Evidence on the welfare of exotic pets in Scotland

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This review was carried out by Lucy Oldham, working within the Animal Behaviour and Welfare team at Scotland's Rural College (SRUC). The research was funded by the Rural and Environmental Science and Analytical Services Division of the Scottish Government (RESAS). Guidance was provided by members of the Scottish Animal Welfare Commission (SAWC).

Evidence on the Welfare of Exotic Pets in Scotland: Executive Summary

This is a scoping review on the welfare of exotic pets, requested by the Scottish Animal Welfare Commission, to provide independent evidence to inform recommendations on the keeping of exotic pets. The interim report on exotic pets in Scotland outlined concerns about the welfare of some non-domestic species which are in private ownership and highlighted a lack of information available on the number of animals which are traded and owned, the conditions in which they are bred and/or transported to the UK, and the suitability of captive environments in both commercial and private environments.

It has been suggested that the suitability of animals as pets depends on four main factors; they are easy to keep in terms of basic physiological, behavioural and ecological needs; do not present an overt risk of becoming invasive in the natural environment; do not pose a disproportionate risk to human health and they have reliable husbandry guidance available

This review focuses on species which are known or estimated to be for sale in Scotland, while excluding those species which are already banned due to CITES or Alien Invasive Species legislation, and very common exotic pets, such as rabbits, small rodents (except dwarf hamsters) and canaries.

This review presents evidence for animal welfare issues associated with captivity, in particular the attributes which make each animal species more or less “easy to keep” and the availability of reliable information on their keeping. Each section is summarised at the taxonomic level of “order”, focussing on the species of interest identified by SAWC. The review includes scientific papers where available, including experimental studies, case studies and reviews, surveys and conference abstracts. Other sources, including book chapters and guidance provided by professional organisations (e.g., RSPCA, EAZA), are included where appropriate.

The risk to human health presented by these species, in terms of hosting zoonotic disease, antibiotic-resistant pathogens and causing bite injuries, is described where such information is available. However, formal analysis of the risks associated with each species, in terms of clinical disease presenting to medical authorities, could be the subject of a separate study, as human health data are outside of the scope of this review.

The breadth of species included and their individual welfare issues (including variation in the quality of information available) is difficult to summarise. Evidence of the health and welfare of exotic pets living in Scotland is sparse in almost all cases. Owing to the nature of veterinary journals, many studies focus on novel or interesting clinical cases and do not give an idea of the health of the pet population overall. Furthermore, there is evidence that reptile owners have low engagement with vets, and this is likely to apply to many of the species in this review (as reflected in the lack of evidence and the lack of responses to a DEFRA call for evidence among pet primate owners).

However, the following factors relating to the needs of exotic pets are suggested as particular barriers to meeting their need for a suitable environment:

1. Need for natural light, UVB and warmth, in combination with sufficient exercise. Particularly for birds, large or dangerous species of mammals and reptiles the enclosure size required to allow for normal behaviours, such as flying, burrowing, leaping or climbing, mean that several sources of heat and light (see section on tegu lizards) are required, and this may be beyond the means and space available to most owners.

2. Understanding and managing the social needs of animals, especially those which commonly live in large and/ or dynamic groups. Even where evidence of suffering is not available for social animals kept in isolation, this can be expected based on broad evidence across species.

3. Complex or unknown dietary needs. Particularly at risk from dietary imbalances are those animals which consume plant exudates, either as an obligatory or facultative requirement, and those which require very high levels of protein (e.g., cephalopods) and for which formulated diets are still not well tailored to the species (e.g., ornamental marine fish).

4. Where evidence for optimum (or minimal) husbandry conditions is known, more evidence is required to know whether owners are meeting these standards. Previous investigations have found gaps in information given to owners (e.g., reptiles) by pet suppliers and veterinary case studies highlight insufficiencies in care.

5. Inbreeding and breeding for rare phenotypes is a risk to welfare, notably in the African pygmy hedgehog and pythons. The unregulated and informal breeding of pet animals should be investigated and recording of congenital conditions would help to reach decisions about how to reach more transparent and responsible industry breeding standards.

