AMPHIBIAN AND REPTILE PET MARKETS IN THE EU: AN INVESTIGATION AND ASSESSMENT

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SUMMARY

Wildlife markets occur in several regions of the world and take different forms. According to region, wildlife markets offer animals for various reasons including culinary, medicinal, and pet purposes. These events have attracted interest and concern from both the scientific (including biological, veterinary and medical fields), and animal welfare and species protection communities. For this investigation and report we have focussed on amphibians and reptiles at pet markets.

We conducted onsite inspections at three European events: Terraristika (Hamm, Germany), the IHS Show (Doncaster, UK), and Expoterraria (Sabadell, Spain), and we also conducted a desktop study. Three primary subject areas were identified for focussed study: animal welfare; public health and safety; and invasive alien species potential.

Animal welfare was assessed using scientifically established non-invasive observation of behavioural signs of stress in amphibians and reptiles. Public health and safety was assessed by analysing visitor behaviour at stalls that sold animals. Invasive alien species potential was assessed using historical invasives success data, propagule-pressure theory, tolerable thermal range (climate matching), taxonomic relationship with known invasives, popularity within the pet trade, reproductive potential, and thermal and dietary requirements. This was supplemented with an additional assessment of invasive risk which we called 'intuitive-risk' (IR). This mode of assessment is based on considering and balancing a variety of factors including those already mentioned plus our interpretation of 'species overall plasticity'. We also considered several additional relevant subjects including: wild-caught versus captive-bred animals on offer; commercial and non-commercial sellers; proponents', organisers' and sellers' awareness and assessment of stress and welfare at markets; the temporary nature of markets; and unusual species.

Our study found that:

- *Animal welfare* – the type and high prevalence of behavioural signs of stress observed at exotic pet markets show that a significant and major representation of both amphibians and reptiles at these events are stressed. This indicates that significant animal welfare problems are associated with exotic pet markets and that current key concerns are justified.

- *Human health* – the established nature of amphibians and reptiles as a reservoir of known pathogens means that all animals, their containers, seller facilities, and the sellers themselves must be regarded as potential sources of zoonotic pathogen contamination. Indeed, we postulate that it would be reasonable to conclude that within a relatively brief period all public attendees potentially may be subjected to some level of contamination.

- *Invasive alien species* – there is little doubt that a wide range of species found at exotic pet markets have the adaptive potential to become invasive across numerous regions within the EU. Our assessment is that the continued occurrence of exotic pet markets makes the regular introduction of invasive species almost assured.

Accordingly, we recommend that the European Commission pursue a policy of prohibition on exotic pet markets within its boundaries, and this should cover all biological classes of vertebrate animals. In addition, authorities should compile a database of all known pet markets and their historical venues and make this information available for enforcement authorities to ensure local compliance with all prohibitive measures. Existing EU regulations and initiatives are available to implement these recommendations.

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INTRODUCTION

GENERAL

Wildlife markets occur in several regions of the world and take different forms. According to region, wildlife markets offer animals for various reasons including culinary, medicinal, and pet purposes.

In Asia, these events tend to be open or partly open 'street' markets (also sometimes referred to as 'wet markets') selling a very wide variety of animals including fishes, amphibians, reptiles, birds and mammals, as well as animal products such as bushmeat (Brown, 2004; Chomel *et al*., 2007). In North America and Europe, wildlife markets typically involve indoor areas, and the public may pay entry fees to gain access in many examples (Brown, 2004; Warwick, Toland and Glendell, 2005; Colazzi, 2004; Warwick, 2006; Chomel *et al*., 2007; Karesh *et al*., 2005).

In Asia and some parts of North America, wildlife markets commonly involve culinary, medicinal and pet purposes, whereas in Europe these events appear most commonly aimed at the pet industry (Warwick, Toland and Glendell, 2005; Warwick, 2006; Karesh *et al*., 2005).

The present report will focus on wildlife markets and issues as they relate to the sale of pets, with an emphasis on events within the European Union (EU).

Wildlife markets have attracted interest and concern from both the scientific (including biological, veterinary and medical fields) and animal welfare and species protection communities for several reasons of which three are of primary relevance to this report. For this report we focussed on amphibians and reptiles as pets.

Animal welfare

Animal welfare is reported to be poor at these events (Warwick, Toland and Glendell, 2005; Warwick, 2006), and in the UK, for example, the selling of pets at markets is unlawful for this reason (Warwick, Toland and Glendell, 2005; Warwick, 2006; Toland, 2006). The view that wildlife markets are centres of poorly or unregulated trade is also frequently cited (Colazzi, 2004; Toland, 2006; Warwick, 2006). Poor husbandry and other practices are indicated as leading to animal suffering (for example, Warwick, 2004a; Toland, 2006).

It should be presumed that amphibians and reptiles, like other animals, are sensitive to aversive stimuli (pain, trauma) (Cooper, 1989). Environmental stressors, including physical (such as thermal and humidity extremes and irregularities) as well as psychological and behavioural are also important considerations (Arena & Warwick, 2004; Warwick, 2004a).

Animal welfare and its assessment are based on biological considerations, and these refer to physical, physiological, functional anatomical, psychological and behavioural issues. 'Biological needs' may be complex and often subtle and extend beyond basic warmth and nutrition to include providing for appropriate mental stimulation and behaviour. Relatedly, the spatial needs of animals, important thermal ranges, chemically stimulating surroundings, and many other positive factors may contribute to good animal welfare.

Conversely, 'stressors' such as handling, photo- (light) invasive environments (especially for nocturnal species), small enclosures, single or constant temperature environments, atypical social pressures, and many other negative factors may contribute to poor animal welfare.

Amphibian and reptile sellers, breeders, and keepers are well known to interpret signs such as animals being 'good feeders', having 'good bodyweight' and manifesting 'active reproduction' as being indicators of good welfare and adequate housing conditions. However, these signs are poor indicators of welfare that in the absence of an appropriate range of other indicators may be highly misleading (Broom & Johnson, 1993). Also, the presence of 'positive' indicators, even in the presence of broader positive signs, should not be presumed to convey good welfare where any concomitant negative health or welfare sign is identified (Warwick, 2004a).

A major issue of concern is that amphibian and reptile sellers and keepers, along with many professionals including veterinarians and biologists, lack the knowledge-base either to understand the important biological needs of these animals as they relate to welfare as well as the abilities to interpret problematic behaviours that are to an experienced observer readily identified and understood (Warwick, 2004a).

Scientific assessment of stress as a measurement of welfare broadly fits into two camps, physiological and behavioural.

Physiological measurement typically involves obtaining blood samples from animals and examining particular parameters of (commonly) corticosterone, which is a steroid hormone associated with adrenal gland function and a component of a complex interaction and response to stress (Guillette *et al*., 2004). The 'adreno-corticosterone' response to stress is considered to be associated with a form of pain- and other trauma-reduction/modifying mechanism. In other words, an animal that is stressed by an event (including capture and handling) produces this physiological response that consequently acts to control the trauma involved. Physiological stress is naturally associated with *acute* stress 'survival' scenarios, rather than with *chronic* stress situations (Dickens *et al*., 2010). Occasional acute stress episodes, while physiologically demanding, are tolerable within the context of health and welfare whereas chronic stress is associated with the dysregulation of the acute stress response and results in increased ill-health vulnerability and pathology (Dickens *et al*., 2010).

Many researchers adopt physiological measurements as a guide to stress-levels in animals. This is particularly notable where laboratory animals are concerned as well as when monitoring wildlife during translocation. Assessing stress in a typical clinical, zoological or pet animal context commonly involves behavioural rather than physiological measurements.

There are, however, some important drawbacks to using physiological measurement in the assessment of stress in animals, including amphibians and reptiles. Among these is the issue that there appear to be few detailed data on physiological values in undisturbed free-living amphibians and reptiles. Accordingly, reliable baseline information important to formulating comparative analysis is lacking or absent in very many scenarios. Also, the basic 'bias' influence exists that obtaining a physiological sample (often via blood) is itself an invasive procedure that causes a physiological reaction. Non-invasive techniques are available, such as analysis of faecal samples from free-living and captive animals (Harper *et al*., 2011) and these can provide 'purer' comparative data. However, it remains unclear whether life habit differences, such as in diet and season–related hormonal condition, between wild and captive animals results in mismatched sample values.

Studies of the human cortisol response (cortisol is the human equivalent of corticosterone in amphibians and reptiles) allow both objective and subjective analyses to be performed, rather than purely objective analyses in animals. Human studies report that cortisol may be mediated by mood (for example, agitation-related stimuli) whereas states including perceived stress, anxiety, and depression may not increase cortisol (vanEck *et al*., 1996). On this basis, states such as under-stimulation in amphibians and reptiles may not be revealed through physiological measurement, which is consistent with the results of behavioural assessment.

Further, corticosterone measurement represents a very narrow marker (commonly linked in the reptile research field to reproductive fitness) in the extremely diverse and dynamic internal physiological environment of an organism. Also, varied physiological responses from a diversity of, for example, reptile species illustrate a risk in extrapolating information regarding adrenal function (Jones & Bell, 2003). While corticosterone measurement may be revealing of certain types of stress and stressor, and of its associations with particular physiological states, there is little scientific evidence to support the use of physiological measurement for the assessment of amphibian and reptile welfare in a holistic context.

A common finding in 'physiologically stressed' animals is that there is a decrease in sex steroids leading to reduced reproductive success (Guillette *et al*., 2004). These general findings in some respects are consistent with the common view that reproductively successful animals are unlikely to be experiencing stress-related raised corticosterone levels. However, this association allows very limited conclusions to be reached about an animal's psychological and behavioural condition because many reptiles with successful reproductive histories both manifest captivity-related pathologies (Frye, 1991) and captivity-related stress behaviour (Broom & Johnson, 1993; Warwick, 2004a).

Behavioural measurement typically involves observing what animals do and, in the context of welfare, assessing what behaviour is normal or abnormal. Normal behaviour includes not only behaviours known to be part of an animal's life in nature, but also to form a balanced component of a range of behaviours that reflect the species natural history. For example, in nature it may be normal and healthy for an animal to spend hours of exploratory locomotor activity in order to hunt for prey, whereas it may be abnormal and unhealthy for an animal to spend even far less than one hour pacing a small enclosure in captivity with plentiful food.

Certain stressors are not absent in nature, rather they occur commonly. However, stressors in nature are typically contextualised within a functional and overall positive process, in other words they 'come and go', contribute to awareness and other useful factors, and are balanced by life in an environment that has an over-arching suitability. By contrast, captive conditions typically replace many parameters of the natural world with artificial and frequently poorly matched alternatives that deprive animals of known normal behaviour and associated biological needs, such as hunting, spatial range, and habitat variation (Warwick, 2004a). The assessment of normal and abnormal behaviour, therefore, offers greater holistic opportunities for the assessment of welfare. Abnormal behaviours indicate that 'something is wrong' with the present environment, regardless of what narrow physiological data emerges from selected blood or faecal sampling.

Generally, captivity-related chronic stress behaviour may result in *increased* abnormal behaviour, behavioural inhibition, vigilance behaviour, hiding, fearfulness and frequency of startle, aggression, and freezing behaviour, and *decreased* exploratory behaviour, reproductive behaviour, behavioural complexity, and latency to freeze as summarised in Morgan and Tromborg (2007). However, these criteria are subject to various differences according to animal class and species. We have adopted established behavioural assessments and, as stated elsewhere in this report, included amphibian- and reptile-specific behavioural target signs as summarised in Warwick (2004a) and Warwick, Lindley and Steedman (2011).

While not seeking to detract from the value of physiological monitoring, behavioural assessments are well-established and non-invasive criteria for the evaluation of stress and, we maintain, more reliable indicators of normality and abnormality.

Proponents, organisers and sellers associated with wildlife markets have claimed that the animals kept and offered for sale at the events are caused no stress (Anon, 2010). Relatedly, proponents also claim that the temporary nature of the markets (commonly one-day sales) means that the short-term housing and minimalistic provisions typically associated with these animals is acceptable (Anon, 2010). These two claims are central justifications for proponents, organisers and sellers associated with European pet markets in respect of the counter-criticisms concerning animal welfare.

Human health

Human health is reportedly a key concern at wildlife markets due to the attendance of the public, because many animals are likely to harbour transmissible pathogens (Warwick, 2004b, 2006). Pathogenic infections and infestations transmissible from animals to humans are known as zoonotic diseases or zoonoses. There are around 200 zoonoses (Krauss *et al*., 2003), and approximately 40 of these are associated with amphibians and reptiles (for examples, see Appendices 1 & 2).

Captive reptiles are routinely identified as reservoirs of certain bacteria, for example *Salmonella* (Geue & Löschner, 2002) and all reptiles should be presumed to harbour *Salmonella* (Ward, 2000; Mermin *et al*., 2004; Brown, 2004; Warwick, Toland and Glendell, 2005; Warwick, 2006; Warwick *et al*., 2006; Burgos & Burgos, 2007).

Relatedly, epidemiological surveys in the United States in the 1960s and 1970s showed that approximately 14% of all cases of human salmonellosis were associated with the keeping of pet baby terrapins (called 'turtles' or 'sliders' in the US) (Lamm *et al*., 1972). As a consequence of those studies US agencies formally described the trade in pet terrapins as a "significant" and "major" threat to public health, and banned the primary national trade in terrapins under 10cm (4") in 1975. Prior to the 1975 ban, the pet baby terrapin trade constituted approximately 14 million animals per year. That prohibitive action resulted in a 77% reduction in relevant human salmonelloses cases in the following year (Mermin *et al*., 2004).

More generally, a survey of 1,410 human diseases found 61% to be of potentially zoonotic origin (Karesh *et al*., 2005). Brown (2004) states that 75% of global emerging human diseases are zoonotic. Jones *et al*. (2008) found that over 60% of emerging infectious diseases are zoonotic, and that almost 72% of these originate from wildlife.

The United States Government Accountability Office (Anon, 2010b) recently completed a survey of major authorities and scientists variously involved in border protection and prevention of potentially harmful pathogens entering the US. The risks from zoonotic and animal diseases associated with live animal imports (including exotic pets) were a key feature in both the remit and the recommendations.

It is believed that epidemics such as SARS (Severe Acute Respiratory Syndrome), monkey-pox, and avian influenza H5N1 may have emerged from wildlife markets (Brown, 2004; Warwick, Toland and Glendell, 2005; Warwick, 2006; Warwick, 2006; Karesh *et al*., 2007; Burgos & Burgos, 2007). The arbitrary mixing of a wide variety of species that would not normally meet together in conditions of highly questionable animal husbandry and public health protection measures raise multifactorial concerns about these markets and their effects on animals, people, species conservation, and the environment (Warwick, Toland and Glendell, 2005; Warwick, 2006; Warwick *et al*., 2006; Chomel *et al*., 2007; Karesh *et al*., 2007; Burgos & Burgos, 2007).

Nations that currently permit exotic animals to be traded and kept in their homes likely already face significant public health-related issues arising from this practice but epidemiological 'under ascertainment' (a lack of formal recording and recognition of relevant issues) may occur concomitantly and 'mask' problematic prevalence. Numerous zoonoses symptomatically superficially resemble common illnesses such as gastrointestinal, respiratory, influenzal, and dermatological disease. General medical practitioners may be unfamiliar with zoonoses and do not typically enquire of patients about direct or indirect contact with an exotic animal (Warwick, 2004b). Zoonoses may be mild, moderate or severe in their symptoms and outcomes.

Significant case numbers of zoonotic disease arise from indirect contact with an animal—that is, contamination that does not transmit directly from animal-to-human but instead transmits from intermediary surfaces such as door handles, clothes, table tops, walls, household utensils, shaking of hands, and so on (Anon, 1995; Mermin *et al*., 1997; Warwick *et al*., 2001). Accordingly, an affected person may be unaware that they were infected by an inanimate object or by another individual. In such cases, even if asked by medical staff about their habits in relation to exotic animals, the patient may genuinely not be aware of this indirect contact. Also, doctors frequently make little or no effort to source-trace an infection or infestation and a potential epidemic may long go uncontrolled.

An additional consideration relating to the prevention and control of diseases acquired from amphibians and reptiles involves the issue that unlike endotherms (birds and mammals) that procedurally undergo 30 days compulsory quarantine designed to identify, in particular, threats such as rabies and exotic Newcastle disease, ectotherms (amphibians and reptiles), despite harbouring a vast array of human and agricultural pathogens undergo no quarantine. This system allows for the rapid importation of amphibians and reptiles, especially where transportation by air is concerned (Warwick, 2006). The purchase of exotic animals from wildlife markets enables diverse pathogens direct access to the domestic environment via sellers and keepers ignorant or disregarding of salient contaminant transmission issues.

The presumed primary transmission route for many amphibian- and reptile-borne potential pathogens is faecal-oral ingestion (Lamm *et al*., 1972). However, human skin scratches from the claws of lizards (Frye, 1995) or chelonians, and bites from snakes and lizards also may transmit contaminants (Frye, 1995; Warwick *et al*., 2001). Also, direct contact between any contaminated reptile and open human lesions, such as sores, or via reptile debris penetrating human orbital (eye) or aural (ear) sites are further potential routes of infection (Warwick *et al*., 2001). Aquatic turtles may contaminate large bodies of water—resulting in contaminated splashes, droplets, and smears that may lead to human infection; lizards are handled more than turtles and are more likely to introduce infection via skin scratches; and snakes may be handled far more frequently than lizards and thus may spread contaminants more widely and consistently. Diverse surfaces may act as intermediary carriers of many biotic contaminants and once a surface is contaminated potential contagions may long persist.

Hand washing and the use of disinfectant gels and sprays are commonly recommended and perceived as sufficient hygiene measures to eradicate *Salmonella* and any other potential pathogens (Warwick *et al*., 2001). However, these hygiene methods as generally practiced *do not* provide reliable protection against diverse amphibian- and reptile-borne contaminants. Indeed, the use of these materials and methods generates undue over-reliance and misplaced confidence in personal disease prevention and control that may lead to infection from complacency (Warwick, Lindley & Steedman, 2011). For example, in order to adequately cleanse human hands alone rigorous hand-washing protocols comparable to that among pre-theatre surgeons would need to be adopted and even here such measures are not wholly reliable and practically impossible in both the wildlife market and the domestic environments.

Relatedly, contaminants are easily spread over diverse surfaces including the individual's clothes (including pockets), hair and skin, as well as inanimate objects and other people around them (Warwick, *et al*., 2001). Accordingly, even *theoretically* 'sterile' hands are subject to rapid re-contamination via momentary contact with any previously touched and thus contaminated item or area (Warwick *et al*., 2001).

Proponents, organisers and sellers associated with wildlife markets have claimed that public health risks are minimal and that the use of sanitising products such as gels and sprays provide adequate control against infection (Anon, 2010b).

Invasive alien species

Ecological issues including species conservation and risk of introducing invasive alien species derive from the presence of wild-caught animals at markets, reports of taxonomically novel species on sale, and also because of the particularly casual manner of animal sales that may result in unwanted animals escaping or being abandoned (Warwick *et al*., 2006; Toland, 2006).

In addition to climate change, overexploitation, pollution and habitat destruction/modification, invasive alien species (IAS) are considered to be one of the major threats to the natural biodiversity of Europe (Shine *et al*., 2010). Invasive alien species are non-native species of animals and plants that, once introduced and established, cause widespread destruction with negative economic, social and environmental impacts (Shine *et al*., 2009; Keller *et al*., 2011).

Through direct or indirect methods, IAS may compromise human health and are responsible for hundreds of billions of dollars in economic damage and ecosystem management around the world (Strayer *et al*., 2006). In the European Union (EU) it has been estimated that the annual cost of damage from IAS is approximately €12.5 billion (European Commission, 2011). This is up from a figure of around €10 billion reported just a few years earlier (European Commission, 2008). These figures likely are gross underestimates of the actual cost of damage caused by IAS simply because, for much of Europe, the extent of damage is unknown. Furthermore, as will be pointed out later, it is likely that the true impact of IAS and the associated costs will remain unknown for a number of years (or even decades) – a period known as a 'lag' phase (Keller *et al*., 2011). Indeed, Vilà *et al*. (2009) pointed out that the above figures most likely represent approximately 10 percent of real figures.

Across Europe, the economic value of losses from IAS, in terms of species and biodiversity loss and impact on areas such as forestry, fisheries and tourism, are also not readily available (Shine *et al*., 2009). However, with respect to species diversity alone, of the 174 European species listed as critically endangered by the IUCN (International Union for Conservation of Nature) Red List, 65 are in danger as a result of IAS. Despite proposed initiatives to target biodiversity loss in 2001, currently only 17% of European habitats and species and approximately 10% of key ecosystems are in a state referred to as "favourable" (European Environment Agency, 2010).

