invasions, with over 9 million reptiles imported in the USA between 2000 and 2004, belonging to at least 799 species, of which 89 per cent were alien.⁶⁹ Negative impacts of invasive species include: predation, competition, hybridisation and pathogen pollution.⁷⁰ Although not all alien species cause harm, and many have been beneficial to human beings, some may become agents of human-accelerated environmental change.⁷¹ In the inventory of European alien species,⁶⁸ DAISIE, 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 hybridise with native species may cause 'genetic pollution' through introgression (eg, hybridisation of different species of green frog (*Pelophylax* species)).⁷² 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.⁷³ 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 (eg, 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, for example, through the banning by the EU 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.⁷⁴ The pet trade is an important source of pathogen pollution,⁷⁵ including the introduction of ranavirus from North America to the UK,⁷⁶ the introduction of *Batrachochytrium salamandrivorans* to Europe¹⁵ and the introduction of *Batrachochytrium dendrobatidis* globally.⁷⁷ *B. dendrobatidis* has been identified as one of the most important causes of amphibian population declines and extinctions globally.⁷⁸ 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 amphibian chytrid fungi are listed by the World Organisation for Animal Health and measures should be taken to ensure that amphibians are free of these agents before 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 minimise disease threats to captive and wild animals.⁷⁹ 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* species) and turtles (*Terrapene* species)^{80–83} and, very recently, *Devriesea agamarum* infections in threatened iguanids.⁸⁴ Captive reptiles constitute a large potential reservoir of pathogen pollution for many fungal (eg, snake fungal disease) and viral (eg, arenaviruses) infections.^{85–87} 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 2000.⁸⁸ 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.⁸⁹ The sheer quantity of faeces produced by domestic dogs poses a significant environmental concern.⁹¹ 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 2006.⁹⁰ Minimising 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, ENDCAP is a pan-European coalition of animal welfare organisations and wildlife professionals).⁹¹ 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 (eg, CITES legislation), imposes minimum requirements (eg, requirements for pet shops selling reptiles and amphibians in Belgium, Royal Decree April 27, 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', eg, 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

TABLE 1: Summary of advantages and disadvantages of keeping of pet reptiles and amphibians

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 programmes 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. Wellbeing 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.

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 downplayed 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.⁴⁴ This should preferentially be done at the 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. The authors do not, however, believe that keeping reptiles and amphibians presents a disproportionate burden on public health or animal welfare compared with that posed by the keeping of other companion animals. The authors 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 (eg, 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.

Competing interests None declared.

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References

- 1 ORLANDO L, GINOLHAC A, ZHANG G, *et al*. Recalibrating *Equus* evolution using the genome sequence of an early Middle Pleistocene horse. *Nature* 2013;499:74–8.
- 2 FREEDMAN AH, GRONAU I, SCHWEIZER RM, *et al*. Genome sequencing highlights the dynamic early history of dogs. *PLoS Genet* 2014;10:e1004016.
- 3 SCHUBERT M, JÓNSSON H, CHANG D, *et al*. Prehistoric genomes reveal the genetic foundation and cost of horse domestication. *Proc Natl Acad Sci U S A* 2014;111:E5661–E5669.
- 4 SCHUPPLI CA, FRASER D, BACON HJ. Welfare of non-traditional pets. *Rev Sci Tech* 2014;33:221–31.