6. The welfare of captive-bred juvenile animals, including fishes, decapods and cephalopods, is a critical area for investigation. Rearing non-domestic animals to become “tame” is a high-risk strategy, and unintended consequences have life-long implications, e.g., in primates and birds of prey, where animals cannot be handled or trained (and therefore do not benefit at all from living around humans and may be fearful in captivity) and are unsuitable for rehoming.

7. Evidence of positive welfare, including the human-animal bond, is not often published, but is crucial to determine which animals make suitable pets.

Animals that have are bred responsibly and domestically, well cared for, provided with an appropriate diet, expressing normal behaviours and experiencing positive welfare may not appear anywhere in the literature.

While the use of “positive lists” would help to guide owners as to which animals are more likely to succeed in captivity, compliance with existing animal welfare legislation is largely unknown. To address this in part, regular presentation to veterinary surgeons or other suitably qualified people, with sufficient knowledge of the species concerned, for routine health checks, along with record keeping (especially where dietary imbalances are common or where artificial environmental conditions must be maintained to ensure health) are sensible next steps by owners. Where animals present to vets for the first time with preventable and advanced malnutrition and other severe and difficult to resolve conditions, such as feather-damage, the prognosis for the animal having good welfare is poor and the relationship between owners and vets will be negative. Regular health checks should include discussions of reproductive health and breeding should be planned, which should consider the availability of appropriate homes, and the expertise of the owner. Regular veterinary checks would increase the capability and confidence of veterinarians, as well as allowing the scientific assessment of how well animals are being kept and potentially gathering of data from multiple veterinarians for wider epidemiological analysis.

Further research directed at some of the population level health and welfare issues apparent from this review would be valuable to inform future guidance or legislation.

Table of Contents

Introduction

This review was produced following an interim report by the Scottish Animal Welfare Commission (SAWC) and aims to identify and assemble any documented evidence of measured welfare harms that have been published in the scientific literature for key species identified by SAWC at any stage of their life (from breeding to ownership). Contributing factors towards the welfare of non-traditional pets are described in the “Pet suitability framework” (Koene *et al.*, 2016). These are based on the animals’ needs and behaviour in the wild and the relative difficulty of providing for their welfare needs in a domestic setting. Where positive lists exist for exotic pets (e.g., Belgium), the assessment criteria require that the species: "must be easy to keep in terms of its basic physiological, ethological, and ecological needs; must not present an overt risk of becoming invasive in the natural environment; must not pose a disproportionate risk to human health; must have reliable husbandry guidance available" (Toland *et al.*, 2020).

This review presents the evidence for animal welfare issues associated with captivity, and in particular the attributes which make each animal more or less “easy to keep” and the availability of reliable information on their keeping. This information can be interpreted in the context of the other ethical issues of pet ownership to assess their suitability for keeping in Scotland. Each section is summarised at the taxonomic level of “Order”, within which there is a focus on the species identified *a priori* by SAWC.

Methods

The literature search used the search engine “Web of Science”. Each search string included the common and scientific name(s) of the selected species (see table 1), plus the terms “‘behaviour; transport; captivity; infectious disease; husbandry; welfare; mortality; nutrition; nutritional disease; metabolic bone disease; trauma’. Additional search terms added after a preliminary search were “self-injury, self-trauma, aggression, destructive, vocal*, pain, lethargy, stereotypy, pacing*, distress, fur chewing*, grooming and feather pecking*” (*included where relevant to the species).

When search results for “behaviour OR behavior” returned a large body of work relating to wild animals in their natural habitat, or were used as experimental models, the terms “AND captive OR pet” were added as modifiers. The term “transport” was ambiguous and often returned studies of physiological processes (e.g., ion transport), whereas studies of welfare in transport mostly used the term “transport stress”. Therefore, to refine these results, the search line “(transport OR relocation) AND (stress OR welfare)” was included.

The journals: “Journal of Exotic Pet Medicine, Journal of Avian Medicine and Surgery, Journal of Herpetological Medicine and Surgery, Veterinary Clinics of North America: Exotic Animal Practice” were also searched according to the species being examined. Additional sources were EAZA Best Practice Guidelines, AZA and USDA APHIS Animal Care Guides.