The complexity of IAS issues is such that the effects not only are often difficult to detect, but also the impacts may be both direct and indirect. Direct impacts may include competition with local species for both food and habitat for which the results are often quite visible and relatively straightforward to deal with. However, indirect impacts are often more complex and difficult to deal with as they may result in a series of 'flow-on' effects. One example is when the introduced invading organism acts as a host for potentially destructive pathogens. For example, the American bullfrog *Rana catesbeiana* is responsible for the decline of many amphibians in Europe through direct competition for food and habitat, but also indirectly, through the introduction of *Batrachochytrium dendrobatidis*, which causes chytridiomycosis, a fungal disease responsible for the extinction of approximately 200 species of amphibian worldwide (Ficetola *et al*., 2007; Fisher *et al*., 2009; Skerratt *et al*., 2007). Indirect impacts may also be extremely difficult to monitor as the process may involve a series of subtle changes over a long period of time such as when the presence of an invasive species as predator or prey (or both) alters the myriad of dependencies within a food web.

It is clear that IAS have significant negative impacts on many native species and almost all ecosystems that they invade. The brown tree snake *Boiga irregularis* of Australia and Papua New Guinea, through accidental introduction in the 1950s, has caused millions of dollars worth of economic damage and decimated the endemic fauna of Guam. This IAS has thrived in response to the lack of natural predators and abundance of prey items, impacting on the island's ecology and economy, affecting human health (through serious snake bites) and causing power blackouts whilst foraging on power lines (Johnston *et al*., 2002). The cane toad *Bufo marinus*, another opportunistic generalist feeder, was intentionally introduced into Australia in the 1930s as a form of biological control that failed. The amphibians multiplied and are now well established in northern Australia, directly impacting upon populations of larger predators such as varanid and scincid lizards, elapid snakes, freshwater crocodiles and carnivorous marsupials (Shine, 2010). The cost of damage resulting from the direct and indirect impact of this species has not yet been quantified.

In Europe, it has been estimated that more than 50 species of amphibians and reptiles have become established (Kark *et al*., 2009). Of these, the African clawed frog *Xenopus laevis* (widespread throughout many US states) has been recorded in established populations in Wales (Measey & Tinsley, 1998) and is known to be spreading through Portugal (Rebelo *et al*., 2010). *Xenopus*, in addition to being a voracious and aggressive feeder in a similar way to *Rana catesbeiana*, is another known host of *Batrachochytrium dendrobatidis* (Skerratt *et al*., 2007). Regardless, this species is still promoted as an ideal 'beginner's frog' and is currently sold in pet shops and wildlife markets across Europe.

It cannot be denied that the exotic pet trade is a major contributor to the introduction and establishment of IAS (Keller *et al*., 2011). While not suggesting that amphibians and reptiles make 'good' pets it is reasonable to assume that just as certain biological features of these species (such as dietary and in some examples thermal plasticity) renders them attractive, these traits arguably also equip these animals with the means by which they are able to establish themselves, should they enter a foreign habitat either accidentally or intentionally.

Ironically, despite the recognised destructive potential of IAS, the management of these species in Europe, prior to 2010, was not guided by clearly established policy (Shine *et al*., 2010). Furthermore, the lack of coordination governing approaches to the issue of IAS in the European Union has been described as a "serious shortcoming" (Keller *et al*., 2009).

There have been attempts at producing legislation that would restrict the trade in potentially invasive alien species. This includes 'black lists' of species as proposed in Council Directive 2000/29/EC. However, there is much disagreement between countries as to which species should be included on black lists. Moreover, key stakeholders (eg the pet trade, animal breeders) have actively opposed greater regulation and control of the importation, holding and movement of exotic species, for example, HR 669: The Non-native Wildlife Invasion Prevention Act. In response, Warwick, Arena and Steedman (2009) rejected the introduction of 'positive lists' of introduced species that could be kept by individuals and, instead, recommended the continued restriction on the exotic pet trade and live keeping of amphibians and reptiles in Norway.

Following the tenth Conference of the Parties (CoP10) to the Convention on Biological Diversity (CBD), held in Nagoya in 2010, the EU 2020 biodiversity strategy was developed, which included a target aimed at "promoting a more resource efficient, greener and more competitive economy" including addressing the issue of biodiversity loss across Europe (http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/1_EN_ACT_part1_v7%5B1%5D.pdf). Target 5 of the Conference document is dedicated to combating invasive alien species and includes strengthening animal health regimes. A further step in a positive direction is the development of the DAISIE (Delivering Alien Invasive Species Inventories for Europe) project – a website inventory designed to provide the most up-to-date information on alien invasive species across Europe (see http://www.europe-aliens.org/). According to DAISIE, more than 11,000 invasive species have entered Europe.

PROJECT REMIT

The project remit required the assignment of a team of three scientists with special academic and professional qualifications and experience covering amphibian and reptile biology, welfare, ecology, and public health to investigate wildlife markets in the EU. Having been commissioned to undertake this research we were to conduct onsite inspections of the physical conditions at key wildlife markets and gather evidence, as well as conduct a desktop study of wildlife markets in the EU. EU events to be attended were Terraristika (Hamm, Germany), the IHS Show (Doncaster, UK) and Expoterraria (Sabadell, Spain).

Three primary subject areas were identified for focussed study:

ANIMAL WELFARE

- conduct observations of animal behaviour to assess arousal and discomfort states as they may relate to welfare
- conduct temperature monitoring of macro and meta environments to assess thermal conditions as they may relate to welfare

PUBLIC HEALTH AND SAFETY

- conduct observations of human visitor behaviour as may relate to potential hygiene and pathogen transfer issues
- conduct assessments regarding *in situ* public health and safety protocols

INVASIVE ALIEN SPECIES

- identify as many species as practicable to facilitate an assessment of invasive species potential
- review literature and current assessments of invasive species
- conduct assessments regarding potential ecological implications arising from animals kept and sold via wildlife markets

RELEVANT KEY LITERATURE

BRIEF OVERVIEW OF SOME KEY EXISTING REPORTS ON WILDLIFE MARKETS

It is not our aim to engage in a detailed critique of existing reports that relate to wildlife markets. However, it may be both useful and reasonable in the present context to assign, somewhat arbitrarily, a value scale to these reports acknowledging their level – ie status describable as scientific, semi-scientific or non-scientific.

Scientific

The following reports are written by authors including academically and/or professionally qualified scientists/biologists/veterinarians/medics and published in scientific publications and were subjected to full independent peer-review prior to publication: Brown (2004); Warwick (2004a,b); Karesh *et al.* (2005); Karesh *et al.* (2007); Burgos and Burgos (2007); Chomel *et al.* (2007). These are well-regarded, authoritative publications and are widely cited.

- **Brown** (2004) primarily focuses on emerging infectious disease and secondarily focuses on exotic pet matters and on wildlife markets as a notable infection hub, and other issues.

- **Warwick** (2004a) primarily focuses on captive reptile welfare and secondarily focuses on wildlife markets as a notable trade source, and other issues.

- **Warwick** (2004b) primarily focuses on gastrointestinal and zoonotic disease and secondarily focuses on exotic pet matters and on wildlife markets as a notable infection hub, and other issues.

- **Karesh *et al.*** (2005) primarily focuses on wildlife trade (including as pets) and emerging infectious disease and secondarily focuses on environmental matters and on wildlife markets as a notable infection hub, and other issues.

- **Burgos and Burgos** (2007) primarily focuses on wildlife trade (including as pets) and avian influenza transmission and secondarily focuses on wildlife markets as a notable infection hub, and other issues.

- **Karesh *et al.*** (2007) primarily focuses on wildlife trade (including as pets) and emerging infectious disease and secondarily focuses on environmental matters and on wildlife markets as a notable infection hub, and other issues.

- **Chomel *et al.*** (2007) primarily focuses on wildlife trade (including as pets) and emerging infectious disease, and secondarily focuses on environmental and ecological matters and on wildlife markets as a notable infection hub, and other issues.

Semi-scientific

The following reports are written by authors including academically and/or professionally qualified scientists/biologists/veterinarians/medics and published in semi-scientific publications and were subjected to limited independent peer-review prior to publication: Warwick *et al.* (2001); Warwick, Toland and Glendell (2005); Karesh and Cook (2005); Toland (2006); Warwick 2006; Altherr, Brückner and Mackensen (2010); Warwick, Lindley and Steedman (2011a,b). These are professional publications and moderately cited or very recently published and therefore citation frequency is unclear.

- **Warwick *et al.*** (2001) primarily focuses on zoonotic disease and secondarily focuses on exotic pet matters and on wildlife markets as a notable infection hub, and other issues.
- **Warwick, Toland and Glendell** (2005) primarily focuses on multi-factorial issues of wildlife markets and secondarily focuses on exotic pet matters, and other issues.
- **Karesh and Cook** (2005) primarily focuses on zoonotic disease and secondarily focuses on exotic pet matters and on wildlife markets as a notable infection hub, and other issues.
- **Toland** (2006) primarily focuses on multi-factorial issues of wildlife markets and secondarily focuses on exotic pet matters, and other issues.
- **Warwick** (2006) primarily focuses on zoonotic disease and secondarily focuses on exotic pet matters and on wildlife markets as a notable infection hub, and other issues.
- **Altherr, Brückner and Mackensen** (2010) primarily focuses on wildlife markets in the EU as a notable trade source and secondarily focuses on other issues. This is a detailed report by scientists for an animal welfare and conservation organisation.
- **Warwick, Lindley and Steedman** (2011a,b) primarily focuses on exotic pet welfare and public health for facility inspectors and secondarily focuses on wildlife markets as a notable trade source, and other issues.

Non-scientific/not-determined

The following reports are written by authors whose academic and/or professional status is unknown and published in non-scientific publications or self-published and were subjected to unknown or no confirmed peer-review prior to publication: **Anon** (2010a); **Colazzi** (2004); **Catchpole** (2006).

- **Anon.** (2010a) primarily focuses on wildlife markets, in particular, the Terraristika event and secondarily focuses on other issues. The document is a response by the organisers of the Terraristika event to **Altherr, Brückner and Mackensen** (2010). The status (professional or otherwise) of this document is unclear although detailed, recently published, and citation frequency is unclear.
- **Colazzi** (2004) primarily focuses on bird markets (including as pets) and secondarily focuses on legislation, and other issues.
- **Catchpole** (2006) primarily focuses on wildlife markets and secondarily focuses on wildlife markets as a notable infection hub, and other issues

The most EU-related of these reports are: Warwick *et al*. (2001); Karesh and Cook (2005); Warwick, Toland and Glendell (2005); Catchpole (2006); Warwick (2006); Toland (2006); Altherr, Brückner and Mackensen (2010); Anon. (2010a); Warwick, Lindley and Steedman (2011a,b).

PROTOCOL & METHODS

ANIMAL WELFARE ASSESSMENT

Each investigator engaged in one minute of observation at a selected location (eg a trader stall) by selecting a visually manageable number of animal containers (here we refer to this as an 'arbitrary grid') within line of sight (see Figure 1). Each arbitrary grid was presumed to be a reasonable representation of the entire trader stall. Test periods of five minutes observation were used to assess whether there was any observable difference between one minute and five minute observation periods and no significant difference was noted.

Animal welfare was assessed by observation of animal behaviour within the arbitrary grid. Signs of arousal and discomfort were regarded as determinate findings whereas an absence of signs was regarded as indeterminate. Determined signs of arousal and discomfort were regarded as indicators of prevalence. The number of determinate compared with indeterminate signs was used to establish prevalence. Other investigators of (reptile) behaviour have used three criteria for welfare assessment (Rosier & Langkilde, 2011), whereas we used seven criteria. Signs of arousal and discomfort were selected based on a practical short-list derived from Warwick (2004a) and Warwick, Lindley and Steedman (2011). The variable number of total animal containers observed at each arbitrary grid/stall visited was recorded first, followed by the number of target signs as shown in Figure 2.

Table 1 outlines the stress-related behavioural signs targeted for observation. The listed signs refer to captivity-stress-related behaviour that is abnormal, destructive, maladaptive, does not self-resolve, and is never desirably observed.

Monitoring of the thermal environment

Monitoring of macro and meta environments to assess thermal conditions was conducted using a thermal laser monitoring device, with temperatures taken at floor and table top levels at five locations throughout a large section of each event.

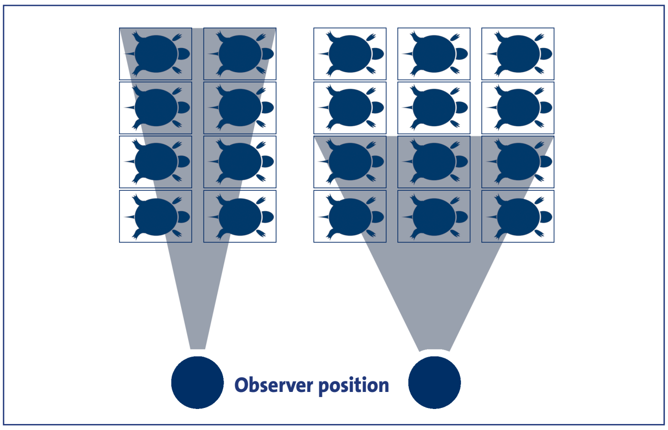

Figure 1. Line of sight. Animals were observed in arbitrary grid clusters that enabled both clear observation and quantification. For example, the diagram shows a cluster of 4 x 2 containers (total = 8) on the left and 2 x 3 (total = 6) on the right. The size and arrangement of cages determined the number of cages that could be effectively observed.

No.	10								
ITB	3								
HAC									
HAL									
RBM	2								
FLT									
HH									
INF	1								
OTH									

SAMPLE

Figure 2. Sample table giving recording method for signs of arousal and discomfort and related keys. ***Key***: *No. = number of containers observed in line of sight; ITB = interaction with transparent boundary; HAC = hyperactivity; HAL = hyperalertness; RBM = rapid body movement; FLT = flattened body posture; HH = head-hiding; INF = inflation of the body; OTH = other significant sign (eg rostral lesion)*

Table 1. Behavioural signs of captivity-stress (derived from Warwick 2004a and Warwick, Lindley & Steedman 2011).

Signs	Behaviour	Aetiology
Persistent (up to 100% activity period) attempts to push against, crawl up, dig under or round the transparent barriers of their enclosure	Interaction with transparent boundaries (ITB)	Stress. Related to exploratory and escape activity. Self-compounding and destructive. Inherent psychological organisation and adaptational constraints result in failure to recognise abstract invisible barriers.
Abnormal high-level physical activity, surplus or redundant activity	Hyperactivity	Stress. Often associated with ITB. Overcrowding. Self-compounding and destructive. Overly restrictive, deficient and inappropriate environments
Abnormal high level of alertness 'nervousness' to environmental stimuli	Hyperalertness	Stress. Often related to fear, defence and escape behaviour. Common in overly restrictive, and exposed, deficient and inappropriate environments.
Abnormal 'jerky' locomotor or jumping actions.	Rapid body movement	Stress. Often related to fear, defence and escape behaviour, common in overly restrictive, and exposed, deficient and inappropriate environments.
Flattening of body against a surface often combined with hyperalertness	Flattened body posture	Stress. Often related to fear, defence and escape behaviour. Common in overly restrictive, and exposed, deficient and inappropriate environments.
Deliberate seclusion of head under objects or substrate.	Head-hiding	Stress. Often related to fear or light stress behaviour. Common in overly restrictive, and exposed (including light for nocturnal species), deficient and inappropriate environments.
Deliberate inflation (may be accompanied by repeated inflation and deflation) of the body.	Inflation of the body	Stress. Often related to fear, defence and escape behaviour. Common in overly restrictive, and exposed (including light for nocturnal species), deficient and inappropriate environments.

Note: *We elected to observe for stress-related signs of arousal and discomfort and non-determinable signs, rather than for signs of quiescence and comfort for two reasons: 1. Signs of quiescence and comfort generally require longer observation periods to establish and also typically require a range of behaviours and sufficient interaction with the spatial environment in order to evaluate. The conditions at the markets, in particular the spatial limitations of enclosures, are not amenable for sufficient evaluations of quiescence and comfort and while some enclosures were, for instance, capable of containing a heat lamp and basic furnishings, and thus could have enabled observation for signs of quiescence and comfort, we considered that the very minimal representation of these types of enclosures at markets prohibited appropriate assessment; 2. Given some of the difficulties involved in establishing these signs, the additional time burden versus collectable information was considered unjustifiable. Animals showing no determinable signs were recorded as 'non-determinable' and this neither implies that the animals were stressed nor unstressed, merely that insufficient signs were observed to make a determination during the observation period.*

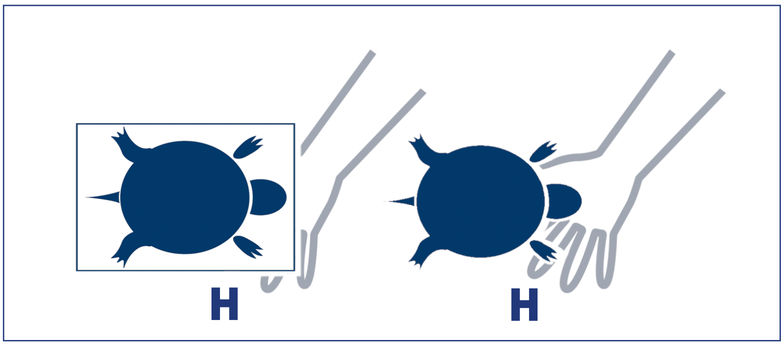

Figure 3a. Initial mode of contact observation system. H = hand. Left = indirect contact with an animal (eg with container, table, seller). Right = direct contact with/handling of an animal.

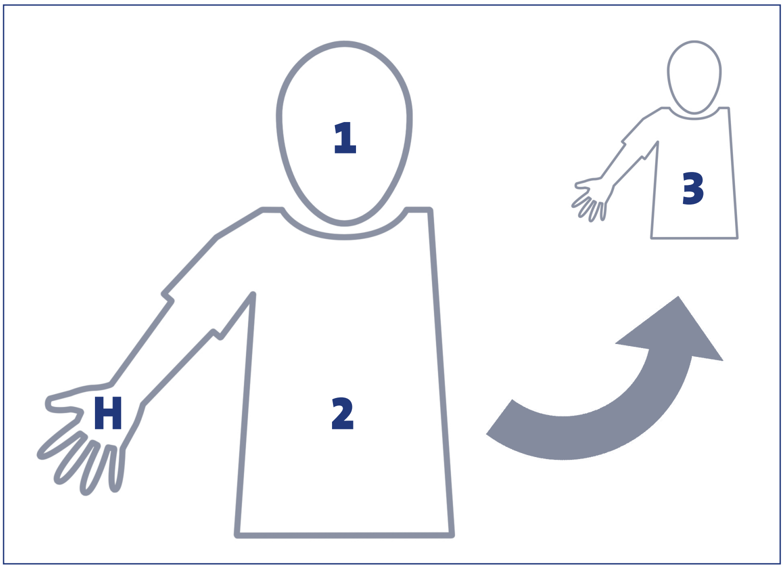

Figure 3b. Subsequent mode of contact observation system. H = hand (+ contact): H1 = observed contact between hand and head (inc mouth); H2 = observed contact between hand and body or clothes; H3 = observed contact between hand and another individual.

No.	10									
H1	1									
H2										
H3										
D	2									
IND										

SAMPLE

Figure 4. Mode of contact recording system. ***Key***: *H1 = contact between contaminated object (eg hand) and head (inc mouth); H2 = contact between contaminated object (eg hand) and body or clothes; H3 = contaminated person-to-person contact; IND = indirect contact with an animal (eg with container, table, seller); D = direct contact with/handling of an animal*

HUMAN HEALTH AND VISITOR BEHAVIOUR ASSESSMENTS

Hygiene and potential pathogen transfer were assessed by observation of public visitor and trader behaviour, with special reference to contact involving animals, animal containers, related intermediary surfaces (such as table tops), as well as contacts involving hands, body and clothing.

Contact between traders and the public was also noted, including such issues as the shaking of hands, exchange of money, and contact with other intermediary items. All items (including animals and inanimate items) directly associated with the sellers' stalls were presumed contaminated. Pathogen transfer is well know to be liberally disseminated in respect of any local contamination source, and it is reasonable to anticipate that on a stall at which animals are sold, all animals and related material will probably have been affected by microbial transfer and dissemination.

Each investigator engaged in five minutes of observation at a location (eg. a trader stall) and noted all visitor contact behaviours. Figures 3a,b outlines the mode of contact observation system. If an individual made any initial 'direct' or 'indirect' contact with a presumed contaminated source they were further observed to establish whether they subsequently touched their own head, body or other person.

Observed behaviours were then recorded for each contact category using a recording system involving the key abbreviations (see Figure 4).