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- 5 WELLS DL. Domestic dogs and human health: an overview. *Br J Health Psychol* 2007;12:145–56.
- 6 WELLS DL. The Effects of animals on human health and well-being. *J Soc Issues* 2009;65:523–43.
- 7 SMITH B. The 'pet effect'—health related aspects of companion animal ownership. *Aust Fam Physician* 2012;41:439–42.
- 8 WHITEFORD G. Occupational deprivation and incarceration. *J Occup Sci* 1997;4:126–30.
- 9 LANGFIELD J, JAMES C. Fishy tales: experiences of the occupation of keeping fish as pets. *British Journal of Occupational Therapy* 2009;72:349–56.
- 10 HERZOG H. The impact of pets on human health and psychological well-being: fact, fiction or hypothesis? *Curr Dir Psychol Sci* 2011;20:236–9.
- 11 LI VIGNI F. A life for reptiles and amphibians. Germany: Chimaira, Frankfurt am Main, 2013.
- 12 GASCON C, COLLINS JP, MOORE RD, *et al.* Amphibian conservation action plan. Proceedings: IUCN/SSC Amphibian Conservation Summit 2005. Switzerland and Cambridge, UK: Gland, 2007.
- 13 TAPLEY B, BRADFIELD KS, MICHAELS C, *et al.* Amphibians and conservation breeding programmes: do all threatened amphibians belong on the ark? *Biodivers Conserv* 2015;24:2625–46.
- 14 MARTEL A, SPITZEN-VAN DER SLUIJS A, BLOOI M, *et al.* *Batrachochytrium salamandrivorans* sp. nov. causes lethal chytridiomycosis in amphibians. *Proc Natl Acad Sci U S A* 2013;110:15325–9.
- 15 MARTEL A, BLOOI M, ADRIAENSEN C, *et al.* Wildlife disease. Recent introduction of a chytrid fungus endangers Western Palearctic salamanders. *Science* 2014;346:630–1.
- 16 SPARREBOOM M. Salamanders of the Old World. : KNNV Publishing, the Netherlands Australian Family Physician, 2014:41: 439–42.
- 17 LANGLEY R, MACK K, HAILEYESUS T, *et al.* National estimates of noncanine bite and sting injuries treated in US Hospital Emergency Departments, 2001–2010. *Wilderness Environ Med* 2014;25:14–23.
- 18 WOLF BC, HARDING BE. Fatalities due to indigenous and exotic species in Florida. *J Forensic Sci* 2014;59:155–60.
- 19 SCHAPER A, DESEL H, EBBECKE M, *et al.* Bites and stings by exotic pets in Europe: an 11 year analysis of 404 cases from Northeastern Germany and Southeastern France. *Clin Toxicol* 2009;47:39–43.
- 20 WARRELL DA. Treatment of bites by adders and exotic venomous snakes. *BMJ* 2005;331:1244–7.
- 21 DALY JW, KANEKO T, WILHAM J, *et al.* Bioactive alkaloids of frog skin: combinatorial bioprospecting reveals that pumiliotoxins have an arthropod source. *Proc Natl Acad Sci U S A* 2002;99:13996–4001.
- 22 BRADLEY SG, KLIKA LJ. A fatal poisoning from the Oregon rough-skinned newt (*Taricha granulosa*). *JAMA* 1981;246:247.
- 23 HITT M, ETTINGER DD. Toad toxicity. *N Engl J Med* 1986;314:1517–8.
- 24 GOWDA RM, COHEN RA, KHAN IA. Toad venom poisoning: resemblance to digoxin toxicity and therapeutic implications. *Heart* 2003;89:14e–14.
- 25 JOHNSON-DELANEY CA. Reptile zoonoses and threats to public health. MADER DR, ed. Reptile Medicine and Surgery. St. Louis, USA: Elsevier. In Press, 2006:1017–30.
- 26 DAMBORG P, BROENS EM, CHOMEL BB, *et al.* Bacterial zoonoses transmitted by household pets: state-of-the-art and future perspectives for targeted research and policy actions. *J Comp Pathol* 2016;155:S27–S40.
- 27 PFLEGER S, BENYR G, SOMMER R, *et al.* Pattern of *Salmonella* excretion in amphibians and reptiles in a vivarium. *Int J Hyg Environ Health* 2003;206:53–9.
- 28 AIKEN AM, LANE C, ADAK GK. Risk of *Salmonella* infection with exposure to reptiles in England, 2004–2007. *Eurosurveillance* 2010;15:11–18.
- 29 MERMIN J, HUTWAGNER L, VUGIA D, *et al.* Reptiles, amphibians, and human *Salmonella* infection: a population-based, case-control study. *Clin Infect Dis* 2004;38 Suppl 3:S253–S261.