Owing to the large number of species covered with vastly differing degrees of information available, the search criteria were adapted according to the level of information available on Web of Science. Where the available studies did not provide any information about the life of a particular animal in captivity, additional avenues were explored:

1) Cascading by searching the references cited by the publications available.
2) Searching Pubmed, Google Scholar or Hobbyist/ sales websites.
3) Searching for RSPCA care guides.

Evidence from Scotland was prioritised and where evidence was unavailable, studies were included in the following order of priority: Rest of UK, Europe/ North America (for easier comparison, evidence was prioritised in studies where the climate and pet-keeping practices are more similar to Scotland, and where species are kept as “exotic” pets rather than in their native countries). Regulatory monitoring is mentioned where it applies to a particular species (with respect to CITES, importation into the UK and “Dangerous Wild Animal” regulations).

Table 1. Animals included in this review, as defined by Scottish Animal Welfare Commission (SAWC). Terms are listed at species (S), genus (G), Order (O), Class (C) or Family (F) level.

	Common name	**Scientific name**
Mammal		
Insectivore	**African pygmy hedgehog**	*Atelerix albiventris* (S)
Rodents	**Chinchilla**	*Chinchilla lanigera* (S)
	Chipmunks	*Tamius striatus, Eutamius sibiricus* (S)
	Degu	*Octodon degus* (S)
	Dwarf hamsters	*Phodopus roborovskii, Phodopus campbelli, Phodopus sungorus, Cricetulus (barabensis) griseus* (S)
Carnivores	**Coatis**	*Nasua* spp. (G)
	Leopard cats	*Prionailurus bengalensis, Prionailurus javanensis* (S)
	Meerkat	*Suricata suricatta* (S)
	Ocelot	*Leopardus pardalis* (S)
	Serval	*Leptailurus serval* (S)
Primates	**Bushbabies**	*Galago* spp., *Otolemur* spp. (G)
	Capuchin monkeys	*Cebus* spp., *Sapajus* spp. (G)
	Lemurs	*Lemur catta, Varecia variegata, Eulemur fulvus* (S)
	Marmosets	*Callithrix jacchus, Callithrix geoffroyi, Cebuella pygmaea* (S)
	Squirrel monkeys	*Saimiri* spp. (G)
	Tamarins	*Saquinus* spp., *Leontocebus* spp. (G)
Marsupials	**Sugar glider**	*Petaurus breviceps* (S)
	Wallabies	*Macropus* spp., *Notamacropus* spp. (G)
Birds		
Parrots	**African grey parrot**	*Psittacus erithacus* (S)
	Amazon parrots	*Amazona* spp. (G)
	Cockatoos	Cacatuidae (F)
	Eclectus parrot	*Eclectus roratus* (S)
	Macaws	*Ara* spp. (G)
	Ring-necked parakeet	*Psittacula krameri* (S)

Perching birds	**Finches (except canaries)**	Fringillidae (F)
Birds of prey	**Barn owl**	*Tyto alba* (S)
	Eagles	Accipitridae (F)
	Eagle owls	*Bubo* spp. (G)
	Harris hawk	*Parabuteo unicinctus* (S)
	Lanner falcon	*Falco biarmicus* (S)
	Saker	*Falco cherrug* (S)
	Peregrine falcon	*Falco peregrinus* (S)
Fishes		
	Cichlids	Cichlidae (F)
	Clownfishes	*Amphiprion* spp., *Premnas* spp. (G)
	Koi carp	*Cyprinus rubrofuscus* (S)
	Siamese fighting fish	*Betta splendens* (S)
Reptiles		
	Ball (Royal) python	*Python regius* (S)
	Burmese python	*Python bivittatus* (S)
	Bearded dragons	*Pogona* spp. (G)
	Chameleons	Chamaeleonidae (F)
	Corn snake	*Pantherophis guttatus* (S)
	Garter snakes	*Thamnophis* spp. (G)
	Green iguana	*Iguana iguana* (S)
	Tegus	*Salvator* spp. (G)
	Tortoises	*Testudo* spp. (G)
Amphibians		
	Alpine newt	*Ichthyosaura alpestris* (S)
	Argentinian horned frog	*Ceratophrys ornata* (S)
	Fire-bellied toads	*Bombina* spp. (G)
	Tree frogs	Hylidae (F)
Invertebrates		
	Cephalopods	Cephalopoda (C)
	Decapods	Decapoda (O)
	‘Tarantulas’	Theraphosidae (F)