Hygiene efforts (referring to intentional efforts of a person to sanitise their hands or related action) were not formally tabulated. Regardless of this information not being formally recorded, no individuals were observed using sanitiser products during our five-minute observation periods.

INVASIVE ALIEN SPECIES ASSESSMENT

Establishing species taxonomic and biological profile provided the fundamental data on which invasive species potential would be based. One investigator was assigned the primary duty of identifying amphibian species present, while another was assigned the primary duty of identifying reptile species present. Where doubt existed regarding species taxonomic status, these examples were photographed and assessed at a later time. Photographs were also taken to confirm identification when it was believed that species were mislabelled.

Once taxonomically confirmed, the invasive history or invasive potential of each species was determined based on records obtained from general literature searches and specific sources of data on invasive species including Kraus (2009), distribution data from the IUCN Red List of Threatened Species, version 2011.11 (http://www.redlist.org), Invasive species of South Africa (http://invasives.org.za), Bomford (2008); Bomford *et al.*, (2009) and Henderson and Bomford (2011). These sources provided information for a risk assessment based on the following criteria: history of invasion, number of times introduced (propagule pressure), climate matching and taxonomic relationship with a known IAS. In summary, species that had a known history of invasion were labelled 'IAS'. Following this, each species was assessed in terms of its potential to become invasive based on additional factors and traits such as popularity in the pet trade, high reproductive potential and tolerance in terms of thermal and dietary requirements. This provided a very arbitrary assessment of invasion risk using rankings of low, moderate, high, serious and extreme, dependent on the level of risk. We will consider all forms of invasion as critical events.

For the purpose of providing a snapshot of the potential risk of species becoming well-established invasives in Europe, we focused on the species with a history of invasion and those with a historical invasion risk of 'serious' or 'extreme', although lower levels of risk are also included. Relevantly, certain species, for example some South American species, are known to constitute serious or extreme risks in some regions, but are unlikely invaders in cooler or highly variable temperature and less humid zones as typically found in Europe.

However, as a supplementary consideration we have included potential IAS derived from our own 'intuitive-risk' concept, which is based on established risk factors plus our interpretation of 'species overall plasticity'. Relatedly, we have graded these separately with 'low' to 'extreme' based on how this potential risk may vary with cooler or warmer EU zones. As discussed later, we considered our approach to be conservative. Figures 12 and 13 summarise our IAS 'intuitive-risk' assessment and Appendix 4 (Tables A-E) addresses specific species.

RESULTS

ANIMAL WELFARE

Figures 5, 6 and 7 present a breakdown of the combined data on 1,533 welfare based observations (776 at Terraristika, 339 at the IHS Show and 418 at Expoterraria) of prevalence of stress-related behaviour, and proportion of observed stress-related behaviour. These data show that within one-minute observation periods stress-related behaviour prevalence was: interaction with transparent boundary 27.5%; hyperactivity 11%; hyperalertness 1.8%; rapid body movement 2.1%; flattened body posture 2.4%; head-hiding 4.6%; inflation of the body 0.5%; other significant sign (eg. rostral lesion) 1.0%.

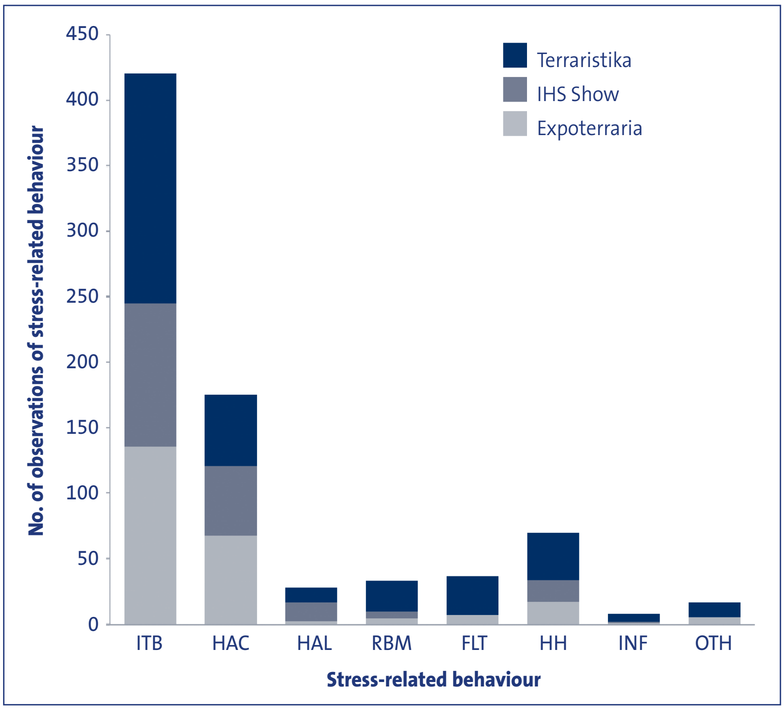

Figure 5. Stress-related behaviours among amphibians and reptiles at European markets during 1 minute observation periods. The number of containers/animals observed in line of sight was 776 (Terraristika), 339 (the IHS Show) and 418 (Expoterraria). ***Key***: *ITB = interaction with transparent boundary; HAC = hyperactivity; HAL = hyperalertness; RBM = rapid body movement; FLT = flattened body posture; HH = head-hiding; INF = inflation of the body; OTH = other significant sign (eg. rostral lesion)*

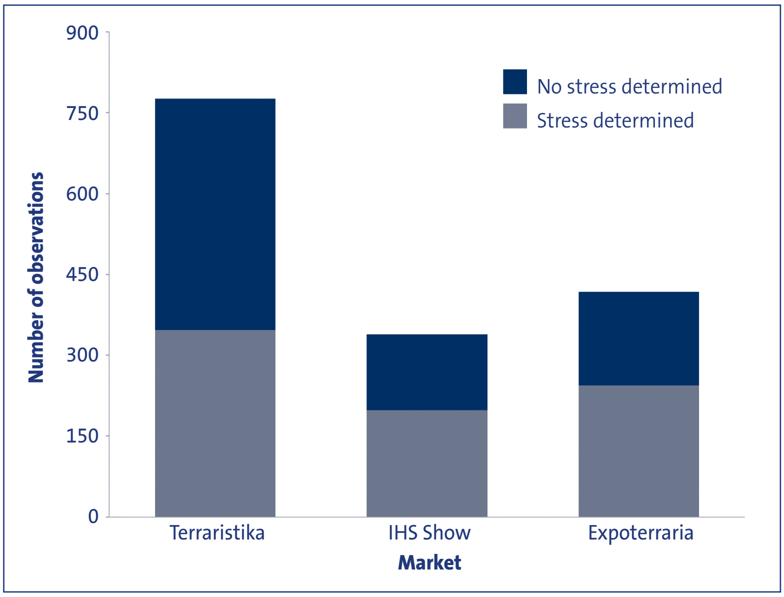

Figure 6. Proportion of animals exhibiting determined stress-related versus undetermined (no visible stress signs observed at time) behaviours at European markets during 1 minute observation periods. The number of containers observed in line of sight was 776 (Terraristika), 339 (the IHS Show) and 418 (Expoterraria).

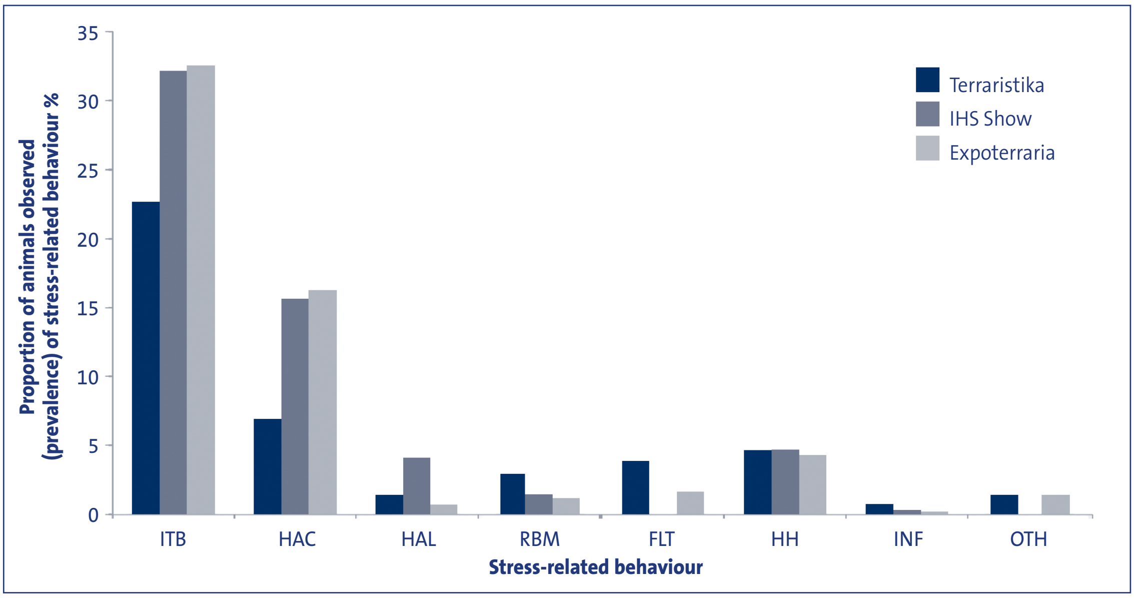

Figure 7. Proportion of animals exhibiting specific stress-related behaviours during display at European markets during 1 minute observation periods. The number of containers observed in line of sight was 776 (Terraristika), 339 (the IHS Show) and 418 (Expoterraria). ***Key:*** *ITB = interaction with transparent boundary; HAC = hyperactivity; HAL = hyperalertnes; RBM = rapid body movement; FLT = flattened body posture; HH = head-hiding; INF = inflation of the body; OTH = other significant sign (eg. rostral lesion)*

Monitoring of the thermal environment

Monitoring of macro and meta environments to assess thermal conditions was conducted using thermal laser monitoring device, with temperatures taken at ground and table top levels. Readings were taken centrally and peripherally within the main hall (inside the event building), as well as ambient-climatic (outside the event). Table 2 lists thermal recording obtained.

Table 2. Thermal recordings at three exotic pet market events

Event	Temperature recording (°C)		
	Floor level	Table-top level	Ambient/ Climatic
Terraristika	25	29	31
	24	27	
	22	29	
	29	33	
	25	29	
IHS Show	25	26	26
	25	27	
	23	26	
	25	28	
	23	27	
Expoterrraria	27	28	29
	28	27	
	26	27	
	26	27	
	28	27	

PUBLIC HEALTH AND VISITOR BEHAVIOUR

For all three markets, a total of 813 members of public visitors were observed as they attended vendors. Of these, 29 (3.6%) made direct contact with an animal and 222 (27.3%) made indirect contact through touching containers, tables and other materials at a stall (Table 3). This pattern of behaviour was consistent between markets with the majority of observed visitors to vendors making indirect contact with animals through touching animal housing, tables, sellers, money and other merchandise associated with vendors. The proportion of these visitors that engaged in subsequent modes of contact was 18.7% hand to mouth (H1), 52.2% hand to body (H2), and 19.9% person to person (H3) (Figure 8). Figure 9 provides the breakdown of these contact behaviours for each of the three markets visited.

The proportion of visitors to vendors that engaged in contact behaviours at each of the markets is illustrated in Figure 10. The patterns of contact were similar between each of the visibly larger events (Expoterraria and Terraristika) however, at the IHS Show, during the five-minute periods of observation, no direct contact with animals was seen. This may partly reflect the location of the IHS Show event – a leisure centre where many attendees were families and appeared to be visiting the linked pool, shops and other recreational facilities and

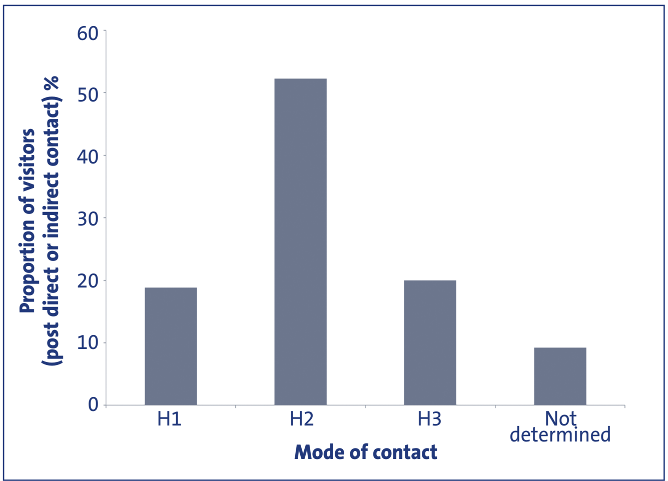

Figure 8. The proportion of visitors to vendors making subsequent modes of contact having initially contacted a presumed contaminated source. ***Key:*** *H1 = observed contact between hand and head (inc mouth); H2 = observed contact between hand and body or clothes; H3 = observed contact between hand and another individual. Total number of visitors making direct and indirect contact was 251.*

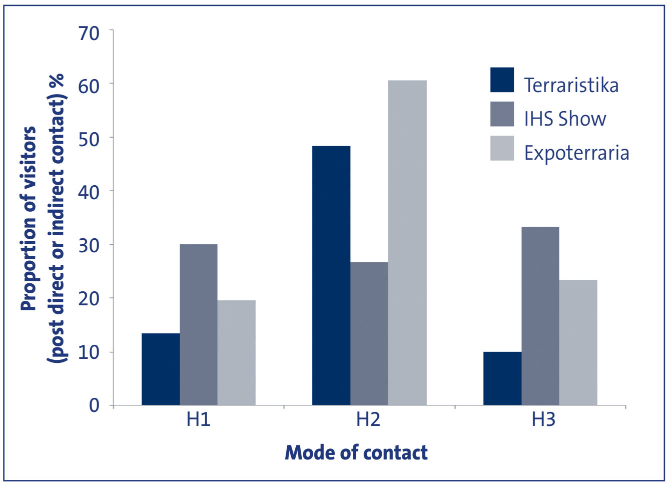

Figure 9. The proportion of visitors to vendors at each market making subsequent modes of contact having initially contacted a presumed contaminated source. ***Key:*** *H1 = observed contact between hand and head (inc mouth); H2 = observed contact between hand and body or clothes; H3 = observed contact between hand and another individual. Total number of visitors making direct and indirect contact was 251.*

Table 3. The number of visitors to vendors at three European markets and the proportion that engaged in direct and indirect contact with presumed contaminated sources.

Total number of visitors *	Mode of contact	
	Direct	Indirect
813	29 (3.6%)	222 (27.3%)

** Cumulative total of visitors to vendors recorded during five-minute observation periods.*

may have entered the pet market for its 'entertainment' value rather than intending to purchase animals. Regardless, numerous direct contact episodes did occur at the IHS Show that were noted informally and indirect contact with cages and other vendor items was common.

We again emphasise that these data were acquired during five-minute observation periods and as such these provide 'snapshots' of general conditions. Therefore, other relevant additional behaviours may occur that were not observed and recorded.

Relatedly, at Terraristika, for example, many transactions took place very soon after admission was permitted and numerous rapid sales and pre-ordered multiple-animal consignments involved considerable direct animal handling episodes but were not recorded during our formal observations.

Disinfectant hand gels were proportionately more widely available at the IHS Show than at Terraristika,

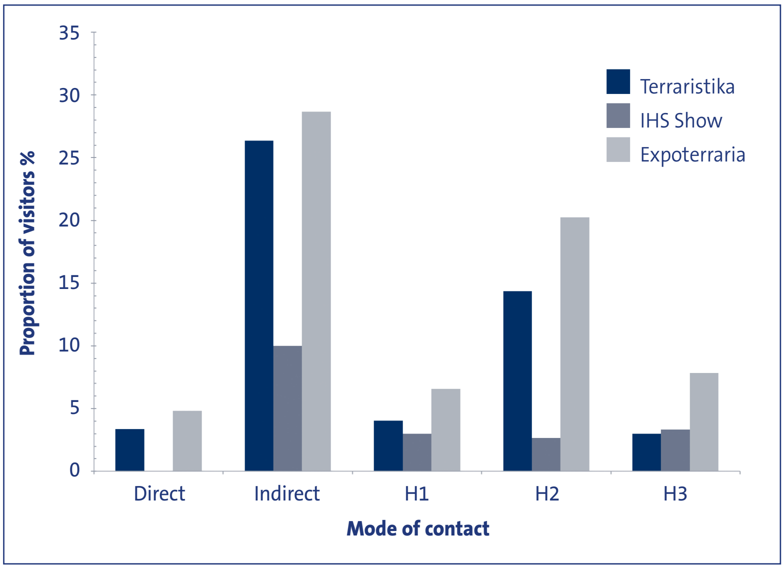

Figure 10. Public health and visitor behaviour at three European markets. The total number of observed visitors to vendors was 813 (395 at Expoterraria; 300 at Terraristika; 118 at the IHS Show). ***Key****: Direct = direct contact with an animal; Indirect = indirect contact with an animal (eg. with container, table, seller). H1 = observed contact between hand and head (inc mouth); H2 = observed contact between hand and body or clothes; H3 = observed contact between hand and another individual.*

although visitors rarely used these products, whereas no disinfectant products were noted at Expoterraria.

At all events person-to-person contamination is likely to rapidly increase its representation as presumed contaminated attendees move around a venue and readily form incidental contacts with a large number of people.

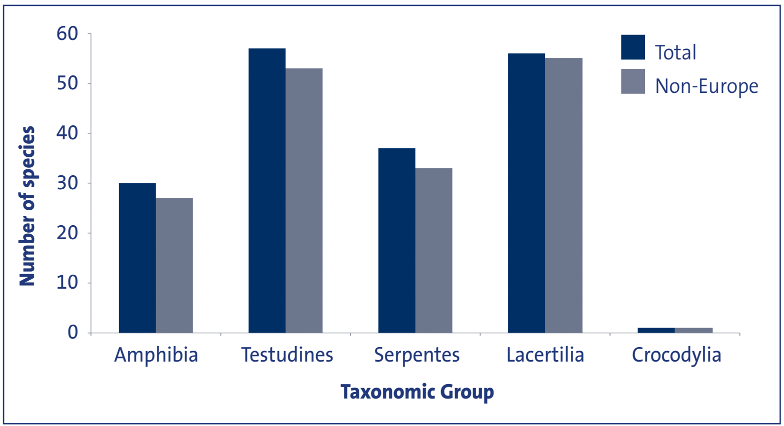

Figure 11. Total number of non-European species of amphibian and reptile present at three European markets.

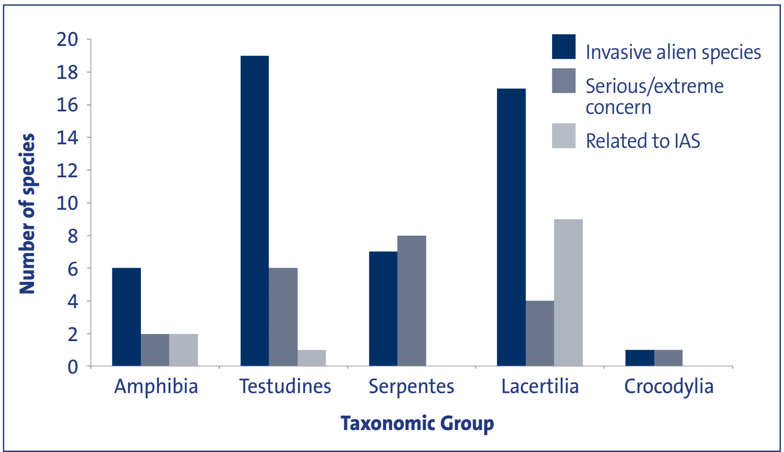

Figure 12. Number of recognised Invasive Alien Species of amphibian and reptile recorded at three European markets including those with an invasion risk of 'serious' or 'extreme', in addition to species taxonomically related to IAS.

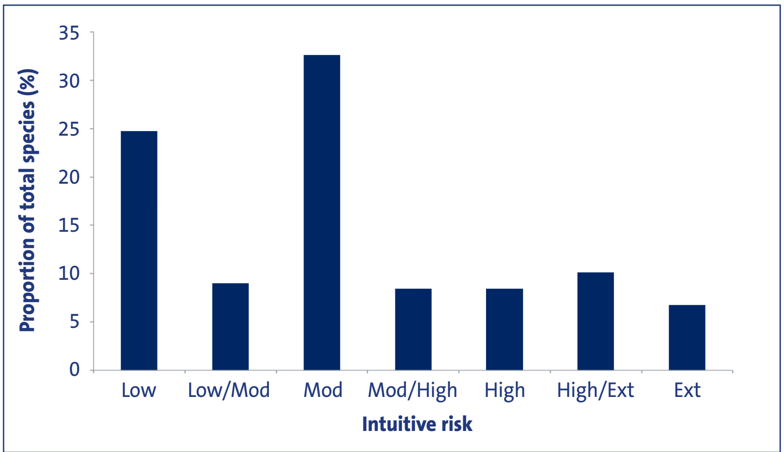

Figure 13. Intuitive invasive risk of amphibian and reptile species present at three European markets. Classification of each species was based on historical and phenotypical data and overall plasticity. Mod = moderate; Ext = extreme.