- 30 ARAV. Association of reptilian and amphibian veterinarians. 2017 <http://ARAV.org> (accessed 5 Jan 2017).
- 31 PIERCE J. Run, Spot, Run: the ethics of keeping pets: The University of Chicago Press Books/Chicago, USA, 2017.
- 32 DUTAU G, RANCE F. Exotic pet animals and their risk as sources of allergy. *Revue Française d'Allergologie* 2009;49:272–8.
- 33 JENSEN-JAROLIM E, PALI-SCHÖLL I, JENSEN SA, *et al.* Caution: reptile pets shuttle grasshopper allergy and asthma into homes. *World Allergy Organ J* 2015;8:1–5.
- 34 CORNELISSEN JM, HOPSTER H. Dog bites in The Netherlands: a study of victims, injuries, circumstances and aggressors to support evaluation of breed specific legislation. *Vet J* 2010;186:292–8.
- 35 QUIRK JT. Non-fatal dog bite injuries in the U.S.A., 2005–2009. *Public Health* 2012;126:300–2.
- 36 DE KEUSTER T, LAMOUREUX J, KAHN A. Epidemiology of dog bites: a Belgian experience of canine behaviour and public health concerns. *Vet J* 2006;172:482–7.
- 37 TALAN DA, CITRON DM, ABRAHAMIAN FM, *et al.* Bacteriologic analysis of infected dog and cat bites. *N Engl J Med Overseas Ed* 1999;340:85–92.
- 38 BUTLER T. *Capnocytophaga canimorsus*: an emerging cause of sepsis, meningitis, and post-splenectomy infection after dog bites. *Eur J Clin Microbiol Infect Dis* 2015;34:1271–80.
- 39 OWNBY DR. Pet dander and difficult-to-control asthma: The burden of illness. *Allergy Asthma Proc* 2010;31:381–4.
- 40 STEVENS JA, TEH SL, HAILEYESUS T. Dogs and cats as environmental fall hazards. *J Safety Res* 2010;41:69–73.
- 41 SCHUPPLI CA, FRASER D. A framework for assessing the suitability of different species as companion animals. *Animal Welfare* 2000;9:359–72.
- 42 MELLOR DJ, STAFFORD KJ. Integrating practical, regulatory and ethical strategies for enhancing farm animal welfare. *Aust Vet J* 2001;79:762–8.
- 43 MICHAELS CJ, GINI BE, AND PREZIOSI, R.F. The importance of natural history and species-specific approaches in amphibian ex situ conservation. *The Herpetological Journal* 2014;24:135–45.
- 44 DGHT. Sachverständigengruppe tierschutzgerechte Haltung von Terrariertieren. Mindestanforderungen an die Haltung von Reptilien vom 10. Januar 1997. Deutsche Gesellschaft für Herpetologie und Terrarienkunde, 1997. <http://www.bmel.de/cae/servlet/contentblob/383050/publicationFile/22241/HaltungReptilien.pdf>. (accessed 5 Jan 2017).
- 45 COLLIS AH, FENILI RN. The modern U.S. reptile Industry, Report of the Georgetown Economic Services. Washington, DC, USA: LLC, 2011.
- 46 BAINES FM, CHATTELL J, DALE J, *et al.* How much UVB does my reptile need? The UV-Tool, a guide to the selection of UV lighting for reptiles and amphibians in captivity. *JZAR* 2016;4:42–63.
- 47 SKN (1995) Sachkundenachweis. Deutsche Gesellschaft für Herpetologie und Terrarienkunde. <http://www.sachkundenachweis.de>. (accessed 2 Jan 2017).
- 48 TAPLEY B, GRIFFITHS RA, BRIDE I. Dynamics of the trade in reptiles and amphibians within the United Kingdom over a ten-year period. *Herpetological Journal* 2011;21:27–34.
- 49 DEMING C, GREINER E, UHL EW. Prevalence of cryptosporidium infection and characteristics of oocyst shedding in a breeding colony of leopard geckos (*Eublepharis macularius*). *J Zoo Wildl Med* 2008;39:600–7.
- 50 BURGHARDT GM. Environmental enrichment and cognitive complexity in reptiles and amphibians: Concepts, review, and implications for captive populations. *Appl Anim Behav Sci* 2013;147:286–98.
- 51 PASMANS F, BLAHAK S, MARTEL A, *et al.* Introducing reptiles into a captive collection: the role of the veterinarian. *Vet J* 2008;175:53–68.
- 52 ROBINSON JE, ST JOHN FA, GRIFFITHS RA, *et al.* Captive reptile mortality rates in the home and implications for the wildlife trade. *PLoS One* 2015;10:e0141460.