SAWC agreed to exclude species that are already prohibited from sale/transfer/breeding under invasive species legislation, such as raccoon dogs, *Nyctereutes procyonoides*, raccoons, *Procyon lotor*, red-eared terrapins, *Trachemys scripta elegans,* etc. but left in South American coatis, *Nasua nasua*, as other species are being traded (e.g., white-nosed coati, *Nasua narica*).

Results

Evidence for compromised welfare is presented in the following order:

i) Capture or breeding
ii) Transport and handling
iii) Behaviour (behavioural needs and evidence of abnormalities in captivity)
iv) Conditions in commercial premises
v) Housing requirements
vi) Nutrition
vii) Health and disease
viii) Mortality

For some animals, no information was found for some or even most of the headings. Where information was only available on the behaviour of animals in their wild habitat, this was not included. Headings are only used where relevant evidence is available (see table of contents).

The licensing of pet breeding and trading is set out in the Scottish statutory instrument: “The Animal Welfare (Licensing of Activities Involving Animals) (Scotland) Regulations 2021”. This statute makes specific provisions for dogs, cats and rabbits (schedules 6-8), but the requirement for licensing, and the duty to provide appropriate care, record keeping and information to owners applies to all the species in this review apart from fishes.

Sections of the general guidance may be particularly difficult to apply to exotic pets, e.g., in schedule 2 “If the animals are kept in premises from which the licensable activity is carried on, active and effective environmental enrichment must be provided to the animals in inside and any outside environments” and in schedule 3: “For species whose welfare depends partly on exercise, opportunities to exercise which benefit the animals’ physical and mental health must be provided”. Where

there is no objective, published evidence on what level of exercise is conducive to good welfare, nor on suitable enrichment which provides animals with control over their environment, as well as exercise and expression of normal behaviours, it is difficult to see how compliance will be achieved.

Captive-bred animals can be privately traded and imported but must meet IATA live animal regulations (LAR) (https://www.iata.org/en/publications/store/live-animals-regulations/).

Key to symbols used in summaries

	Biological or behavioural needs which are difficult to provide in captivity.
	Evidence of harm associated with captivity.
	More information is needed to understand the welfare of this animal.

1.0. Mammals

The welfare of mammals kept as pets in the UK is affected by their origin and journey to the UK. The licensed trade in exotic pets gives an indication of which species are most commonly kept in the UK (Elwin *et al.*, 2020). Licenses held by UK traders selling mammals most frequently listed chinchillas (301 listings; max. number = 3052) and degus (283 listings; max. number = 3056). Also for sale were hedgehogs/African pygmy hedgehogs (28 listings; max. number > 357), sugar gliders (10 listings; max. number = 89), opossums/short-tailed opossums (two listings; max. number = 65), skunks (five listings; max. number of individuals=48),

No results about pets

For the following mammalian species, there was no information on the welfare of these animals as owned by private individuals in Scotland or the rest of the UK. Where literature relevant to their health and welfare was found, it relates only to animals in zoos, laboratories, or sanctuaries.

Carnivores

- Coatis
- Leopard cats
- Meerkat
- Ocelot
- Serval

Primates

- Tamarins
- Squirrel monkeys
- Marmosets
- Lemurs
- Capuchin monkeys
- Bushbabies

Marsupials

- Wallabies
- Sugar glider

Rodent

- Chipmunks

genets/West African large spotted genets (two listings; max. number>2), and primates (including, e.g., marmosets and ring-tailed lemurs). Between 2014 and 2018, 75% of non-CITES wildlife imports were rodents and 19.5% were lagomorphs (Green *et al.*, 2020). In this period, 943 individual carnivores were imported from 47 countries across seven different regions, according to the APHA database.