INVASIVE ALIEN SPECIES

In total, 179 species of amphibian and reptile were identified at the Terraristika, the IHS Show and Expoterraria markets (see Appendix 3). All species were then assigned to their appropriate taxonomic group, country of origin, classification in terms of invasive history and level of invasive risk based on the literature (Appendix 4, Tables A-E). It is important to note that even though a species may been recognised as an IAS, other factors such as climate, reproductive biology or dietary constraints, may have resulted in the species being considered a 'low' or 'moderate' risk in terms of invasive potential. Furthermore, for reasons noted below (see **Wild-caught versus captive-bred animals on offer**) it was difficult to ascertain with certainty whether some amphibians and reptiles offered for sale were wild-caught or captive-bred and this ratio clearly varied between the three European markets. Regardless, a species' origin plays a key role in determining its potential to become invasive.

Country of origin

The majority of species of amphibian and reptile offered for sale at the three European markets did not originate from Europe (Figure 11, Appendices 3 and 4: Tables A-E).

Of the 30 species of amphibian recorded at the three markets, 27 (90%) originated from Central and South America, Africa (including Madagascar), the USA, Asia and Australia (including Papua New Guinea).

Of the 57 species of Testudines recorded at the three markets, 53 (93%) originated from Central and South America, the USA, Asia, Africa (including Madagascar), Canada, and Australia (including Papua New Guinea).

Of the 37 species of snakes (Suborder: Serpentes) recorded at the three markets, 33 (89%) originated from the USA, Asia, Central and South America, Africa (including Madagascar), and Australia (including Papua New Guinea).

Of the 56 species of lizard (Suborder: Lacertilia) recorded at the three markets, 55 (98%) originated from Central and South America, Africa (including Madagascar), the USA, Asia and Australia (including Papua New Guinea).

The only crocodilian offered for sale was the spectacled caiman (*Caiman crocodylus*) which originated from Central/South America.

Figure 12 illustrates the number of species recorded at the attended European markets that were classed as IAS, related to IAS and those given an invasion risk of 'serious' or 'extreme'.

Approximately 28% of species noted at all three European

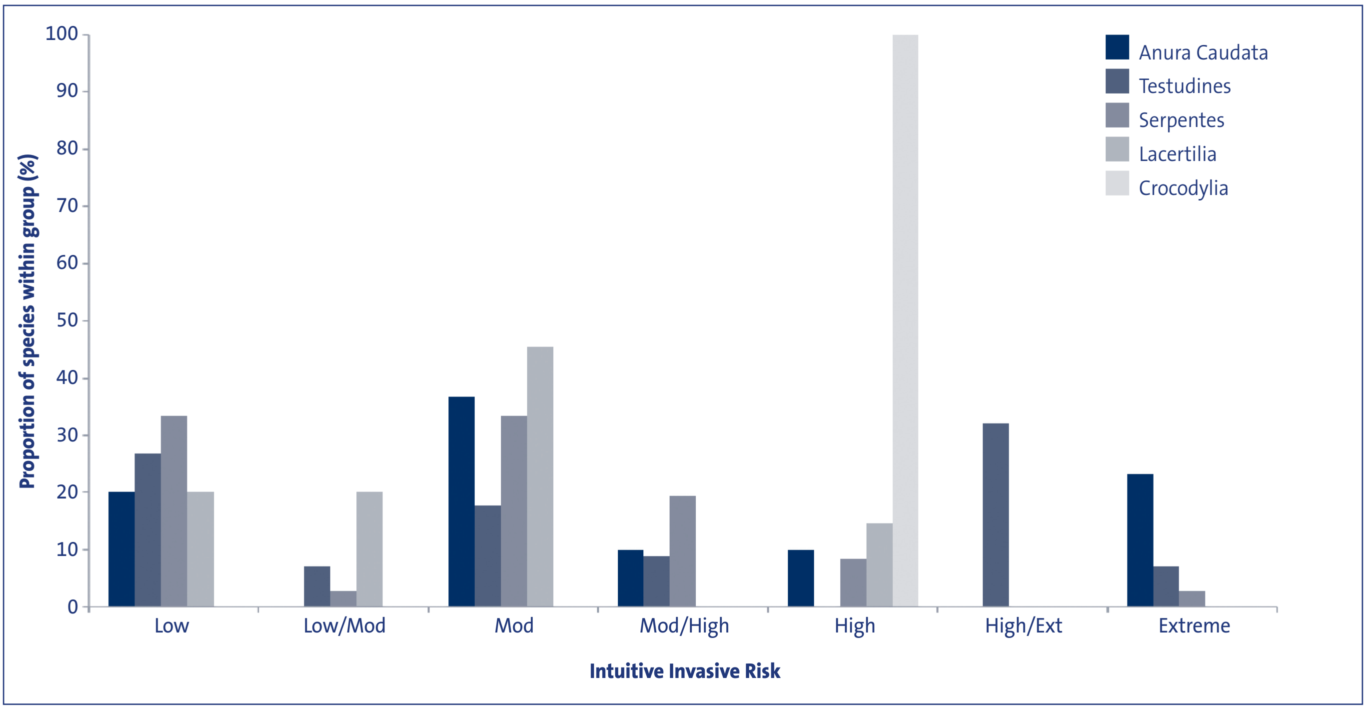

Figure 14. Intuitive invasive risk of amphibian and reptiles species by taxonomic group.

markets had a recorded history of being an IAS. This represents 50 of the 179 species of amphibian and reptile present at these events. The disparity between the number of IAS and those species with an invasion risk of serious or extreme, is due to the number of IAS that to date, are still ranked as low to moderate risk of widespread invasion.

The number of species that are related to known invasive taxa (either species, genera or family) was 2 (Amphibia), 1 (Testudines) and 9 (Lacertilia). These included newts in the genus *Triturus*, turtles in the genus *Trachemys* and lizards in the genera *Anolis*, *Chamaeleo*, *Phelsuma*, *Tupinambis*, *Rieppeleon* and *Varanus* (see Appendix 4, Tables A-E).

The intuitive invasive risk (IR) of all species is illustrated in Figure 13. For this analysis, all species were pooled and allocated to an appropriate risk factor category. Approximately 25% of species were ranked with a 'low' IR, 9% were ranked with a 'low to moderate' IR, 33% were given a 'moderate' IR and 8% were ranked with a 'moderate to high' IR. Twenty five percent of all species were assigned an IR factor between high and extreme (Figure 13).

The intuitive risk for invasion of all species was broken down further into taxonomic groups (Order and Suborder) (Figure 14). The 100% IR factor for Crocodylian species simply indicates the presence of one potentially highly invasive species, *Caiman crocodylus*.

DISCUSSION

ANIMAL WELFARE

We consider that the one-minute observation period for target signs was sufficient for assessment of overt behavioural abnormalities. Important behavioural signs were noted within the one-minute period, and on-site sampling of one-minute versus five-minute periods showed no difference in either type or prevalence of signs. It is possible that significantly longer observation periods may have revealed additional target and other signs. However, we consider that the observed signs offered important insight into both the type of behaviours and their prevalence among amphibians and reptiles at exotic pet markets. Some abnormal and stress-related behaviours (for example hypoactivity) require long observation periods to assess, and others require animals to be observed as groups (for example co-aggression). We did not observe for these behaviours due to both the dynamic nature of seller actions (for example moving animals and containers around a stall and housing them individually) and because of time constraints. However, by not observing-for these additional signs this does not detract from our establishment of the presence and prevalence of target signs of stress. Accordingly our data show determined compared with undetermined findings – 'undetermined' meaning that no visible signs of stress were seen at the time of observation.

Intuitively, the longer the observation period the greater are the probabilities of observing a range of behaviours. Indeed, it would be expected that the level of stress exhibited by species that were crepuscular or nocturnal (such as many gecko lizards and amphibians) would rise throughout the day of exhibition, particularly if they were not presented with some form of temporary respite from exposure in terms of shelter. Zero recorded signs of stress in the context of medium or long observation periods may indicate no or low prevalence of significant animal welfare problems and concerns. Few or many recorded signs of stress in the context of medium or long observation periods would indicate the presence of significant animal welfare problems and concerns. In effect, a greater number of observations of stress signs seen during a shorter observation period reveals a greater problematic prevalence and suggests significant concern for animal welfare. Our findings show that many recorded signs of stress can be observed during short periods.

Behavioural signs of stress in animals were broadly the same at all events. Where variations in prevalence of stress-related behaviours occurred we attribute this largely to the physical nature of venue set-up rather than major differences in stress aetiologies. For example, signs of 'head-hiding' (HH) were less commonly recorded at the IHS Show, which may be due to the fact that opportunities to head-hide (for instance using substrate or cage furnishings) were lower there because many cages had no floor coverings or other useable features in which to head-hide. Similarly, at Expoterraria a large number of animals were confined in containers that did not permit sufficient physical movement to observe interaction with transparent boundaries (ITB) thus this lack of behavioural opportunity probably accounts for the comparatively lower prevalence of ITB in that case.

Spatial restrictions for animals in enclosures at markets were extreme and severe and a likely major factor in stress associated with these events. As noted above, the absence of substrate in containers was particularly prevalent at the IHS Show. Apart from depriving the animals of opportunities to hide or burrow, this deficiency also compels animals to be in contact with a non-absorbent surface and possibly faeces or urine, which can negatively impact on animal health. Relatedly, 'light-stress' is likely a major stressor for many animals, in particular nocturnal species such as some gecko lizards, which were also major components of all events.

We did not attempt to make any focussed assessment of the physical condition of the animals present. Physical examinations commonly require approximately 10-20 minutes per animal to conduct and such exploration was not possible. We did maintain a general awareness for any overt signs of injury or clinical disease and, while our observations cannot take into account subtle signs that may be revealing on closer inspection nor indeed could we view all animals, we can report that very few animals were observed that showed overt signs of injury or clinical disease. Exceptions included rostral lesions, emaciation, damaged claws and tails, open-mouth breathing, depressed behaviour, and probable dietary-related skeletal issues (for example, metabolic bone disease). We emphasise that these signs of injury and disease were observed in a small minority of animals, although these problems are important. The fact that overt injuries and clinical disease was infrequently noted does not rule out the possibility that animals could have underlying subclinical health problems.

However, our study shows that signs of stress in both amphibians and reptiles at exotic pet markets are highly prevalent. Whether or not long observation periods would reveal additional signs of stress is unknown. Regardless, our observations indicate that significant animal welfare problems are associated with exotic pet markets and that key current concerns are justified.

Thermal considerations

The thermal environments at all three events were significantly determined by the ambient climatic conditions. We remain unclear as to whether the internal thermal controls for the buildings were capable of (and/or may be used towards) maintaining a generally acceptable background temperature. Accordingly, we cannot determine whether, had the ambient climatic temperature been unacceptably low or high, that the animals would have been affected by such change.

In the context of the diversity of species observed at all three events, we did not consider the thermal range to be *directly* problematic and harmful. This is because, in our view, none of the thermal values appeared to exceed the normal thermal ranges of the species observed. This does not imply that the thermal environment was 'correct' for any species (a single temperature for a species would be abnormal and may also be potentially harmful), rather that the observed temperatures did not fall outside a range that any one species observed might be expected to safely occupy.

At all three events, the great majority of animals had no dedicated heat source, either in the form of background or focussed sources. At all three events, a number of containers possessed dedicated light sources, but these were commonly the light emitting diode (LED) type and were for illumination purposes only. None of the enclosures observed at Terraristika, the IHS Show or Expoterraria had spatial dimensions of sufficient size to enable appropriate thermal gradation and thus holistic thermoregulation by occupants.

Our primary concern regarding the thermal environment as observed involves the lack of provisions that would enable animals to holistically thermoregulate. As indicated above, this general deficiency was universally observed at all three events. Thermoregulation, including maintaining subtle changes in body temperature, is highly important to health and welfare for many animals. In ectothermic animals (which includes both amphibians and reptiles) a regular response to stress (including from emotional stress, handling and transport, cage restriction, exposure to perceived potential predators such as humans, disease, and many other stressors) is to elevate body temperature by seeking a focussed heat source. This 'behavioural' or 'emotional' fever response corresponds to physiological fever in endotherms such as birds and mammals and is fundamental to wellbeing, controlling the prevention or progression of disease and to recovery. In addition, ectotherms will often seek out raised heat sources post-feeding to facilitate the digestive process (this is particularly true of snakes). If this cannot be achieved, their food may not be properly digested. Failure to provide for this need to thermoregulate constitutes poor husbandry practice and is in our view tantamount to animal abuse. That the animals are confined to these thermally highly restrictive conditions, even for a few hours, may result in either short- or long-term compromised health.

Reptiles that were provided with dedicated and focused heat sources ('hotspots') almost invariably utilised those hotspots by basking behaviour, indicating that higher than background temperatures were required at times. This confirms our position that despite reasonable background temperatures focused heat sources are important and wrongly absent in the market environment. Because background temperatures were within 'comfort zones' for the animals, we postulate that animals with basking opportunities probably sought to raise their body temperatures at least in part due to stressful conditions. It is highly probable that the generalised absence of dedicated focused heat sources creates an environment in which animals are deprived of important thermoregulatory needs.

General issues

The proximal positioning of predator and prey animals, whether in or out of visual range of each other is likely to cause many prey animals stress, and this represents a ubiquitous problem throughout the market environment. Both chemical and visual cues are likely to convey potential predatory threats to some animals that are already trapped in small containers and therefore at potentially increased perceived vulnerability.

Many species utilise seismic (vibrational) cues to detect prey and, more relevantly here, also to detect predator approach. The market environment is richly 'polluted' with such background stimuli, such as the movements and vocalisations of people and the touching and handling of animal containers, and at least some of this is likely to act as a general stressor for many animals.

The dearth of furnishings in most containers is highly concerning. Not only do furnishings offer opportunities for seclusion and active and passive behaviours, but also for some species, such as semi-aquatic turtles and semi-aquatic or aquatic amphibians, furnishings offer important occupation zones in or on which animals can rest. The absence of such provisions forces many animals to swim or struggle to reach the surface and this may be both stressful and energetically demanding and can result in stress and exhaustion.

The large accumulations of animals at pet markets from diverse world regions and sources, together with their routine proximal location with others, as well as the frequent handling and indirect communication introduces a considerable concern regarding potential transference of pathogens and cross-contamination between sick and healthy individuals.

PUBLIC HEALTH AND VISITOR BEHAVIOUR

We consider that the five-minute static observation period for target activities was sufficient for assessment of potential microbial contamination and transference. Target activities were noted within the five-minute period, and indeed a shorter observation period may have been as informative. However, a longer static observation period would unlikely have been more informative because the general through-put of the public arriving at, inspecting and then leaving the seller stall frequently occurred within a five-minute period. Mobile observation periods that involve monitoring the actions of people moving through the venue may have been additionally informative in revealing certain incidental contacts, although given the relatively crowded nature of the events these additional contacts may reasonably be presumed to occur without specific observation.

Our data show that both opportunities and actual direct and indirect contact with presumed contaminated animals and inanimate items constitute a significant and major concern. Relatedly, these problems are unresolvable given the format of the exotic pet market environment.

The rapid dispersal of attendees (with and without animals) on conclusion of the events means that the potential pathogenic microbial dissemination is both swift and pervasive. Relatedly, the observed lack of recording purchaser details and low availability of seller details means that in the event of a disease outbreak or major epidemic linked to animals acquired at an exotic pet market, contact-tracing of potentially infected persons and thus epidemiological containment would be curtailed or thwarted.

At Expoterraria, while there appeared to be less direct handling of animals from the small containers, some animals were accessible, and where this was available the handling of animals, including by small children, was regular and sometimes intensive. Also at Expoterraria food and drink was being served centrally in the main animal market hall, and this represented a strong direct public health concern.

INVASIVE ALIEN SPECIES

It has recently become clear that the factors affecting the successful establishment of exotic species of amphibians and reptiles can be very complex. Major factors in the successful invasion of a species (from introduction through to establishment and widespread ecological sequelae) include: a proven history of invasion; climate matching; and taxonomic relationship of species to a known invasive alien species (IAS) (Bomford *et al*., 2005; Bomford, 2008).

In this investigation, these factors played a key role in determining the potential for species of amphibian and reptile to become successful invaders once they entered Europe through trade markets. Thus our assessment of amphibian and reptile invasive potential is based primarily on past history of invasion, the number of times a species has been introduced to a novel environment, climate matching (which we refer to as 'climate-facilitated distribution') and taxonomic relationship with a known IAS. Furthermore, we have expanded on issues of behavioural and phenotypic plasticity and how conditions imposed by captivity may result in some degree of channelling this plasticity towards enhanced IAS potential. As stated elsewhere, we have devised a supplementary approach to IAS assessment using the 'intuitive-risk' concept, which is based on considering and balancing a variety of factors including historical risk factors plus our interpretation of 'species overall plasticity'.

Approximately 28% of species noted at all three European markets had a recorded history of being classified as an IAS. These included the African clawed frog (*Xenopus laevis*), cane toad (*Bufo marinus* = *Rhinella marina*), Zaire dwarf clawed frog (*Hymenochirus boettgeri*), common snapping turtle (*Chelydra serpentina*), painted terrapin (*Chrysemys picta*), spiny softshell turtle (*Trionyx spiniferus*), Burmese python (*Python molurus bivittatus*), green iguana (*Iguana iguana*) and spectacled caiman (*Caiman crocodylus*). Detailed discussion of all species would be impractical. However, the extent to which some of these confirmed IAS are already present or are likely to become established within the EU will be discussed.

An example involves *Xenopus laevis*, native to Africa, and one of the most widespread amphibians in captivity, which appears to be well established in some EU states, particularly those that experience a 'Mediterranean' climate. As indicated earlier, populations of this species have become established in Wales (Measey & Tinsley, 1998) and Portugal (Rebelo *et al*., 2010) and a large population has been recorded in Sicily (Faraone *et al*., 2008; Lillo *et al*., 2005). It has also been recorded from areas in western France (Fouquet & Measey, 2008). *Xenopus laevis* has a very high reproductive potential, is an opportunistic species and able to colonise non-flowing water-bodies with ease. When breeding sites dry up, *Xenopus* is able to migrate in wet conditions, which facilitates its ability to spread (Faraone *et al*., 2008).

Of extreme concern is that it is thought that *Xenopus* has been acting as a host for the fungus responsible for chytridiomycosis across the world without itself being affected by the disease. The causal fungus (*Batrachochytrium dendrobatidis*) is listed as one of world's worst invasive species and it has been suggested that the long history of trade in this *Xenopus*, for both research and recreation, has significantly contributed to the spread of chytridiomycosis across the world (Weldon *et al*., 2004). It is disturbing that this species is still being sold in European exotic animal markets and still touted as an ideal 'beginner's frog' through the pet trade. The expansion of chytridiomycosis is one example among very many and diverse scenarios demonstrating the inability of the commercial pet trading community to regulate dangers inherent to its operations.

Another example involves the cane toad (*Bufo marinus*, which has recently been renamed as *Rhinella marina*) native to Central and South America. This notorious coloniser is, as yet, not recorded in European habitat. However, given the species tolerance of a broad range of habitats and climates, as well as its status as one of the world's most invasive animals, its presence within European exotic animal markets signals the low or absent awareness among traders and other market proponents of the established threats these animals pose. This ignorance (or disregard) is of great concern.

A further example involves the common snapping turtle (*Chelydra serpentina*), which is native to North America, Central America and northern South America. The international pet trade is responsible for its introduction into various areas in Europe including Italy, the Canary and Balearic Islands, and Mallorca (Pinya & Carretero, 2011). In Italy, large, sexually mature specimens have been found in water bodies across the country. Early in 2011, a 20 kg (44 lb) specimen was captured in a canal near Rome (Corriere Della Sera, 2011) and anecdotal evidence suggests that the species is quite widespread in this region. Furthermore, specimens representing at least two different age groups were removed from a pond in the village of Renens, Switzerland in June 2011 (Parlange, 2011). In 2004, adult specimens were captured or observed crossing roads in Mallorca (Pinya *et al*., 2007). In recent times, Italy has recorded other introduced species including rattlesnakes, a "3-foot long iguana", an alligator and a python and their presence is being blamed on the "growing" practice of abandoning exotic pets (UPI, 2010).