- 53 ASHLEY S, BROWN S, LEDFORD J, *et al.* Morbidity and mortality of invertebrates, amphibians, reptiles, and mammals at a major exotic companion animal wholesaler. *J Appl Anim Welf Sci* 2014;17:308–21.
- 54 BAKER SE, CAIN R, VAN KESTEREN F, *et al.* Rough trade: animal welfare in the global wildlife trade. *Bioscience* 2013;63:928–38.
- 55 HERREL A, VAN DER MEIJDEN A. An analysis of the live reptile and amphibian trade in the USA compared to the global trade in endangered species. *Herpetological Journal* 2014;24:103–10.
- 56 HUTTON JM, LEADER-WILLIAMS N. Sustainable use and incentive-driven conservation: realigning human and conservation interests. *Oryx* 2003;37:215–26.
- 57 ROE D. Trading nature: a report, with case studies, on the contribution of wildlife trade management to sustainable livelihoods and the Millennium Development Goals: TRAFFIC International, 2008.
- 58 MOORHOUSE TP, BALASKAS M, D'CRUZE NC, *et al.* Information could reduce consumer demand for exotic pets. *Conserv Lett* 2017;10:337–45.
- 59 BUSH ER, BAKER SE, MACDONALD DW. Global trade in exotic pets 2006–2012. *Conserv Biol* 2014;28:663–76.
- 60 AULIYA M, ALTHERR S, ARIANO-SANCHEZ D, *et al.* Trade in live reptiles, its impact on wild populations, and the role of the European market. *Biol Conserv* 2016;204:103–19.
- 61 STUART BL, ROWLEY JJ, PHIMMACHAK S, *et al.* Salamander protection starts with the newt. *Science* 2014;346:1067–8.
- 62 LINDENMAYER D, SCHEELE B. Do not publish. *Science* 2017;356:800–1.
- 63 STUART SN, CHANSON JS, COX NA, *et al.* Status and trends of amphibian declines and extinctions worldwide. *Science* 2004;306:1783–6.
- 64 BÖHME W, ZIEGLER T. *Varanus melinus* sp. n., ein neuer Waran aus der V. indicus-Gruppe von den Molukken, Indonesien. *Herpetofauna* 1997;19:9.
- 65 AULIYA M, GARCÍA-MORENO J, SCHMIDT BR, *et al.* The global amphibian trade flows through Europe: the need for enforcing and improving legislation. *Biodivers Conserv* 2016;25:2581–95.
- 66 LYONS JA, NATUSCH DJD. Wildlife laundering through breeding farms: Illegal harvest, population declines and a means of regulating the trade of green pythons (*Morelia viridis*) from Indonesia. *Biol Conserv* 2011;144:3073–81.
- 67 PIMENTEL D, MCNAIR S, JANECKA J, *et al.* Economic and environmental threats of alien plant, animal, and microbe invasions. In: PIMENTEL D, ed. Biological invasions: economic and environmental costs of alien plant, animal and microbe species. Boca Raton, FL, USA: CRC Press, 2002:307–29.
- 68 DAISIE. Delivering alien invasive species inventories Europe, 2008. <http://www.europe-alien.org>. (accessed 30 Nov 2016).
- 69 PERRY G, FARMER M. Reducing the risk of biological invasion by creating incentives for pet sellers and owners to do the right thing. *J Herpetol* 2011;45:134–41.
- 70 PILLIOD DS, GRIFFITHS RA, KUZMIN SL. Ecological impacts of non-native species. In: BIOLOGY A, HEATWOLE J, WILKINSON JW, eds. Conservation and Decline of Amphibians: Ecological Aspects, Effects of Humans, and Management. . Baulkham Hills, NSW, Australia: Surrey Beatty & Sons, 2012:10. 3343–82.
- 71 SIMBERLOFF D, MARTIN JL, GENOVESI P, *et al.* Impacts of biological invasions: what's what and the way forward. *Trends Ecol Evol* 2013;28:58–66.
- 72 HOLSBECK G, MERGEAY J, VOLCKAERT FAM, *et al.* Genetic detection of multiple exotic water frog species in Belgium illustrates the need for monitoring and immediate action. *Biol Invasions* 2010;12:1459–63.
- 73 GARCÍA-DÍAZ P, ROSS JV, AYRES C, *et al.* Understanding the biological invasion risk posed by the global wildlife trade: propagule pressure drives the introduction and establishment of Nearctic turtles. *Glob Chang Biol* 2015;21:1078–91.