Another general issue affecting the welfare of exotic pet mammals is iron storage disorder, which is believed to occur because of a discrepancy between wild and captive diets. This condition is diagnosed at necropsy where transferrin saturation occurs in the liver (Clauss and Paglia, 2012). However, the clinical relevance of excess dietary iron (which may be supplemented inadvertently in combined mineral supplements) across many species is yet to be determined. Screening programmes and experimental studies of the effect of diet on health are required to determine the significance of this issue for captive mammals.

1.1. Insectivores

1.1.1. **African pygmy hedgehog, *Atelerix albiventris***

Using the pre-defined search terms, only 30 results were found on Web of Science (WoS). Most studies described clinical illness in hedgehogs or referred to their potential to carry zoonotic disease, including fungal skin infections and antibiotic-resistant *Salmonella* (see appendix 1).The most cited illnesses are neoplasia (Diaz-Delgado et al., 2017; Go et al., 2019; Kondo et al., 2019; Siddle et al., 2021; Singh et al., 2006; Song et al., 2014; Wozniak-Biel et al., 2015) and skin disease (Han et al., 2011; Iacob and Iftinca, 2018; Pantchev and Hofmann, 2006; Romero Nunez et al., 2019; Romero et al., 2015).

Bament and Mancinelli (2014) published veterinary guidance on the care of pet African pygmy hedgehogs. They are nocturnal and males cannot be kept together due to aggression. Climate is a key factor, which prevents these hedgehogs from living outdoors for most of the year in Scotland (they enter a state of torpor below 18°C), but in wild conditions they will swim, climb, dig and live in burrows during the day (Johnson, 2010). Veterinarians cite obesity as a common problem (Hedley, 2011; Bament and Mancinelli, 2014), but its prevalence in the UK pet population is not known.

Neoplasia was present in 60% of pet African pygmy hedgehogs submitted for necropsy in a Japanese study (Okada *et al.*, 2018). Raymond and Garner (2001) found similar results, in hedgehogs presented to an American pathology lab (HCS/ZooPath); 53% of the animals between 2 and 5.5 years of age had at least one tumour type, while 8.6% of the animals had more than one tumour type". Other health concerns include the neurological abnormality, "Wobbly hedgehog syndrome" (WHS), which is associated with inbreeding and low genetic diversity (Thompson *et al.*, 2020). WHS is progressive and associated with a poor prognosis (Hedley *et al.*, 2013).

Owners do not always recognise symptoms of illness until they are posing severe harm to welfare. Thompson *et al.* (2020) described a case of WHS presented to a veterinary teaching hospital (Hokkaido) for diagnosis with a three-week history of illness, and which had progressed to tetraparesis (inability to stand or roll into a ball) and gangrene. A 3-year-old hedgehog presented at Mahidol University with advanced neoplasia "suddenly developed screaming, gasping for air and lethargy shortly before dying" and was presented for necropsy.
No other search terms yielded information about the welfare of these animals in breeding, transport, commercial premises or as pets.

Summary: African pygmy hedgehogs

- Adapted to a warm climate
- Broad behavioural repertoire (digging, climbing, swimming)
- Predisposition towards neoplasia (cancer).

- Little information on the conditions in which pet African pygmy hedgehogs are bred, traded and owned.

- Males, kept in isolation to avoid aggression, have no social contact, which may mean we are not providing for their social needs; more research is needed.

Key resources
African Pygmy Hedgehogs- Care and Treatment Advice (Bament and Mancinelli, 2014)

African Pygmy Hedgehog Care (Hedley, 2011)

African Pygmy Hedgehogs (Johnson, 2010)

A retrospective study of disease incidence in African pygmy hedgehogs (*Atelerix albiventris*) (Okado *et al.*, 2018).