There are many other species of amphibian and reptile IAS that could be discussed here. However, just as it is important to focus on those species that are recognised IAS, it is of equal importance to focus on the issue of *potential* invaders and the processes involved in enabling them to become successfully established within Europe and other non-native regions. The following sections deal with the concept of phenotypic plasticity and the traits that will potentially favour the successful establishment of alien species of amphibians and reptiles in Europe.

Tolerable thermal range and climate-facilitated distribution

Tolerable thermal ranges for amphibians and reptiles are not comprehensively established. For some species, good field data are available that include seasonal as well as macro- and microclimate variation. However, many thermal ranges stated for amphibians and reptiles are essentially of poor anecdotal or empirical origin. For the present report, we have adopted climate-facilitated distribution as one basis for assessing invasive potential. Accordingly, we have considered the natural climate and distribution for each species listed in Appendix 3, and compared that material with European Union region-based climatological data, and assessed these climate overlaps.

Our approach to climate-facilitated distribution, we feel, allows for greater pragmatism for the assessment of invasive species potential because this system accommodates ecologically broad principles regarding the potential for species to adapt to novel habitats.

For some species, macro- and micro-similarities between natural climate and habitat and European conditions imply a potentially fertile environment for invasion and establishment. For other species, where a potential for invasion and establishment exists, this may not be immediately apparent. For example, a region of southern Europe may climatologically approximate the natural environment for an Australian or Central American species, but the large majority of that European region may be unsuitable habitat for the potential invader. However, this does not preclude a (or many) species actively seeking out appropriate microclimate and microhabitat environments and becoming established. Invader-altered habitat may, in theory, also lead to progressive expansion of suitable habitat and therefore accelerated invasion.

Unlike larger amphibians and reptiles that are characteristically found in tropical and subtropical climates, smaller species are frequently capable of occupying the former regions as well as temperate climates.

In brief, climatically tolerable regions of Europe, even where apparently unsuitable habitats are involved, may allow an amphibian or reptile species at least an ecological 'foot in the door', and while not immediately apparent, microclimate and microhabitat occupation may represent an invasive 'investment' in future distribution. With predicted changes in climate, this is likely to play a key role in the spread of invasive species where each foothold may become a stronghold.

Dietary plasticity-facilitated distribution

Dietary plasticity refers to the nutritional flexibility of an animal and the associated diversity of items it can eat to survive. Typically, species in trade include insectivorous, omnivorous, herbivorous, and carnivorous forms. While this designates species' 'target' foods, it does not necessarily imply everything they consume. For example, herbivorous animals often incidentally consume invertebrates with their plant-based diet, and carnivores often incidentally consume plants that their prey has eaten. These incidental ingestions may be important to health and thus may have an influence on the ability of a species to become invasive, although this is not quantifiable at present.

Specialist feeders imply low dietary plasticity. For example, animals such as the Australian thorny devil *Moloch horridus* possess specialised anatomy and physiology that effectively restricts the reptile to naturally feed on ants alone. Intuitively speaking, this lizard, and similarly specialised insectivorous feeders, are improbable invaders in environments where prey items, such as ants are absent. It follows that they may become likely invaders where their specific prey item is abundant.

Broadly speaking however, many small lizards and most amphibians are insectivorous and consume a wide variety of invertebrates. This food source is richly available in most environments, which effectively removes an obstacle to invasive establishment that limits highly specialised feeders.

Other, more generalist omnivorous feeders such as bearded dragons (e.g. *Pogona vitticeps*) and larger skink species (e.g. *Tiliqua spp.* and *Egernia spp.*) consume a wide range of invertebrates, small vertebrates and vegetable matter and thus prey specificity is less impinging, potentially providing these reptiles with access to a widely available diet under many habitat conditions.

Carnivorous species, such as snakes and monitor lizards are capable of feeding on a very wide range of animals, and in the case of monitor lizards, few vertebrate or invertebrate species are rejected, whether alive or as carrion. Many species in trade are also large and voracious predators including python and boa snakes, monitor and tegu lizards, and soft-shelled and snapping turtles. These are significant, primary or apex predators in their natural habitats, meaning that they have few or no natural enemies, especially as they become larger. These species are potentially capable of displacing many similar status predators in some EU regions.

Relatedly, the absence of natural predators may allow some animals with wide dietary plasticity, such as many freshwater turtles and terrestrial tortoises, to flourish.

Some species undergo dietary 'shifts' from being primarily or exclusively insectivorous as hatchlings and juveniles to becoming omnivorous or herbivorous around maturity and beyond. This ontogenetic change may limit a species' invasive potential where the abundant food source is invertebrate-based rather than vegetable-based – making the natural dietary shift difficult or impossible as the species matures. However, this 'limiting factor' assumes a very narrow margin for dietary plasticity, and may not fully reflect the actual adaptability of species in a natural setting.

It may be highly salient that amphibian and reptile species currently available in the exotic pet trade, and almost all among those species actually identified during this study, have in part become present in trade because their dietary plasticity is relatively strong – that is, they are adaptable to a wide variety of foods. As Figures 11, 12 and 13 and Appendix 4 (Tables A-E) show, European Union regions are variously yet substantially exposed to invasive species on the basis of their dietary plasticity and, while thermal considerations impact on this, EU regions offer some abundant opportunities for many amphibian and reptile species.

Artificial dietary habituation

It should also be noted that in captivity, amphibians and reptiles are rarely provided with their natural diet; they are raised on artificial diets (with a nutritional component aimed to replicate their natural diet – although frequently poorly so) or provided with live prey that, in many cases, differs from prey items they would encounter in nature. With regards to the latter, in addition to purchased live prey, these may constitute species of locally bred or locally captured (and bred) invertebrates. As such, captive (and potentially invasive) species are encouraged to explore foodstuffs beyond their normal diets and in a sense, are becoming accustomed to a new food source – and an endemic one.

For example, wild geckos feed on a wide variety of invertebrates mostly consisting of wall-crawling spiders and moths. In captivity, however, geckos are most often fed, and become 'accustomed' to taking crickets and other ground-dwelling invertebrates. As such, it is reasonable to assume that should such an individual escape or be released into local habitat, that it may be better able to thrive, given that it has now acquired 'upgraded' dietary habits. Conceivably, a wide variety of such apparently subtle changes in dietary habit of many captive amphibians and reptiles may effectively (and at least partially) be pre-set factors to facilitate local habitat invasion.

What may follow is a series of 'diet-linked keys' that aid in the opening of niche doors, allowing released animals to inch closer to establishment as an invasive alien species.

The introduction and establishment of an invasive alien species may be subtle, long-term, and discretely progressive. Novel species introductions may adopt a different niche from its native one (Bomford *et al*., 2005). Stealthy infiltration by isolated individuals and colonies may conceivably go undetected or unsuspected for years or decades prior to major invasive establishment and recognition.

Artificial trait development

The expansion of captive-breeding of both amphibians and reptiles by the non-scientific 'hobbyist' community and the commonplace deliberate artificial selection of genetic traits has led to the development of certain perceived 'desirable' outcomes. These traits are well known to include atypical colours and patterns and other variations, but also include anecdotal reports at attempts to produce 'hardier' animals, for example, animals that show greater tolerance to aberrant thermal ranges and are more resistant to some diseases.

We are not aware of any scientific validation for the claims of artificial selection actually producing hardier animals. And there is no evidence that such anecdotal alterations result in animals that are psychologically or behaviourally 'better adjusted' to captivity. However, as a concept, the issue of artificially 'engineered' and environmentally hardier amphibians and reptiles raises serious concerns about 'hobbyist-made' forms possessing enhanced prospects for both already potentially viable invasive species as well as presently improbably viable species becoming actually established.

Captive ectotherms often do not have the freedom to thermoregulate as they would freely do in the wild.

Indeed, the restricted confines of captivity are unlikely to replicate the myriad of processes involved in enabling an individual to achieve its optimal range of body temperatures. Should these thermal limits be challenged by poor husbandry, the more sensitive species (that is, less thermally flexible) are likely to suffer or simply not survive. However, more thermally tolerant species and/or individuals may be 'pushed' beyond their 'wild' or natural thermal extremes. Gradual acclimatisation in captivity may in essence be a means by which an introduced species or individual is equipped with the ability to cope with a new environment, contributing to its transition into becoming an invasive one.

Relatedly, if any of these anecdotal accounts are correct, even to a minor degree, then this introduces a very disturbing new element into the invasive species potential and effectively implies that few or no species can safely be presumed 'non-invasive'.

It has been demonstrated that reptiles such as the bearded dragon, *Pogona vitticeps* (the most commonly kept lizard within the pet trade) is able to use compensatory mechanisms when its thermal requirements are not met by environmental conditions. Behaviours such as postural changes, gaping, panting, and cardiac changes are all mechanisms that are recruited in thermoregulation (Seebacher, 2005). Thus, these animals are in some respects relatively well equipped to deal with some challenging conditions. Unless exposed to particularly poor thermal quality conditions, *P. vitticeps* is able to maintain its body temperature, although a factor that is compromised is precision. When the costs of thermoregulation are low, lizards use very effective but energetically costly behavioural mechanisms. When the costs are high, lizards use less expensive methods (Cadena & Tattersall, 2009). Thus when environmental temperatures are less favourable these lizards can adopt more conservative strategies to regulate their body temperatures.

An important point is that introduced and successful IAS do not remain static; it appears that a form of natural selection plays a role in altering the morphology and, likely, the physiology of at least some IAS as they invade new environments and face novel challenges. Shine, Brown and Phillips (2011) use the term 'spatial sorting' to describe the evolutionary process that guides the development of traits that better facilitate invasion in cane toads (*Bufo marinus*). At the expanding edge or 'front' of an invasive population, those individuals that have become established are most likely to breed and pass on the traits that have contributed to their success. Cane toads at the 'front' of an invasive population have been shown to have longer legs. Similarly, introduced individuals of invasive lizard species (such as *Anolis sagrei*) have been found to develop a larger body size than in their native habitat (Kolbe, Larson & Losos, 2007). It is important to note that regardless of any prediction analysis of invasive potential of alien species, there is clear evidence that species of amphibians and reptiles are being released throughout Europe.

It may be reasonable to assume that a short-lived, dietary-specific species with a narrow range of preferred temperatures may not persist for very long in a new host environment. As such, its direct impact on its habitat may be minimal. However, there is certainly potential for long-lived, dietary-generalist species that tolerate a wide range of ambient temperatures to either establish a rogue population or to even persist long enough to alter the local ecosystem. The appearance of the common snapping turtle (*Chelydra serpentina*) in European waterways is an example of this. *Chelydra serpentina* are opportunistic omnivores acting as both scavengers and active hunters (Brown, 1969; Hammer, 1972; Obbard, 1977; Carroll, 1996). They are known to consume a wide variety of prey items from vegetation through to invertebrates, fish, frogs, reptiles, birds and small mammals (Coulter, 1957; Brown, 1969; Hammer, 1972; Obbard, 1977; Carroll, 1996). Given that this species may live for over 50 years and conceivably over 100 years in the wild (Brown, 1969; Obbard, 1983; Congdon *et al*., 1987), it is reasonable to assume that even a few individuals may have a major impact on a local ecosystem.

Furthermore, an individual *C. serpentina* may often weigh over 15kg and exceptionally up to 39kg in an obese example (Conant, 1975) and requiring substantial care in terms of feeding and housing, they may quickly outlive their appeal as pets and be released into the wild.

OPPORTUNITY FOR INVASION

Although it was not possible to estimate the number of individual animals offered for sale at all three European markets, it is possible to determine numbers of annual events at which exotic species of amphibians and reptiles are offered for sale. This information can be gleaned from internet sources including various forums and websites of commercial sellers.

In 2011, a total of 98 European 'reptile' (= exotic species) shows were listed online which spanned 13 countries (Figure 15). Slovakia, Slovenia and Switzerland hosted a single show each, while Germany hosted (or was due to host) 41 events alone.

Given that approximately 100 shows were listed for 2011 (according to Altherr, Brückner & Mackensen [2010] possibly 700 events occur annually in Germany alone) and an assumed significantly high number of shows have been conducted annually in Europe's past, this alone represents the first and highly significant stage in providing opportunity for introduction of an invasive species. As has been cited throughout the

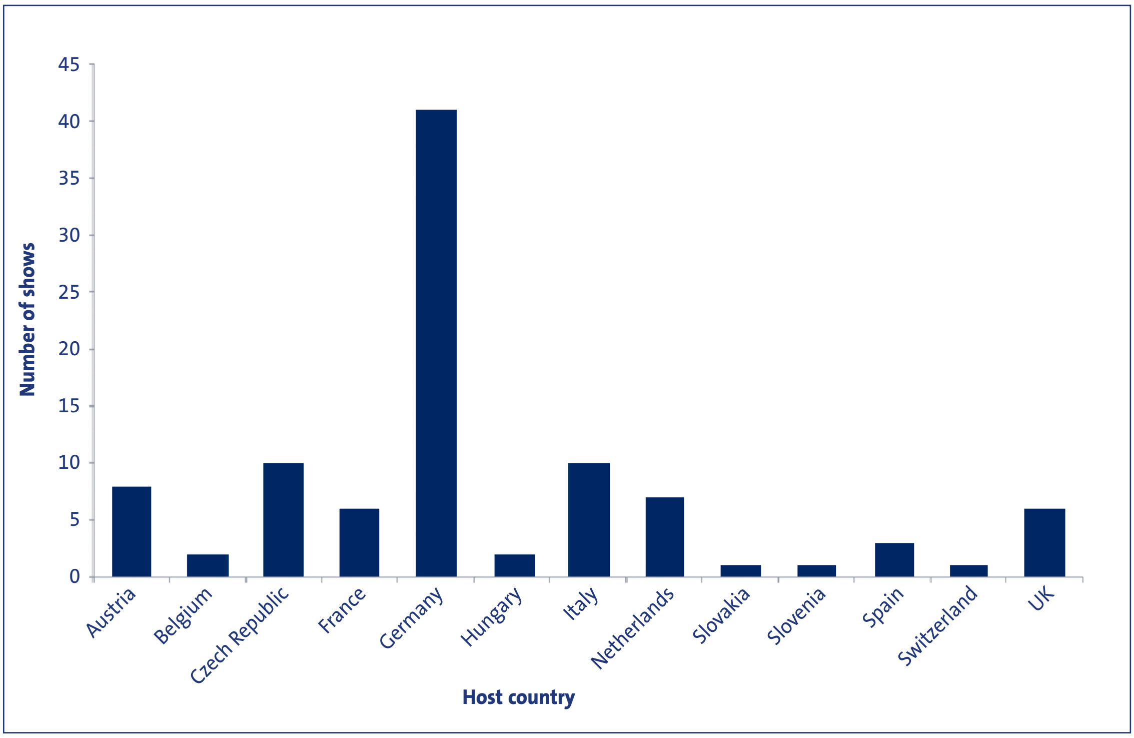

Figure 15. European countries hosting reptile shows in 2011 (retrieved from United Herps 2011).

literature, propagule pressure (or the number of animals released) is a key factor in the successful establishment of an invasive species. The large number of events, holding many individuals of known and potential invasive species presents a significant propagule pressure-based risk. Furthermore, as noted by Henderson and Bomford (2011) prevention is a much more cost effective solution than the cost of eradication where even a single species has become established.

Opportunities for incidental escapes at markets

At all three events the physical layout of the buildings was amenable to allow animals (including invertebrates) that escape from their containers to exit into the indigenous habitat. This was especially apparent at Terraristika, which had several large doors opening direct to the outside with little monitoring and very little opportunity to intervene should an animal break free. At Expoterraria in particular, many invertebrates including locusts and crickets were freely ranging the building and the exit of some of these from the building was probable.

It is worth noting that in the event of escaped animals, including invertebrates, *prima facie* significant opportunities may exist for their immediate rapid local establishment proximal to the market venues. Habitats proximal to Terraristika and especially Expoterraria (due to climate and local habitat) offer opportunities of rapid local establishment of escapees. In relation to the IHS Show, with its relatively northern situation the opportunities for rapid local establishment of escapees is arguably lower.

META ISSUES

The meta issues discussed below are not intended to form an exhaustive list of currently debated subjects. Rather, these represent selected commonly raised matters that the authors are called on to address from time to time and that are relevantly revisited in the context of our investigation.

WILD-CAUGHT VERSUS CAPTIVE-BRED ANIMALS ON OFFER

Although not a primary component of this investigation, we nevertheless did seek to assess whether amphibians and reptiles on offer at the markets visited appeared to be wild-caught (WC) or captive-bred (CB) as well as seek to estimate the WC to CB ratio. However, time constraints and impractical access to a sufficient number of animals precluded detailed assessment. Nevertheless, we were able to satisfy ourselves that both wild-caught and captive-bred animals were on offer, and the majority of these *prima facie* appeared to be captive-bred.

Our observations of sellers and their stalls at Terraristika raised certain additional queries regarding the supplies to some of these sellers and these may warrant further investigation in order to assess potential relevance to the WC versus CB composition of animals on offer. In particular, we noted a considerable number of both opened and unopened international transportation containers holding a substantial number of animals. Among the opened containers, sacks were observed holding animals, and these sacks were piled on top of each other. The transportation containers were labeled as checked under US Fish and Wildlife Service controls. Numerous sales appeared to be being made from these containers as well as from the seller stalls. Similarly, another (single) consignment of animals was noted in a transportation container labeled as originating in Thailand and having been imported via London Heathrow.

Further, at Terraristika a large number of containers, many clearly with animals in sacks and in incidentally low-lit boxes were stored behind seller stalls or on the floor beneath tables and neither the species nor the condition of the animals could be ascertained. At the IHS Show many animals were also stored on the floor, although this practice appeared less prevalent. At Expoterraria fewer animals were stored on the floor than at Terraristika or The IHS Show. Also at Expoterraria we estimate that a higher proportion of wild-caught animals, in particular, numerous chelonian and lizard species, as well as generally greater species diversity were on offer than at Terraristika or the IHS Show.

ESTIMATION OF THE NUMBERS OF ANIMALS AT EVENTS

Although not a primary component of this investigation, we nevertheless aimed to estimate the number of amphibians and reptiles on offer at each event. At all three events this aim was thwarted because very many animals were variously stored under tables and in vehicles in main car parks or stacked in multi-layers making approximate numbers impossible to assess. In addition, time constraints prohibited stock counts. Terraristika involved a very substantial number of both amphibians and reptiles, although we estimate that reptiles were singificantly more numerous. At the IHS Show and Expoterraria the great majority of animals were reptiles, with amphibians being minimally represented.

COMMERCIAL AND NON-COMMERCIAL SELLERS

It was not part of our remit to attempt to estimate the ratio of formalised commercial animal traders compared with informal animal traders. Had this been part of our remit it would anyway have been very difficult to achieve because at all three events there was a generalised near complete absence of literature such as stock-lists and price-lists as well as other material that would enable individual sellers to be identified and that one would normally expect to accompany sellers. Some traders advertised the fact that they operate as formal commercial businesses while most made no declaration.

The typical near complete absence of stock-lists, price-lists or other seller-identifying details was apparent even where clearly commercial companies used self-promotion banners above their stalls. This lack of overt dealer identification is unhelpful and curious. Anecdotal accounts suggest that this dearth of information is at least partly attributable to some dealers wishing to remain relatively anonymous either to evade certain income tax declarations or to enable them to avoid detection where some sales may involve species of questionable legality.

Some traders were clearly very small operations that offered few animals (for example around 10-20 individuals) and appeared to possess no reserve stock underneath or behind their stalls. We are inclined to accept that in this small minority of examples the sellers may be offering animals that were surplus to their interest as hobbyists. In law, however, at least in the UK, a business may be loosely defined as carrying on an activity that involves a degree of repetition, making (in this context) even these ‘non-commercial’ sellers informal businesses because they both involve regular multiple sales and also attend various events and act as regular stalls.

Regardless, the great majority of sellers’ set-ups and activities were effectively indistinguishable from each other and, based on their display and reserve stocks, business-like manner of sales, and general mode of operation we confidently assert that by far most sellers were commercial traders whether or not their activities were declared and formalised.

PROPONENTS’, ORGANISERS’ AND SELLERS’ AWARENESS AND ASSESSMENT OF STRESS AND WELFARE AT MARKETS

Proponents, organisers and sellers frequently claim that there are no general animal welfare problems at exotic pet markets. This strongly suggests that the awareness and assessment capabilities of those commentators regarding the evaluation of stress and welfare at markets are poor. It is further reported that inspecting veterinarians and others charged with overseeing amphibian and reptile welfare have generally not identified systematic welfare issues.

This again indicates poor awareness and assessment capabilities by those inspectors who may not possess the sufficiently specialised backgrounds required to interpret both basic and complex issues of stress and welfare associated with these animals. This situation is not entirely unexpected, given that relatively few scientists have undertaken high-level investigation and training in some of these areas.