- 74 CUNNINGHAM AA, DASZAK P, RODRÍGUEZ JP. Pathogen pollution: defining a parasitological threat to biodiversity conservation. *J Parasitol* 2003;89:6.
- 75 KOLBY JE, SMITH KM, BERGER L, *et al*. First evidence of amphibian chytrid fungus (*Batrachochytrium dendrobatidis*) and ranavirus in Hong Kong amphibian trade. *PLoS One* 2014;9:e90750.
- 76 HYATT AD, GOULD AR, ZUPANOVIĆ Z, *et al*. Comparative studies of piscine and amphibian iridoviruses. *Arch Virol* 2000;145:301–31.
- 77 GARNER TW, PERKINS MW, GOVINDARAJULU P, *et al*. The emerging amphibian pathogen *Batrachochytrium dendrobatidis* globally infects introduced populations of the North American bullfrog, *Rana catesbeiana*. *Biol Lett* 2006;2:455–9.
- 78 Amphibian survival alliance. Amphibian Conservation Summit (2005) Amphibian conservation action plan. Washington DC. http://www.globalamphibians.org/acap_5fsummit_5fdeclaration.pdf. (accessed 28 Dec 2016).
- 79 AMPHIBIAN DISEASE ALERT (2015) Disease alert. Reducing disease risks in captive amphibians and protecting our wild native amphibians from invasive disease. http://www.gardenwildlifehealth.org/files/2013/06/Amphibian-disease-alert_June-2015.pdf. (accessed 4 Jan 2017).
- 80 TODD M. Trade in Malagasy reptiles and amphibians in Thailand. A TRAFFIC Southeast Asia report. Selangor, Malaysia: Petaling Jaya, 2011.
- 81 JACOBSON ER, GASKIN JM, BROWN MB, *et al*. Chronic upper respiratory tract disease of free-ranging desert tortoises (*Xerobates agassizii*). *J Wildl Dis* 1991;27:296–316.
- 82 BROWN MB, BROWN DR, KLEIN PA, *et al*. *Mycoplasma agassizii* sp. nov., isolated from the upper respiratory tract of the desert tortoise (*Gopherus agassizii*) and the gopher tortoise (*Gopherus polyphemus*). *Int J Syst Evol Microbiol* 2001;51:413–8.
- 83 FELDMAN SH, WIMSATT J, MARCHANG RE, *et al*. A novel mycoplasma detected in association with upper respiratory disease syndrome in free-ranging eastern box turtles (*Terrapene carolina carolina*) in Virginia. *J Wildl Dis* 2006;42:279–89.
- 84 HELLEBUYCK T, QUESTEL K, PASMANS F, *et al*. A virulent clone of *Devriesea agamarum* affects endangered Lesser Antillean iguanas (*Iguana delicatissima*). Scientific Reports DOI: 10.1038/s41598-017-11874-x 2017.
- 85 HETZEL U, SIRONEN T, LAURINMÄKI P, *et al*. Isolation, identification, and characterization of novel arenaviruses, the etiological agents of bovid inclusion body disease. *J Virol*. 2013;87:10918–35.
- 86 MCBRIDE MP, WOJICK KB, GEOROFF TA, *et al*. *Ophidiomyces ophiodiicola* dermatitis in eight free-ranging timber rattlesnakes (*Crotalus horridus*) from Massachusetts. *J Zoo Wildl Med* 2015;46:86–94.
- 87 LORCH JM, KNOWLES S, LANKTON JS, *et al*. Snake fungal disease: an emerging threat to wild snakes. *Philos Trans R Soc Lond B Biol Sci* 2016;371:20150457.
- 88 BURRIDGE MJ. Ticks (Acari: Ixodidae) spread by the international trade in reptiles and their potential roles in dissemination of diseases. *Bull Entomol Res* 2001;91:3–23.
- 89 LOSS SR, WILL T, MARRA PP. The impact of free-ranging domestic cats on wildlife of the United States. *Nat Commun* 2013;4:1396.
- 90 DE SILVA SS, TURCHINI GM. Towards understanding the impacts of the pet food industry on world fish and seafood supplies. *Journal of Agricultural and Environmental Ethics* 2008;21:459–67.
- 91 ENDCAP. Wild pets in the European union. 2012 <http://endcap.eu/wild-pets-in-the-eu/> (accessed 28 Dec 2016).



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Veterinary Record published online October 19, 2017

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