1.2 Rodents

1.2.1. **Chipmunks, Family Sciuridae**

Invasive alien species legislation, prohibiting the keeping of Siberian chipmunks, *Eutamias sibiricus*, as pets, came into force in August 2016 in Europe (including the UK). Importing, breeding and selling these chipmunks as pets is prohibited, although those already in an owner's possession could still be kept. The maximum recorded lifespan of *E. sibiricus* (in Japan) is 8.5 years and 12.5 years (CABI and EPPO, 2021) and breeding may still be occurring despite the ban. Therefore, it is likely there are still some pet *E. sibiricus* chipmunks in the UK, as well as Eastern chipmunks (*T. striatus*).

a) Transport and handling

Wild-caught and captive alpine chipmunks (*Neotamias alpinus*) showed a significant increase in faecal glucocorticoid response to handling, while lodgepole chipmunks (*N. speciosus*) did not show a similar glucocorticoid response. No behavioural measures of stress were recorded, therefore it is difficult to conclude whether these responses demonstrate differences in coping ability, or whether *N. alpinus* is more stressed by handling (Hammond, Palme and Lacey, 2015).

b) Behaviour

Siberian chipmunks are semi-arboreal squirrels, which also burrow for nesting. In a zoo exhibit (Thessaloniki, Greece), which contained a tree and various cage furniture, the available climbing supports were categorised as terrestrial, arboreal and unnatural (metal cage and poles), then by size, in a study of behaviour frequency and enclosure use (Youlatos *et al.*, 2008). Chipmunks showed a preference for 8-10 cm horizontal supports and hardly used the vertical supports. Locomotion occurred on both terrestrial and 8-10 cm arboreal supports, whereas postural behaviour (clinging, sitting, standing) occurred mostly on 8-10 cm branches. Chipmunks leap less than other squirrels, with "low optimum take-off angles and adducted forelimbs", which make them less suited to leaping long distances, compared to related species. Accelerometer measurement of activity levels in wild chipmunks was validated (Hammond *et al.*, 2016) and this technique could be used to compare the activity of captive chipmunks to assess the adequacy of their husbandry in permitting natural behaviour.

c) Nutrition

A single animal case study was reported from Switzerland, describing urolithiasis of unknown cause (Kohutova and Jekl, 2021). Uroliths are often linked with dietary influence on urinary pH. Little is known about urolithiasis in chipmunks and the veterinarian's opinion in this article suggests that commercially available diets for rodents may not be meeting the needs of pet chipmunks: "Although there are available commercial diets for squirrels, quality of these diets may be poor and insufficient on levels of protein and protein source (plant, insect or animal origin). The chipmunk was fed a diet for rats, which may not be satisfactory regarding chipmunk nutrition."

The RSPCA website (RSPCA, 2022b)details an appropriate chipmunk diet as: "Up to 50% cereals (oats, wheat, barley, corn and millet sprays). You can also give unsalted nuts such as pine nuts. Small amounts of washed, chopped fruit and vegetables such as apples, pears, bananas, oranges, carrots, sweet potatoes, bean sprouts, and tomatoes". The literature search did not find any evidence of nutritional problems in captive chipmunks other than by Kohutova and Jekl (2021).

1.2.2. **Degu**

Degus, *Octodon degus*, are used in research into Alzheimer's disease. Unless relevant to degu welfare, experimental studies as models for human medicine were not included in this review.

a) Capture or breeding

Maternal care and stress responses were compared between recently-captured and captive-bred degus, and the effect of corticosteroid administration was measured (Bauer *et al.*, 2016). Recently-caught mothers were less responsive to their pups than captive-bred degus, and cortisol administration resulted in lower weight offspring born to captive-bred mothers. This was a laboratory study on maternal stress, rather than a reflection of the conditions in which pet degus are caught or bred.

b) Behaviour

The risk to degu welfare in captivity of “inadequate opportunities for learning and satisfaction of cognitive needs” was only described in broad terms and not tested (McBride, 2017).

c) Nutrition

Degus were included in a behavioural review of “small prey species” (McBride, 2017). Potential welfare issues described as specific to degus include the risk of dietary monotony leading to satiety and consequent inadequate fibre consumption. The RSPCA website (RSPCA, 2022c) states their requirement for a high-fibre diet and good quality hay.