In some instances, however, comments by proponent organisers do suggest a positive understanding of some of these occasionally challenging biological concepts. For example, proponents defending the Terraristika event have remarked that stereotypical behaviours do not occur in reptiles. Assuming this statement refers to *maladaptive* stereotypies then this understanding of an important ethological meta issue is (at least partially) correct. By contrast, the same source entirely erroneously concludes as healthy behavioural signs those that actually appear to be descriptions of hyperactive-ITB behaviour, which is a serious sign of stress.

THE TEMPORARY NATURE OF MARKETS

A common claim by exotic pet market proponents, organisers and sellers is that the temporary nature of markets justifies the extreme minimalistic conditions in the same way that the wider community regards animal transportation containers as acceptable.

It is correct that during transportation, animals are often subject to conditions that would not normally be considered acceptable. The basis for these compromised conditions is usually to move animals from acceptable quarters to alternative acceptable quarters in the most practical and expedient manner.

However, the animals at exotic pet markets are not being transported. They have already been subject to transportation. In other situations, transportation conditions are customarily halted on arrival, and animals are enabled to 'recover' in environments that allow greater spatial, thermal, feeding and drinking, and bedding conditions. This is not the case with exotic pet markets.

Anecdotal accounts suggest that animals are sometimes transported from one market venue to another until sold, which means that an animal present at a exotic pet market on any given day may already have been subject to higher than apparent levels of handling and exposure as they are moved from place to place over long periods within the 'transportation'/display containers.

The process of supplying animals to exotic pet markets often involves animals incurring hours (sometimes many hours) of travel and this sometimes including being transported across several national borders or from overseas to reach a destination that will be an EU-based animal wholesaler who then further transports animals to a market to sell. The dealer progressing to another sequentially scheduled market may then extend the process. In addition, purchased animals, such as at Terraristika, for example, were acquired by some attendees who then transported purchased animals on buses to Denmark, the Czech Republic and the UK, among other destinations.

Animals at pet markets are *de facto* present in a large pet shop. It is well known that many exotic pet market proponents, organisers and sellers regularly seek to obtain the same permissions as would be required to operate as a regular 'warehouse' pet shop, acknowledging that their activities are intended to reflect conventional pet selling outlets and not merely operating in transport conditions.

Another issue is that during more typical transportation scenarios, as well as in pet shops, animals are not subject to the level of overt display and associated repeated handling that occurs at exotic pet markets, and that are characteristic stressors associated with markets.

Exotic pet markets involve accumulations of especially diverse animals in substantially greater numbers than animals would encounter either in transport or pet shop conditions. This concentration of animals as well as the liberal movement of large numbers of people substantially elevates the risk factors for the spread of infectious microbes in both a manner and at a scale not present in other scenarios.

Enclosures ('containers') at exotic pet markets set a 'poor example' of animal husbandry that is likely to be adopted by purchasers. In a 'classic' pet shop environment, while we are not proposing such conditions to be ideal, animals are offered greater liberties and care than at pet markets.

Some sellers were noted at all three events, indicating the international nature of the pet market stall trader.

UNUSUAL SPECIES

Although it was not within our remit to address the presence of unusual species we did note several curious species on offer, both in terms of their rarity in trade and their formal status as regulated species. The classification of species followed the IUCN Red List of Threatened Species, version 2011.1 (www.iucnredlist.org). Particular focus was placed on species of testudines as it was clear that many species available for trade were rare or threatened. Thus data on their conservation status was supplemented with data derived from the Turtles of the World, 2010 Update (Turtle Taxonomy Group). The conservation status of the majority of remaining species was listed as 'Data Unavailable' which included those species with an IUCN listing of 'Data Deficient', 'Not evaluated' and 'Not listed'.

Of the 57 species of Testudines identified, 30 (53%) have an IUCN Red List classification (Figure 16). Of these, 8 species (14%) are listed as 'Near Threatened', 14 species (25%) as 'Vulnerable', 6 species (11%) as 'Endangered' and 2 species (4%) as 'Critically Endangered' (Figure 17). The proportion of threatened species offered for sale has serious implications for their conservation as for many of

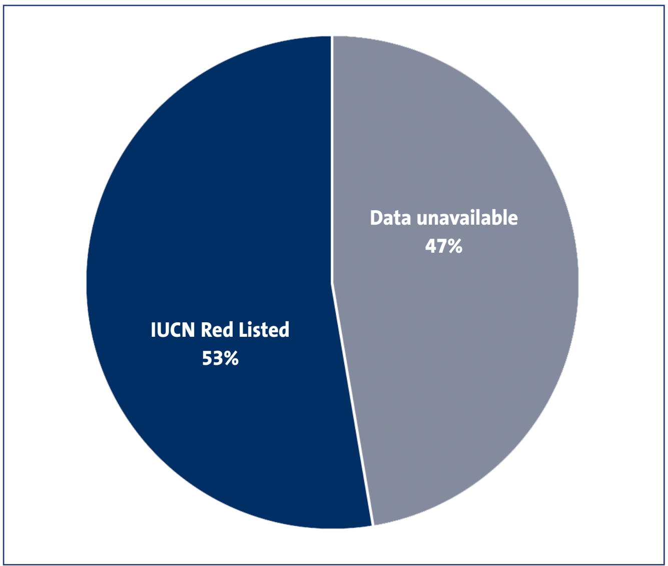

Figure 16. Proportion of IUCN Red Listed species of Testudines offered for trade in European markets.

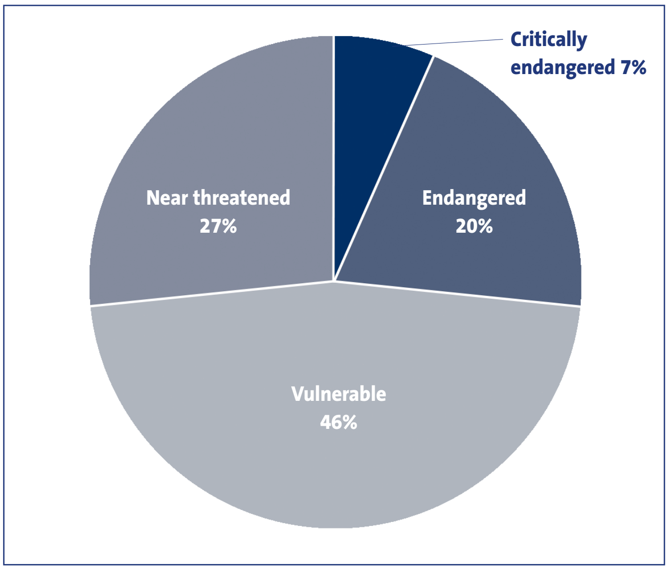

Figure 17. Classification of IUCN Red Listed species of Testudines offered for trade in European markets.

these species their current conservation status is directly related to over-collection for the international pet trade.

There were several examples of usual species offered for sale at the European markets including the Roti Island snake-necked turtle *Chelodina mccordi* and the giant Aldabran tortoise *Aldabrachelys gigantea*. *Chelodina mccordi*, with a conservation status of 'Critically Endangered', was identified at Terraristika. It is a highly prized species in the international pet trade and has been over-collected largely due to its rarity. *Aldabrachelys gigantea*, a species listed as 'Vulnerable', was being offered for sale at Terraristika and also at Expoterraria. Individuals of this species may reach a weight of well over 200 kg and live for more than 200 years. Their size and longevity renders them one of the most impractical reptile pets, as adults are strong enough to counter many domestic attempts at restraint and they will easily outlive their owners.

In addition, various remarkable species of amphibian were offered for sale at the EU markets. These included the 'Critically Endangered' golden mantella *Mantella aurantiaca* (Expoterraria) and the 'Near Threatened' tomato frog *Dyscophus antongilii* (the IHS Show and Expoterraria) both from Madagascar and both overexploited species that have a very restricted range in their native habitat (Andreone *et al*., 2008). Two highly inappropriate species offered for trade were the African clawed frog *Xenopus laevis* (offered for trade at the IHS Show) and the cane toad *Bufo marinus* (= *Rhinella marina*) offered for trade at Expoterraria. Both of these species are globally recognised as highly invasive and the latter is listed as one of the 'World's 100 worse invasive species'.

ADDITIONAL CONSIDERATIONS REGARDING INVASIVE ALIEN SPECIES

It cannot be disputed that the issue of biological invasions is remarkably complex. Not surprisingly, a number of approaches have been developed in an attempt to better understand both the spread of IAS and the potential for introduced species to become established invasives. These include studies of population genetics and genetic diversity. Several of these approaches are relatively new and have yet to be widely used. In fact, the manner in which genetic diversity influences populations of introduced, potential invasives has been described as being "poorly understood" (Simon *et al*., 2011).

However, it has been shown that multiple introductions of a species of reptile to a region can result in greater rather than less genetic diversity, thus enhancing the potential for populations to become invasive (Kolbe *et al*., 2004). In that study, it was found that the genetic diversity of introduced populations of the highly invasive lizard *Anolis sagrei* remained high as a result of multiple introductions of individuals from differing populations over different time periods. The resulting mixing of genetic material resulted in populations that were able to adapt and spread rapidly, evolving into an additional secondary source of animals that were then equipped to spread even further and even alter their morphology as required. Kolbe *et al*.'s study provided strong evidence that "enhanced genetic variation increases the rate of adaptive evolution".

Genetic diversity of reptiles has also been shown to be influenced by even relatively short-term events such as fire, which can alter habitat and through the reduction in the number of individuals, reduce the gene pool. For example, fire has been shown to alter the genetic diversity of three lizard species in Florida (Schrey *et al*., 2011). It is important to note that the impact of fire on the genetic diversity of these species was very species-specific either favouring genetic diversity or restricting it.

Thus, regardless of whether an event is short-term or long-term, it can be assumed that these can potentially alter the genetic diversity of populations of both introduced and endemic species. Looking at this issue another way, everything from habitat disruption to climate change can become a possible mechanism by which an introduced species is provided with the foothold it needs to survive and spread.

GENETIC POLLUTION

While the issue of invasive alien species typically refers to the introduction of species to novel systems, here genetic pollution refers to the introduction of artificial traits into nature, such as novel colour and pattern variations, and hybrid forms of extant species. In essence, a frequent aim of exotic pet hobbyists is to artificially select colour and pattern variants in order to create novel forms as well as 'crossbreed' genetically similar species to produce hybrids. Whereas introduced novel alien species (that is, different from indigenous species) may not be able to breed with those animals, genetically similar, yet artificially manipulated, captive forms may be capable of imparting polluted genetic material to their naturally occurring counterparts. Relevantly, there are countless numbers of genetically similar, yet artificially manipulated, forms of amphibians and reptiles present within the exotic animal trade.

A lack of quantitative data and case studies makes it difficult to evaluate the potential impact of genetic pollution from 'designer' species. However, theoretically, the consequences of this pollution may be that if an abnormally bright marking is introduced to a native species and that trait becomes ubiquitous, then a large number of that species may be more easily targeted by key predators. Alternatively, a naturally dark species may be 'lightened' by colour infiltration and become abnormally reflective of solar heat and fail to thrive. Other potential permutations of genetic alteration include immune condition, fitness, and reduced ability to attract mates.

As has been stated previously, a major portion of the amphibian and reptile species in the exotic pet trade are selected because of some perceptions about their 'hardiness' and (though not necessarily through the owner's conscious effort) their ability to occupy a wide range of conditions and environments. These factors, coupled with an ability to readily breed and interbreed to produce hybrids, colour 'morphs' and other variations, can potentially alter the genetic makeup of individuals such that they are able to tolerate novel habitats beyond their natural boundaries. As such, they may be able to capitalise on any short- or long-term effect that would otherwise limit their ability to establish a viable population.

INTRODUCTION OF NOVEL AND INVASIVE PATHOGENS

In addition, to the primary issue of introduction of invasive species is also the secondary potential issue of incidental introduction of novel and invasive pathogens. All animals harbour a range of microbes on or in their bodies. As with chytrid disease, the potential for release of pathogens into nature and associated harm to populations and even to cause their extinction is very conceivable. Reliable screening or eradication for all, and in most cases even some, of these microbes is impractical or impossible.

CONCLUSIONS

Animal welfare

The type and high prevalence of behavioural signs of stress observed at exotic pet markets show that a major representation of both amphibians and reptiles at these events are stressed. This indicates that significant animal welfare problems are associated with exotic pet markets and that current key concerns are justified.

Contrary to some claims by exotic pet market proponents, organisers and sellers, established signs of stress in both amphibians and reptiles are significant markers of a variety of stressors (including spatially grossly overly-restrictive environments, handling, exposure and other factors). In our view it is easy to argue that the great majority of animals at all three markets were subjected to conditions and treatment tantamount to animal abuse.

Again, contrary to some claims by exotic pet market proponents, organisers and sellers the temporary nature of markets does not in our view justify the minimalistic and stressful conditions for animals.

In our view, not only are the conditions at exotic pet markets typically stressful for animals, but also it is possible that the stressful conditions combined with the dearth of facilities that would otherwise aid in the recovery from stressors may also lead to medium- and long-term compromised animal health and welfare.

On the one hand it may be perhaps perplexing to some that several responsible governmental authority representatives have attended exotic pet markets (in this investigation established for Terraristika and the IHS Show) and failed to identify significant problems, and also regarded the events as consistent with good practice, and further found no stress signs in animals. On the other hand historical inspection and assessment failures are unsurprising given that it is highly unlikely that the inspectors of these events (including the veterinary inspectors) would have possessed either the scientific qualifications or the experience necessary to offer appropriately informed assessment.

Human health

The established nature of amphibians and reptiles as a reservoir of known microbes means that all animals, their containers, seller facilities, and the sellers themselves must all be regarded as a potential reservoir of zoonotic pathogen contamination. The direct and indirect actions and interactions between public attendees and sellers is manifestly capable not only of resulting in acquired infection among attendees, but also of transferring seller-associated potential pathogens among the public and all publicly-accessible intermediary surfaces. Indeed, we postulate that it would be reasonable to conclude that within a relatively brief period all public attendees potentially may be subjected to some level of contamination. In other words, in our view, the potential pathogen contamination of the public at exotic pet markets is probably assured.

No overt guidance on hygiene control was observed at Terraristika, and if this was present then it was not ubiquitously overt. It is also highly unlikely that any method of hygiene control could be practicably implemented in the context of an exotic pet market. Even if comprehensive disinfectant surgical scrub areas were provided with appropriate guidance on contaminant elimination from hands, then this would not offer a reliable solution. Contaminated areas other than hands would remain, and recontamination of hands and other areas from clothes, people and the environment would likely rapidly reoccur once the person returned to the generalised areas of the pet market and its multifactorial contamination sources. Contamination of clothes and hair, for instance, would also represent a robust contamination source that would persist even after leaving a market and regardless of any hand cleansing.

The use of hand sanitiser products such as gels and sprays for the prevention of infection (although infrequently adopted and only casually observed at the visited events) was, when utilised, employed in a less than thorough manner and itself represents a poor form of hygiene management. As indicated earlier, the type of sanitiser products used do not offer comprehensive protection and their promotion encourages misplaced public confidence in an unreliable method. Such over-reliance is likely to lead to complacent behaviour and infection.

The situating of exotic pet markets in venues often used for general public purposes, such as school halls and leisure centres, constitutes a potential public health hazard that realistically may endure for days, weeks or months following the conclusion of the exotic pet market. Certain bacteria, such as *Salmonella* are well understood to viably persist on surfaces in the general environment. At venues hosting exotic pet markets it is reasonable to presume that all public contact surfaces such as door handles, floors, doorways, walls, light switches and many others may remain microbially contaminated and thus potential sources of infection. Given that these same venues may be sequentially used for a wide variety of other public purposes including schooling of children, these venues may pose an ongoing potential residual risk of infection to entirely unsuspecting and unprepared users.

Invasive alien species

In our view there is little doubt that a wide range of species found at exotic pet markets have the adaptive potential to become invasive species across numerous regions within the EU. Indeed, our assessment is that the continued occurrence of exotic pet markets makes the introduction of invasive species almost assured. European markets are key routes by which amphibians and reptiles enter the EU and may become invasive.

It is clear that many species that are recognised IAS are being distributed in international trade and many other species within the trade have the potential to become IAS. If this issue is not addressed swiftly and decisively, then these non-native species will continue to spread throughout the EU. IAS may have either direct and immediate impacts on local ecosystems or, of more concern, establish populations with indirect impacts, to which the extent of damage may not be recognised for years.

A further reason for immediate action is that invasive species, for the very reasons that make them successful as invaders, will continue to evolve in response to novel challenges such as climate change and human disturbance.

FINAL WORD AND RECOMMENDATIONS

We have prepared our recommendations in strict consideration of European Union regulations and initiatives. Our approach aims to apply a scientific evidence-based rationale that is pragmatic, defensible and practicable. Our intention is to promote outcomes based on prevention and control.

Exotic pet market organisers, traders and proponents have all manifestly failed to address (either significantly or at all) the various problems associated with these markets. Formal attempts to impose regulations (for example in Germany and in the UK) have also either been resisted, poorly met, or ignored altogether. The fact that in the UK selling animals as pets at markets is unlawful, yet the law is sometimes flouted, indicates a disregard for formal controls. Some local authorities do little or nothing to enforce the relevant laws or are inept at controlling illegal sales.

As we will set out, our view is that exotic pet markets cannot be safely regulated and permitted. Furthermore, where regulatory controls have been attempted, organisers, traders and proponents of pet markets have, in our view, often sought to avoid even minimalistic measures to control or end their activities. This avoidance of even minimalistic control strongly indicates that there is an endemic inability among organisers and traders to self-moderate or self-regulate. In some respects this is unsurprising given that the exotic pet trade as a commercial system and hobby, does not have a good record concerning compliance with pragmatic controls. Also, traders could choose to not sell known invasive alien species, yet example IAS such as the red-eared slider turtle and the American bullfrog (despite being illegal for import under EU CITES) can still be found sold at markets. Notwithstanding these issues, our view is that permissive regulations sufficient to control the diverse problems associated with pet markets are not workable.

Prevention and control in many cases of problematic animal welfare, human health and ecological issues is already 'too late', and many negative sequelae are attributable to each of these areas. However, prevention and control reside at the heart of what is an extant and developing multifactorial and major problem of exotic pet markets. Pet markets involve potentially catastrophic consequences for animals, people, the environment, and probably also European economies through the introduction of wildlife into the domestic environment and indigenous habitats. A failure to act urgently and robustly to control exotic pet markets is almost certain to permit to occur a situation in which delay is concomitant with exponentially developing difficulties and economic burdens, many of which may be impossible to rectify or recover from.

Accordingly, due to the inherent problems of pet markets including the transitory nature of these events (which travel between Member States as do the buyers of the animals for commercial re-sale and/or personal use), we recommend the following actions by:

European Commission

1. As part of the forthcoming EU Animal Health Law address the health risks of wild animals in trade and for sale at wildlife (pet) markets, by pursuing health requirements or eventually prohibitions on such markets within its boundaries due to the associated health (and ecological risks). Specially licensed pet shops would be allowed to sell certain species where these are proven suitable and consistent with health and ecological safeguards.

2. Integrate the policy of the new EU Animal Health Law with the second Animal Welfare Strategy, also under development, to ensure it includes the welfare of wild animals in captivity including those species subject to the exotic pet trade.

3. As part of the new dedicated legislative instrument for an EU Invasive Alien Species Strategy (Target 5 of the Biodiversity Strategy to 2020), include restrictions on the import, intra-community trade and sale of exotic pet species which represent known or serious potential ecological threats.

4. Pursue a policy of prohibition on wildlife (pet) markets within its boundaries, to cover all biological classes of vertebrate animals.

5. Encourage individual countries where possible to compile a database of all known pet markets and their historical venues within its boundaries and makes this database available for enforcement authorities to ensure local compliance with all prohibitive measures.

Until such time as the European Commission has developed more complete policies associated with health, welfare and invasive species, we also recommend the following actions to close existing regulatory gaps by Member States:

i. Allow only the sale of animals through competent licensed and inspected pet shops. (For example, those subject to staff training and who can be shown to provide responsible information to customers).

ii. Establish restrictions on the types of species which are suitable to be kept as pets based on criteria such as the welfare of the animal, health and safety risks, potential threat to native flora and fauna, and available knowledge on care and husbandry of such species in a captive environment.

Our recommendations could be integrated with policies within Europe and key EU strategies under development, including, but not exclusively:

- Resolution on the Keeping of Wild Animals as Pet Animals into the Multilateral Consultation of Parties to the European Convention for the Protection of Pet Animals (ETS 125) in 1995. (Although not part of the EU, we would encourage all nations to ratify and thereby enhance the Council of Europe (1995) European Convention for the Protection of Pet Animals. Available at:
  http://www.felinewelfare.co.uk/coemcp.htm)

- EU initiative in the protection of biodiversity as an environmental priority for Europe. European Commission. Biodiversity Strategy to 2020. http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/1_EN_ACT_part1_v7%5B1%5D.pdf and http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm

- EU initiative for developing a dedicated legislative instrument for an EU strategy on invasive alien species, as part of its objective (Target 5) to halt the decline in biodiversity by 2020. European Commission. Development of an EU strategy on invasive alien species. http://ec.europa.eu/environment/nature/invasivealien/index_en.htm

- EU Animal Health Strategy (2007-2013) which recognises the potential impact that serious livestock disease outbreaks can have on agriculture. European Commission DG Health and Consumers. The new Animal Health Strategy (2007-2013): "prevention is better than cure".

- EU Commission initiative on protection and welfare of animals 2011-2015. http://ec.europa.eu/food/animal/welfare/actionplan/actionplan_en.htm

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DECLARATION OF INTEREST(S)

The authors declare no vested interests in the subject of this report beyond the commissioned work.

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Phillip Arena graduated with Honours in reptile ecology from Murdoch University in 1986 and in 1991 completed his PhD on reptile and amphibian anatomy and physiology (also from MU).

Phillip has been teaching for more than 20 years at Murdoch University in all major units in Biological and Environmental Sciences, Veterinary Studies and the School of Education. He was Education Officer at the Western Australia Museum working with Primary School children and has worked with various governmental conservation organisations conducting educational programs in environmental awareness, natural history and animal welfare. Phillip has also designed and conducted science units for Technical and Further Education (TAFE) initiatives, aimed at providing an appreciation and understanding of science.

Phillip has contributed to the study and welfare of amphibians and reptiles both locally and internationally, with key contributions to the fields of biology, behaviour, anaesthesia, ecology, and population dynamics, and has published several scientific works on these subjects. He has worked with all major classes of vertebrate, acting as a consultant for various organisations. In 1998, as chief scientist with a self-funded organisation, Phillip conducted ethnozoological work in Ecuador, being the first Australian to win a prestigious BirdLife International, BP Conservation Award. He has received numerous distinctions of excellence in teaching at Murdoch University, has been awarded for his facilitation of online learning, and is a member of the Australian Science Communicators.

Catrina Steedman *BScHons (Psychology) AMSB (Reptile Biology)*

Catrina Steedman completed a BSc(Hons) in psychology at Plymouth University in 1987. Catrina became particularly interested in reptile biology and conservation and quickly engaged in captive reptile studies. Following several months of biological data processing and report-writing she commenced working as an assistant field researcher studying ecological effects of the human harvesting of freshwater terrapin populations in North America, crocodilian slaughter methods used within ranching operations, and reptile behavioural problems in zoos.

In 1989 Catrina helped to establish the Reptile Protection Trust and was responsible for project co-ordination, information collation and dissemination, as well as most management responsibilities. She became heavily involved with benign field and laboratory studies including species status and environmental alteration from snake hunting, biological considerations of reptiles in laboratory projects, monitoring the human culinary markets in turtles and snakes, and the biological considerations of wildlife trade and non-indigenous invasive species. Catrina has also worked on public health projects. She has co-authored several scientific papers and reports that have been published in journals and by the European Commission. Her research work and other professional responsibilities earned her post-graduate AMSB status from the Society of Biology.

Clifford Warwick *DipMedSci (Medicine, Zoonoses) CBiol (Reptile Biology) FSB (Reptile Biology)*

Clifford Warwick qualified in biology in 1990 having specifically worked on non-invasive research involving reptiles, captive-reptile behaviour and biological strategies. In 2004 he also qualified in primary health care at Leeds University Medical School where he specialised in zoonotic disease.

His specialised areas of herpetology include normal ethology, captive reptile behavioural problems, and captivity-stress and stressors. Many biologists and veterinarians consider Clifford to be the world's leading authority on captive reptile behavioural problems. Additional research projects and publications include euthanasia, anatomy, physiology, wildlife biology, ecology, and species and environmental conservation. His work in human medicine has involved zoonoses prevention education, epidemiological research, primary care management of gastrointestinal disease, fever, and biological strategies in health and disease. He was made a Fellow of The Society of Biology for his 'distinction in biological research'. He is also a Fellow of The Royal Society of Public Health.

He has produced around 100 peer-reviewed publications in biology, behaviour, reptile well-being, and human medicine. Among his publication projects is what is probably the definitive advanced scientific reference book on reptile health and welfare for which he was senior editor and which he co-edited with Prof. Fredric L. Frye (the world's leading authority on reptile medicine) and Dr. James B. Murphy.

Clifford is a biological consultant to numerous scientific, environmental, animal welfare and human health organisations worldwide. He has held several honorary editorial positions, including being a board member of Elsevier's Applied Animal Behaviour Science, and an editorial board member for the Society of Biology's Biobits publication. In 1992 he received the Intervet/British Veterinary Association Animal Welfare Award.

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APPENDIX 1

Major amphibian - (A) and reptile - (R) borne zoonotic infections and infestations. *Derived from*: 1. Pathogens as bio-weapons, F.L. Frye, unpublished. 2. Zoonoses: drawing the battle lines, C. Warwick, Clinical Veterinary Times, 2006. 3. Reptile and amphibian communities in the United States, V. Bridges, C., Kopral, R. Johnson, Centers for Epidemiology and Animal health, 2001.

Disease/condition		Genus of Pathogen	Source
Bacterial	Campylobacteriosis	*Campylobacter*	A,R
	Endemic relapsing fever	*Borrelia*	A,R
	Gastroenteritis	*Staphylococcus*	A,R
		Campylobacter	A,R
		Clostridium	A,R
		Escherichia	A,R
		Yersinia	A,R
		Shigella	A,R
	Salmonellosis	*Salmonella*	A,R
	Streptococcosis	*Streptococcus*	A,R
	Tuberculosis	*Mycobacterium*	A,R
	Yersiniosis	*Yersinia*	A,R
	Septicaemia	*Acinetobacter*	A,R
		Alcaligenes	A,R
		Bacteroides	A,R
		Clostridium	A,R
		Citrobacter	A,R
		Corynebacterium	A,R
		Enterobacter	A,R
		Enterococcus	A,R
		Fusobacterium	A,R
		Klebsiella	A,R
		Moraxella	A,R
		Morganella	A,R
		Pasturella	A,R
		Peptococcus	A,R
		Proteus	A,R
		Pseudomonas	A,R
		Salmonella	A,R
		Serratia	A,R
		Staphylococcus	A,R
		Streptococcus	A,R
Viral	Hepatitis-A	*Picornavirus*	A
	Western encephalitis	*Togaviridus*	A,R
	West Nile virus	*Flaviviridus*	A,R
Mycotic	Coccidiomycosis	*Coccidioides*	A,R
	Cryptococcosis	*Cryptococcus*	A,R
	Septicemia	*Candida*	A,R
	Cladoorium	*Aergillus*	A,R
		Curvularia	A,R
		Fusarium	A,R
		Rhodotorula	A,R
Microparasitic	Amoebiasis	*Entamoeba*	A,R
	Cryptosporidiosis	*Cryptosporidium*	A,R
Macroparasitic	Diphyllobothriasis	*Diphyllobothrium*	A,R
	Dracunculosis	*Dracunculus*	A,R
	Fascioliasis	*Fasciola*	A,R
	Larva migrans	*Gnathastoma*	A,R
	Loaiasis	*Loa*	A,R

APPENDIX 2

Minor amphibian - (A) and reptile - (R) borne zoonotic infections and infestations. *Derived from*: 1. Pathogens as bio-weapons, F.L. Frye, unpublished. 2. Zoonoses: drawing the battle lines, C. Warwick, Clinical Veterinary Times, 2006. 3. Reptile and amphibian communities in the United States, V. Bridges, C., Kopral, R. Johnson, Centers for Epidemiology and Animal health, 2001.

Disease		Genus of Pathogen	Source
Bacterial	Vibriosis	*Vibrio*	A,R
	Melioidosis	*Burkholderia*	A
	Mycoplasmosis	*Mycoplasma*	A,R
	Mycobacteriosis	*Mycobacterium*	A
	Streptothricosis	*Dermatophilus*	R
Viral	California encephalitis	*Bunyaviridae*	A,R
Mycotic	Adiaspiromycosis	*Chrysosporium*	A
Microparasitic	Balantidiasis	*Balantidium*	A,R
	Echinostomiasis	*Echinostoma*	A,R
	Giardiasis	*Giardia*	A,R
	Paragonimiasis	*Paragonimus*	A,R
	Rhinosporidiosis	*Rhinosporium*	R
	Sarcocystis	*Sarcocystis*	A,R
Macroparasitic	Ancylostomiasis	*Ancylostoma*	A,R
	Chigger mite dermatitis	*Eutombicula*	A,R
	Dwarf tapeworm infestation	*Hymenolepis*	A,R
	Thelaziasis	*Thelazia*	A,R

APPENDIX 3

List of species observed on display. This list does not distinguish between species and hobbyist-assigned variant forms (eg 'hybrid', 'morph', 'melanistic').

Terraristika	
AMPHIBIANS	
Anurans	
Oriental fire-bellied toad	*Bombina orientalis*
Horned frog	*Ceratophrys*
Phantasmal dart frogs	*Epipedobates anthonyi*
Green and black poison dart frog	*Dendrobates auratus*
Japanese common toad	*Bufo japonicus*
Caudata	
Axolotl	*Ambystoma mexicanum*
Marbled newt	*Triturus marmoratus*
Southern marbled newt	*Triturus pygmaeus*
Baran's spotted newt	*Neurergus strauchi barani*
Spotted salamander	*Ambystoma maculatum*
Crocodile newt	*Tylototriton sp*
African bullfrog	*Pyxicephalus sp*
CHELONIANS	
Aldabran tortoise	*Aldabrachelys gigantean*
Hermann's tortoise	*Testudo hermanni*
Greek tortoise	*tortoise Testudo graeca*
Leopard tortoise	*Stigmochelys pardalis*
Red footed tortoise	*Chelonoidis carbonaria*
African spurred tortoise	*Geochelone sulcata*
Mata mata turtle	*Chelus fimbriatus*
Mud turtle	*Pelomedusa subrufa*
SNAKES	
Royal python	*Python regius*
Indian rock python	*Python molurus bivittatus*
Green tree python	*Chondropython/Morelia viridis*
Boa constrictor	*Boa constrictor*
Amazon tree boa	*Corallus hortulanus*
Corn snake	*Pantherophis/Elaphe guttata*
Milk snake	*Lampropeltis triangulum*
California kingsnake	*Lampropeltis getula*
Rat snake	*Coelognathus flavolineatus*
Elegant pitviper	*Protobothrops elegans*
White-lipped island pitviper	*Trimeresurus insularis*
Bamboo viper	*Trimeresurus stejnegeri*
Sri Lankan green pitviper	*Trimeresurus trigonocephalu*
Flat-nosed pitviper	*Trimeresurus puniceus*
Timber rattlesnake	*Crotalus horridus*
Western diamondback rattlesnake	*Crotalus atrox*
Panamint rattlesnake	*Crotalus stephensi*
Mohave rattlesnake	*Crotalus scutulatus*
Mexican west coast rattlesnake	*Crotalus basiliscus*
Painted saw-scaled viper	*Echis coloratus*

APPENDIX 3

List of species observed on display. This list does not distinguish between species and hobbyist-assigned variant forms (eg 'hybrid', 'morph', 'melanistic').

Terraristika (cont)	
SNAKES (cont)	
West African carpet viper	*Echis ocellatus*
North-east African carpet viper	*Echis carinaus pyramidium*
Saharan horned viper	*Cerastes cerastes*
Algerian horned viper	*Cerastes cerastes mutila*
Papuan taipan	*Oxyuranus scutellatus canni*
LIZARDS	
Bearded dragon	*Pogona vitticeps*
Anolis	*Anolis carolinensis*
Veiled chameleon	*Chamaeleo calyptratus*
Pigmy chameleon	*Chameleo brevicaudatus*
Panther chamelon	*Furcifer Chamaeleo pardalis*
Jackson's chameleon	*Trioceros jacksoni xantolophus*
Chameleon	*Trioceros jacksoni willegensis*
High casqued chameleon	*Trioceros hoehnelli*
Cameroon sailfin chameleon	*Trioceros montium*
Pfeffer's chameleon	*Trioceros pfefferi*
Southern four-horned chameleon	*Trioceros quadricornis*
Rough chameleon	*Trioceros rudis*
Meller's chameleon	*Trioceros melleri*
Leopard gecko	*Eublepharis macularius*
Tokay gecko	*Gecko gecko*
Day gecko	*Phelsuma madagascarensis*
Madagascan green gecko	*Phelsuma quadriocellata*
Dwarf gecko	*Lygodactylus Williamsi*
Thick-toed gecko	*Pachydactylus spp.*
Gargoyle gecko	*Rhacodactylus Auriculatus*
South American marbled gecko	*Homonota fasciata*
Rough knobtail gecko	*Nephrurus amyae*
Gila monster	*Heloderma suspectum*
Green iguana	*Iguana iguana*
Water dragon	*Physignathus cocincinus*
Plated lizard	*Gerrhosaurus major*
Solomon island skink	*Corucia zebrata*
Nile monitor	*Varanus niloticus*
Timor monitor	*Varanus timorensis*

APPENDIX 3

List of species observed on display. This list does not distinguish between species and hobbyist-assigned variant forms (eg 'hybrid', 'morph', 'melanistic').

IHS Show	
AMPHIBIANS	
Anurans	
African clawed frog	*Xenopus laevis*
Zaire dwarf clawed frog	*Hymenochirus boettgeri*
Anthony's poison arrow frog	*Epipedobates anthonyi*
Blue poison dart frog	*Dendrobates azureus*
Cranwell's horned frog	*Ceratophrys cranwelli*
Dyeing dart frog	*Dendrobates tinctorius*
Oriental fire-bellied toad	*Bombina orientalis*
Tomato frog	*Dyscophus antongilii*
Caudata	
Axolotl	*Ambystoma mexicanum*
CHELONIANS	
Marginated tortoise	*Testudo marginata*
Hermanns tortoise	*Testudo hermanni*
Greek tortoise	*Testudo graeca*
Horsfields tortoise	*Testodu horsfieldii*
Red footed tortoise	*Chelonoidis carbonaria*
Leopard tortoise	*Stigmochelys pardalis*
Musk turtle	*Sternotherus odoratus*
Spotted turtle	*Clemmys guttata*
Roti island snake necked turtle	*Phrynops mccordi*
Yellow-bellied terrapin	*Trachemys scripta*
Map terrapin	*Graptemys barbouri*
Painted terrapin	*Chrysemys picta*
SNAKES	
Royal python	*Python regius*
Burmese python	*Python molurus bivittatus*
Boa constrictor	*Boa constrictor*
Carpet python	*Morelia spilota*
Children's python	*Antaresia childreni*
Green tree python	*Chondropython/Morelia viridis*
Corn snake	*Pantherophis/Elaphe guttata*
Milk snake	*Lampropeltis triangulum*
Western hognosed	*Heterodon nasicus*
California kingsnake	*Lampropeltis getula*
LIZARDS	
Bearded dragon	*Pogona vitticeps*
Panther chameleon	*Furcifer pardalis*
Veiled chameleon	*Chameloa calyptratus*
Day gecko	*Phelsuma madagascarensis*
Crested geckos	*Rhacodactylus ciliatus*
Leopard gecko	*Eublepharis macularius*
Madagascan green gecko	*phelsuma quadriocellata*
Smooth knobtail gecko	*Nephrurus levis*
Pink tongue skink	*Hemisphaeriodon/Cyclodomorphus gerrardii*
Iguana	*Iguana iguana*
Nile monitor	*Varanus niloticus*
Argentine tegu	*Tupinambis merianae*
Texas horned lizard	*Phrynosoma cornutum*

APPENDIX 3

List of species observed on display. This list does not distinguish between species and hobbyist-assigned variant forms (eg 'hybrid', 'morph', 'melanistic').

Expoterraria	
AMPHIBIANS	
Anurans	
Oriental fire-bellied toad	*Bombina orientalis*
Dyeing poison dart frog	*Dendrobates tinctorius*
Splash-backed poison frog	*Adelphobates galactonotus*
Golden mantella	*Mantella aurantiaca*
Tomato frog	*Dyscophus antongili*
African bullfrog	*Pyxicephalus adspersus*
Marine toad	*Bufo marinus*
Rococo frog	*Bufo paracnemus*
Cranwell's horned frog	*Ceratophrys cranwely*
Pacman frog	*Ceratophrys ornate*
White's tree frog	*Litoria caerulea*
Budgett's frog	*Lepidobatrachus laevis*
Serrate-legged small treefrog	*Kurixalus odontotarsus*
Yellow-headed poison dart frog	*Dendrobates leucomelas*
Bony-headed toad	*Bufo (Ingerophrynus) galeatus*
Caudata	
Axolotl	*Ambystoma mexicanum*
Emperor newt	*Tylototriton shanjing*
CROCODILIANS	
Spectacled caiman	*Caiman crocodylus*
CHELONIANS	
Aldabran tortoise	*Aldabrachelys gigantea*
African spurred tortoise	*Geochelone sulcata*
Kleinmann's tortoise	*Testudo kleinmanni*
Marginated tortoise	*Testudo marginata*
Hermanns tortoise	*Testudo hermanni*
Greek tortoise	*Testudo graeca*
Iberian tortoise	*Testudo iberia*
Horsfields tortoise	*Testodu horsfieldii*
Forsten's tortoise	*Indotestudo forstenii*
Red-footed tortoise	*Chelonoidis carbonaria*
Yellow-footed tortoise	*Chelonoidis denticulata*
Elongated tortoise	*Indotestudo elongata*
Leopard tortoise	*Stigmochelys pardalis*
Radiated tortoise	*Astrochelys radiata*
Argentine tortoise	*Chelonoidis chilensis*
Hinge-back tortoise	*Kinixys erosa*
Pancake tortoise	*Malacochersus tornieri*
Spiny softshell turtle	*Trionyx spiniferus*
Big bend slider	*Trachemys gaigeae*
Yellow-bellied terrapin	*Trachemys scripta*
Chinese pond turtle	*Chinemys reevesii*
Yellow-spotted river turtle	*Podocnemis unifilis*
Box turtle	*Terrapene carolina*
Common musk turtle	*Sternotherus odoratus*
Razorback musk turtle	*Sternotherus carinatus*
Stripe-necked musk turtle	*Sternotheros minor peltifer*
Narrow-bridged musk turtle	*Claudius augustatus*

APPENDIX 3

List of species observed on display. This list does not distinguish between species and hobbyist-assigned variant forms (eg 'hybrid', 'morph', 'melanistic').

Expoterraria (cont)	
CHELONIANS (cont)	
Spotted turtle	*Clemmys guttata*
Spot-legged turtle	*Rhinoclemmys punctularia*
Mata mata turtle	*Chelus fimbriatus*
Alligator snapping turtle	*Macroclemmys temmincki*
Common snapping turtle	*Chelydra serpentina*
New Guinea snapping turtle	*Elseya novaeguineae*
Malayan snail-eating turtle	*Malayemys macrocephala*
Circled Indian tent turtle	*Pangshura tentoria circumdata*
Diamondback terrapin	*Malaclemys terrapin*
Map terrapin	*Graptemys barbouri*
Black-knobbed map turtle	*Graptemys nigrinoda*
Painted terrapin	*Chrysemys picta*
Flat-headed turtle	*Platemys platycephala*
Side-necked turtle	*Emydura albertisi*
Indian eyed turtle	*Morenia petersi*
Mud turtle	*Pelomedusa subrufa*
Mud turtle	*Kinosternon subrubrum*
Mud turtle	*Kinosternon scorpioides*
Striped mud turtle	*Kinosternon baurii*
Loggerhead musk turtle	*Sternotherus minor*
Chinese box turtle	*Cuora flavomarginata*
Toad head turtle	*Phrynops nasuta*
Gibbus turtle	*Phrynops gibbus*
Cotinga River toadhead turtle	*Phrynops tuberosus*
Big-headed turtle	*Platysternon megacephalum*
Siebenrock's snake necked turtle	*Chelodina siebenrocki*
Senegal flapshell turtle	*Cyclanorbis senegalensis*
Asian leaf turtle	*Cyclemys dentata*
Reeves turtle	*Mauremys reevesii*
SNAKES	
Timor python	*Python timorensis*
Royal python	*Python regius*
Indian rock python	*Python molurus bivittatus*
Reticulated python	*Python reticulatus*
Green tree python	*Chondropython/Morelia viridis*
Boa constrictor	*Boa constrictor*
Carpet python	*Morelia spilota*
Rainbow boa	*Epicrates cenchria*
Colombian rainbow boa	*Epicrates cenchria maurus*
Amazon tree boa	*Corallus hortulanus*
Rosy boa	*Lichanura trivirgata roseofusca*
Kenyan sand boa	*Gongylophis colubrinus*
Corn snake	*Pantherophis/Elaphe guttata*
Gopher snake	*Pituophis catenifer*
California kingsnake	*Lampropeltis getula*

APPENDIX 3

List of species observed on display. This list does not distinguish between species and hobbyist-assigned variant forms (eg 'hybrid', 'morph', 'melanistic').

Expoterraria (cont)	
SNAKES (cont)	
Milk snake	*Lampropeltis triangulum*
Western hog-nosed snake	*Heterodon nasicus*
Rat snake	*Coelognathus flavolineatus*
Stripe-tailed rat snake	*Elaphe taeniura taeniura*
LIZARDS	
Anolis	*Anolis carolinensis*
Bearded dragon	*Pogona vitticeps*
Panther chameleon	*Furcifer pardalis*
Veiled chameleon	*Chamaeleo calyptratus*
Jackson's chameleon	*Trioceros jacksoni xantolophus*
High casqued chameleon	*Trioceros hoehnelli*
Day gecko	*Phelsuma madagascarensis*
Crested gecko	*Rhacodactylus ciliatus*
Leopard gecko	*Eublepharis macularius*
Madagascan green gecko	*Phelsuma quadriocellata*
Gold dust day gecko	*Phelsuma laticauda*
Lined day gecko	*Phelsuma lineata dorsivittata*
Rough knobtail gecko	*Nephrurus amyae*
Electric blue gecko	*Ligodactylus williamsi*
Pictus gecko	*Paroedura pictus*
Henkel's leaf-tailed gecko	*Uroplatus henkeli*
Giant zonure	*Cordylus giganteus*
Fence lizard	*Sceloporus undulatus*
Dabb lizard	*Uromastyx sp*
Pink tongue skink	*Hemisphaeriodon/Cyclodomorphus gerrardii*
Stoke's skink	*Egernia (spiny tailed skink) stokesii*
Major skink	*Egernia frerei*
Green iguana	*Iguana iguana*
Caiman lizard	*Dracaena guianensis*
Texas horned lizard	*Phrynosoma cornutum*
Tanimbar blue-tongued skink	*Tiliqua scincoides chimaerea*
New Guinea blue-tongued skink	*Tiliqua gigas*
Emperor flat lizard	*Platysaurus imperator*
Rainbow whiptail lizard	*Cnemidophorus lemniscatus*
Argentine tegu	*Tupinambis merianae*
Yellow tegu	*Tupinambis duseni*
Nile monitor	*Varanus niloticus*
Quince monitor	*Varanus melinus*
Black tree monitor	*Varanus beccari*
Emerald tree monitor	*Varanus prasinus*
Savannah monitor	*Varanus exanthematicus*
Asian water monitor	*Varanus salvator*
Argus monitor	*Varanus panoptes horni*
Auffenberg's monitor	*Varanus auffenbergi*

APPENDIX 4

Table A: European Market amphibian species, country of origin and invasive potential risk.

Scientific name	Common name	Country of origin	IAS	Invasion risk	Intuitive risk
Class: Amphibia – Order: Anura					
Adelphobates galactonotus	Splash-backed poison frog	*Sth Am*			low
Bombina orientalis	Oriental fire-bellied toad	*Asia (China)*	Y	moderate	moderate
Bufo (Ingerophrynus) galeatus	Bony-headed toad	*Asia*			moderate
Bufo marinus (Rhinella marina)	Marine toad	*Cent/Sth Am*	Y	extreme	extreme
Bufo japonicus	Japanese common toad	*Asia (Japan)*	Y	moderate	moderate
Ceratophrys ornata	Ornate horned frog	*Sth Am*			moderate
Ceratophrys cranwelli	Chacoan horned frog	*Sth Am*			moderate
Ceratophrys ornata	Pacman frog	*Sth Am*			moderate
Dendrobates auratus	Green and black poison dart frog	*Cent/Sth Am*			moderate
Dendrobates azureus	Blue poison dart frog	*Sth Am*			low
Dendrobates leucomelas	Yellow-headed poison dart frog	*Sth Am*			low
Dendrobates tinctorius	Dyeing poison dart frog	*Sth Am*			low
Dyscophus antongilii	Tomato frog	*Madagascar*			moderate
Epipedobates anthonyi	Phantasmal dart frog	*Sth Am*			low
Hymenochirus boettgeri	Zaire dwarf clawed frog	*Africa*			high
Kurixalus odontotarsus	Serrate-legged small treefrog	*Asia (China)*			moderate/high
Lepidobatrachus laevis	Budgett's frog	*Sth Am*			low
Litoria caerulea	Green tree frog	*Aust/PNG*			moderate
Mantella aurantiaca	Golden mantella	*Madagascar*			moderate/high
Pyxicephalus adspersus	African bullfrog	*Africa*			moderate/high
Rhinella schneideri	Rococo frog	*Sth Am*	Y	moderate	moderate
Trachycephalus venulosus	Marbled tree frog	*Cent/Sth Am*	Y	moderate	moderate
Xenopus laevis	African clawedfrog	*Africa*	Y	extreme	extreme
Class: Amphibia – Order: Caudata					
Ambystoma mexicanum	Axolotl	*Cent Am*			extreme
Ambystoma maculatum	Spotted salamander	*USA*			extreme
Neurergus strauchii barani	Baran's spotted newt	*Europe*			extreme
**Triturus marmoratus*	Marbled newt	*Europe*			extreme
**Triturus pygmaeus*	Southern marbled newt	*Europe*			extreme
Tylototriton shanjing	Emperor newt	*Asia (China)*			high
Tylototriton verrucosus	Crocodile newt	*Asia*			high

Aust/PNG *= Australia/Papua New Guinea ;* ***Sth Am*** *= South America;* ***Cent Am*** *= Central America;*
Cent/Sth Am *= Central/South America; * related to taxon of an IAS*

APPENDIX 4

Table B: European Market turtle species, country of origin and invasive potential risk.

Scientific name	Common name	Country of origin	IAS	Invasion risk	Intuitive risk
Class: Reptilia – Order: Testudines					
Aldabrachelys gigantea	Aldabran tortoise	*Africa*	Y	moderate	low/moderate
Astrochelys radiata	Radiated tortoise	*Madagascar*			low/moderate
Chelodina mccordi	Roti island snake-necked turtle	*Asia (Indon)*			moderate
Chelodina siebenrocki	Siebenrock's snake necked turtle	*Asia (Indon)*			moderate
Chelonoidis carbonaria	Red-footed tortoise	*Cent/Sth Am*	Y	high	low
Chelonoidis chilensis	Argentine tortoise	*Sth Am*			low
Chelonoidis denticulata	Yellow-footed tortoise	*Sth Am*	Y	low	low
Chelus fimbriata	Mata mata turtle	*Sth Am*			low
Chelydra serpentina	Common snapping turtle	*USA*	Y	extreme	extreme
Chinemys (Mauremys) reevesii	Chinese pond turtle	*Asia (China)*	Y	low	moderate/high
Chrysemys picta	Painted terrapin	*USA*	Y	serious	high/extreme
Claudius angustatus	Narrow-bridged musk turtle	*Cent Am*			high/extreme
Clemmys guttata	Spotted turtle	*USA*			moderate
Cuora flavomarginata	Yellow-margined box turtle	*Asia (China)*		moderate	moderate/high
Cyclanorbis senegalensis	Senegal flapshell turtle	*Africa*			moderate
Cyclemys dentata	Asian leaf turtle	*Asia*			low/moderate
Elseya novaeguineae	New Guinea snapping turtle	*Asia/PNG*	Y	moderate	moderate
Emydura albertisi	Red bellied short-necked turtle	*PNG*			low
Geochelone sulcata	African spurred tortoise	*Africa*	Y	moderate	extreme
Graptemys barbouri	Barbour's map turtle	*USA*			high/extreme
Graptemys nigrinoda	Black-knobbed map turtle	*USA*			high/extreme
Indotestudo elongata	Elongated tortoise	*Asia*	Y	low	low
Indotestudo forstenii	Forsten's tortoise	*Asia (Indon)*			low
Kinixys erosa	Serrated hinge-back tortoise	*Africa*			low/moderate
Kinosternon baurii	Striped mud turtle	*Can/USA*			high/extreme
Kinosternon scorpioides	Scorpion mud turtle	*Sth Am*			moderate
Kinosternon subrubrum	Eastern mud turtle	*USA*			high/extreme
Macroclemmys temmincki	Alligator snapping turtle	*USA*	Y	moderate	moderate
Malaclemys terrapin	Diamondback terrapin	*USA*			moderate/high
Malacochersus tornieri	Pancake tortoise	*Africa*			moderate
Malayemys macrocephala	Malayan snail-eating turtle	*Asia*			low

Aust *= Australia;* ***Can*** *= Canada;* ***Indon*** *= Indonesia;* ***PNG*** *= Papua New Guinea;* ***Sth Am*** *= South America;*
Cent/Sth Am *= Central/South America; * related to taxon of an IAS*

APPENDIX 4

Table B (cont): European Market turtle species, country of origin and invasive potential risk.

Scientific name	Common name	Country of origin	IAS	Invasion risk	Intuitive risk
Class: Reptilia – Order: Testudines (cont)					
Mauremys reevesii	Reeve's turtle	*Asia*	Y	low	moderate/high
Morenia petersi	Indian eyed turtle	*Asia (India)*			low
Pangshura tentoria circumdata	Circled Indian tent turtle	*Asia (India)*			moderate
Pelomedusa subrufa	African helmeted turtle	*Africa*			moderate/high
Phrynops gibba	Gibbus turtle	*Sth Am*			low
Phrynops nasuta	Toad head turtle	*Sth Am*			low
Phrynops tuberosus	Cotinga River toadhead turtle	*Sth Am*			low
Platemys platycephala	Flat-headed turtle	*Sth Am*			low
Platysternon megacephalum	Big-headed turtle	*Asia (China)*			moderate
Podocnemis unifilis	Yellow-spotted river turtle	*Sth Am*			low
Rhinoclemmys punctularia	Spot-legged turtle	*Sth Am*			low
Sternotherus carinatus	Razor-backed musk turtle	*USA*			high/extreme
Sternotherus minor	Loggerhead musk turtle	*USA*	Y	moderate	high/extreme
Sternotherus minor peltifer	Stripe-necked musk turtle	*USA*			high/extreme
Sternotherus odoratus	Common musk turtle	*USA*	Y	moderate	high/extreme
Stigmochelys pardalis	Leopard tortoise	*Africa*			moderate/high
Terrapene carolina	Common box turtle	*USA*			high/extreme
Testudo (graeca) ibera	Iberian tortoise	*Europe*			high/extreme
Testudo graeca	Greek tortoise	*Europe*	Y	high	high/extreme
Testudo hermanni	Hermann's tortoise	*Europe*	Y	moderate	high/extreme
Testudo horsfieldii	Horsfield's tortoise	*Asia*	Y	extreme	high/extreme
Testudo kleinmanni	Kleinmann's tortoise	*Africa*			high/extreme
Testudo marginata	Marginated tortoise	*Europe*	Y	extreme	high/extreme
Trachemys gaigeae	*Big bend slider	*USA/Cent Am*			extreme
Trachemys scripta	Yellow-bellied terrapin	*USA*	Y	extreme	extreme
Trionyx spinifera	Spiny softshell turtle	*Can/USA*	Y	moderate	high/extreme

***Aust** = Australia; **Can** = Canada; **Indon** = Indonesia; **PNG** = Papua New Guinea; **Sth Am** = South America;*
***Cent/Sth Am** = Central/South America; * related to taxon of an IAS*

APPENDIX 4

Table C: European Market snake species, country of origin and invasive potential risk.

Scientific name	Common name	Country of origin	IAS	Invasion risk	Intuitive risk
Class: Reptilia – Order: Squamata – Suborder: Serpentes					
Antaresia childreni	Children's python	*Aust*			moderate/high
Boa constrictor	Boa constrictor	*Cent/Sth Am*	Y	high	low
Cerastes cerastes	Saharan horned viper	*Africa*			moderate
Cerastes cerastes mutila	Algerian horned viper	*Africa*			moderate
Chondropython/Morelia viridis	Green tree python	*Aust/PNG*			low/moderate
Coelognathus flavolineatus	Yellow striped ratsnake	*Asia*	Y	moderate	moderate
Corallus hortulanus	Amazon tree boa	*Sth Am*			low
Crotalus atrox	Western diamondback rattlesnake	*USA*			moderate/high
Crotalus basiliscus	Mexican west coast rattlesnake	*USA*			moderate/high
Crotalus horridus	Timber rattlesnake	*USA*			moderate/high
Crotalus mitchellii stephensi	Panamint rattlesnake	*USA*			moderate/high
Crotalus scutulatus	Mohave rattlesnake	*USA*			moderate/high
Echis coloratus	Painted saw-scaled viper	*Africa*			moderate
Echis ocellatus	West African carpet viper	*Africa*			moderate
Echis pyramidium	Egyptian saw-scaled viper	*Africa*			moderate
Elaphe taeniura taeniura	Stripe-tailed rat snake	*Asia (China)*	Y	low	moderate
Epicrates cenchria	Rainbow boa	*Cent/Sth Am*		high	low/moderate
Epicrates cenchria maurus	Colombian rainbow boa	*Sth Am*		high	low
Gongylophis colubrinus	Egyptian sand boa	*Africa*		high	low
Heterodon nasicus	Western hog-nosed snake	*USA*	Y	high	high
Lampropeltis getula	Common king snake	*USA*		high	high
Lampropeltis triangulum	Milk snake	*USA/Sth Am*			moderate
Lichanura trivirgata	Rosy boa	*USA*	Y	high	moderate
Morelia spilota	Carpet python	*Aust/PNG*			moderate
Oxyuranus scutellatus canni	Papuan taipan	*PNG*			low
Pantherophis/Elaphe guttata	Corn snake	*USA*		high	extreme
Pituophis catenifer	Gopher snake	*USA*	Y	moderate	moderate/high
Protobothrops elegans	Elegant pitviper	*Asia (Japan)*			moderate
Python molurus bivittatus	Burmese Python	*Asia*	Y	high	high
Python regius	Royal python	*Africa*		low	low
Python reticulatus	Reticulated python	*Asia*			low
Python timorensis	Timor python	*Asia*			low
Trimeresurus albolabris insularis	White-lipped island pitviper	*Asia*			low
Trimeresurus puniceus	Flat-nosed pitviper	*Asia*			low
Trimeresurus stejnegeri	Bamboo viper	*Asia*			low
Trimeresurus trigonocephalus	Sri Lankan green pitviper	*Asia*			low

***Aust** = Australia; **PNG**= Papua New Guinea; **Sth Am** = South America; **Cent/Sth Am** = Central/South America*

APPENDIX 4

Table D: European Market lizard species, country of origin and invasive potential risk.

Scientific name	Common name	Country of origin	IAS	Invasion risk	Intuitive risk
Class: Reptilia – Order: Squamata – Suborder: Lacertilia					
Anolis carolinensis	*Green anole	*USA*	Y	high	high
Chamaeleo calyptratus	Veiled chameleon	*Africa*		high	high
Cnemidophorus lemniscatus	Rainbow whiptail lizard	*Sth Am*	Y	high	low
Cordylus giganteus	Giant zonure	*Africa*			moderate
Corucia zebrata	Solomon island skink	*Oceania*			low
Dracaena guianensis	Northern caiman lizard	*Sth Am*			low
Egernia frerei	Major skink	*Aust*			moderate
Egernia stokesii	Gidgee skink	*Aust*			moderate
Eublepharis macularius	Leopard gecko	*Asia*		high	high
Furcifer pardalis	Panther chameleon	*Madagascar*	Y	moderate	moderate
Gecko gecko	Tokay gecko	*Asia*	Y	extreme	high
Gerrhosaurus major	Sudan plated lizard	*Africa*	Y	low	low/moderate
Heloderma suspectum	Gila monster	*USA*			moderate
Hemisphaeriodon gerrardii	Pink tongue skink	*Aust*			moderate
Homonota fasciata	South American marked gecko	*Sth Am*			low
Iguana iguana	Green iguana	*Cent/Sth Am*	Y	extreme	low/moderate
Lygodactylus williamsi	Electric blue gecko	*Africa*			moderate
Nephrurus amyae	Rough knobtail gecko	*Aust*			moderate
Nephrurus levis	Smooth Knob-tailed gecko	*Aust*			moderate
Pachydactylus spp.	Thick-toed gecko	*Africa*			moderate
Paroedura pictus	Pictus gecko	*Madagascar*			moderate
Phelsuma laticauda	Gold dust day gecko	*Madagascar*	Y	high	high
Phelsuma lineata dorsivittata	*Striped day gecko	*Madagascar*			high
Phelsuma madagascariensis	*Day gecko	*Madagascar*			high
Phelsuma quadriocellata	*Madagascan green gecko	*Madagascar*			high
Phrynosoma cornutum	Texas horned lizard	*USA*			moderate
Physignathus cocincinus	Chinese water dragon	*Asia*			low
Platysaurus imperator	Imperial flat lizard	*Africa*			moderate
Pogona vitticeps	Central bearded dragon	*Aust*			moderate
Rhacodactylus auriculatus	Gargoyle gecko	*Oceania*			low/moderate
Rhacodactylus ciliatus	Crested gecko	*Oceania*			low/moderate
Rieppeleon brevicaudatus	*Pigmy chameleon	*Africa*			low
Sceloporus undulates	Eastern Fence lizard	*USA*	Y	low	moderate
Tiliqua gigas	Indonesian blue-tongued skink	*Asia*			low
Tiliqua scincoides chimaerea	Tanimbar blue-tongued skink	*Asia*			low

Aust *= Australia;* ***PNG****= Papua New Guinea;* ***Sth Am*** *= South America;* ***Cent/Sth Am*** *= Central/South America*

** related to taxon of an IAS*

APPENDIX 4

Table D (cont): European Market lizard species, country of origin and invasive potential risk.

Scientific name	Common name	Country of origin	IAS	Invasion risk	Intuitive risk
Class: Reptilia – Order: Squamata – Suborder: Lacertilia (cont)					
Trioceros hoehnelii	High-casqued chameleon	*Africa*			moderate
Trioceros jacksoni willegensis	Jackson's chameleon	*Africa*	Y	moderate	moderate
Trioceros jacksoni xantolophus	Yellow-crested Jackson's chameleon	*Africa*	Y	high	moderate
Trioceros melleri	Meller's chameleon	*Africa*			moderate
Trioceros montium	Cameroon sailfin chameleon	*Africa*			moderate
Trioceros pfefferi	Pfeffer's chameleon	*Africa*			moderate
Trioceros quadricornis	Four-horned chameleon	*Africa*			moderate
Trioceros rudis	Rough chameleon	*Africa*			moderate
Tupinambis duseni	*Yellow tegu	*Sth Am*			low
Tupinambis merianae	Argentine black and white tegu	*Sth Am*	Y	high	low
Uromastyx sp.	Dabb lizard	*Europe/Asia*	Y	moderate	low/moderate
Uroplatus henkeli	Henkel's leaf-tailed gecko	*Madagascar*			moderate
Varanus auffenbergi	*Auffenberg's monitor	*Asia*			low/moderate
Varanus beccarii	Black tree monitor	*Asia*	Y	low	low/moderate
Varanus exanthematicus	*Savannah monitor	*Africa*			low/moderate
Varanus melinus	*Quince monitor	*Asia*			low/moderate
Varanus niloticus	Nile monitor	*Africa*	Y	high	moderate
Varanus panoptes horni	Argus monitor	*Aust/PNG*	Y	low	low/moderate
Varanus prasinus	*Emerald tree monitor	*Asia*			low
Varanus salvator	Asian water monitor	*Asia*	Y	low	low/moderate
Varanus timorensis	Timor monitor	*Aust/PNG*	Y	low	low/moderate

Aust *= Australia;* ***PNG****= Papua New Guinea;* ***Sth Am*** *= South America;* ***Cent/Sth Am*** *= Central/South America*
** related to taxon of an IAS*

APPENDIX 4

Table E: European Market crocodilian species, country of origin and invasive potential risk.

Scientific name	Common name	Country of origin	IAS	Invasion risk	Intuitive risk
Class: Reptilia – Order: Crocodylia					
Caiman crocodylus	Spectacled caiman	*Cent/Sth Am*	Y	high	high

Cent/Sth Am *= Central/South America*