d) Health and disease

A review of common dental disorders in degus (Long, 2012) examined data submitted to the “Degutopia” website and global internet forum “Degu Information Group” between August 2003 and December 2010. Dental disease is the most common degu complaint presented to veterinarians, with around 60 % of clinical cases being acquired dental disease (Jekl, Hauptman and Knotek, 2011). 137 cases were identified and information was collated on diagnosis, outcome, sex and age of the degus. The most common complaint was molar malocclusion, which is a chronic and painful condition, with spurs irritating the inside of the cheeks and causing difficulty eating and abscessation. In an extreme case tooth elongation led to the patient to stop eating, become dehydrated, lose weight and have difficulty breathing, due to overgrown teeth invading the nasal cavity (Mans and Jekl, 2016). Owing to the data collection method, the actual prevalence and relation to diet is unknown, but dietary causes, such as lack of fibre, are likely to play an important role.

Two clinical studies focussed on reproductive health of degus, (Mancinelli *et al.*, 2013) describes surgical intervention for a case of pregnancy failure (foetal death), and a study of captive-bred degus found that degu pups in breeding colonies (Britain) compared to wild pups (Chile) gained weight more quickly (2-3g/day over 14 days compared with 1-2g per day) (Long and Ebensperger, 2010).

According to the RSPCA website (RSPCA, 2022c), degus have a high risk of type two diabetes, which is linked with feeding a diet too high in sugar (e.g., diets

formulated for chinchillas, rabbits and guinea pigs, which contain fruit or molasses). A laboratory study found that feeding degus high levels of fructose over 28 months resulted in insulin resistance, fatty liver and cognitive impairment, in a condition similar to diabetes mellitus, termed “Fructose-Induced Metabolic Syndrome-Like Condition” (Rivera *et al.*, 2018).

1.2.3 **Dwarf hamsters**

The term “dwarf hamster” includes several species of hamsters sold as pets, including Roborovski’s dwarf hamster (*Phodopus roborovskii),* Campbell’s dwarf hamster (*P. campbelli*), Siberian dwarf hamsters (*P. sungorus*), Chinese dwarf hamsters (*Cricetulus barabensis griseus* or *C. griseus*).

a) Behaviour

Dwarf hamsters are sociable, but territorial and maternal aggression are part of the behavioural repertoire of dwarf hamsters (*P. campbelli* and *P. sungorus*), which has led to their use as models in neurobiological research into aggression and biparental care (e.g., (Gammie and Nelson, 2005; Vella *et al.*, 2005). No studies were found on aggressive behaviour in the context of commercial breeding, transport, or private ownership. Dwarf hamsters were also included in the review by McBride (2017), but no specific behavioural issues were identified. *P. sungorus* was tested for consistent and correlated personality traits in laboratory behaviour tests (Kanda, Louon and Straley, 2012). Individual activity level was the most consistent individual trait, and correlation between activity level and boldness was positive in young animals, but negative in older animals. Individual differences in activity level were not altered, when given an exercise wheel in their home cage (Kanda *et al.*, 2017). This personality difference should be accounted for when assessing the welfare of captive *P. sungorus*. Roborovski’s dwarf hamsters are more active than Siberian dwarf hamsters, which was described as “hyperactivity”. Supplementation with tyrosine for 10 days (consequently decreasing serotonin turnover in the brain) reduced home cage activity (Kabuki *et al.*, 2011). This study was conducted under laboratory conditions (in barren cages), using hamsters as a model for ADHD, and the findings are not interpreted with respect to pet hamsters.

b) Housing requirements

The RSPCA website gives general guidance on keeping hamsters as pets (RSPCA, no date a), which cites (Calderone and Jacobs, 1999), demonstrating that dwarf hamsters have UV vision and can see well in twilight. This review did not find studies evaluating the effect of housing, bedding and environmental enrichment on pet dwarf hamster welfare, but information on paw injuries in Syrian hamsters, *Mesocricetus auratus*, demonstrating that pine bedding was more effective at avoiding paw wounds than beta chip substrate, may be transferrable (Beaulieu and Reebs, 2009).

c) Health and disease

In the Journal of Exotic Pet Medicine most search results were case reports of single animals:

- Uterine horn torsion in a pregnant hamster (Neves *et al.*, 2019). This condition is not common in hamsters and is known to occur in other mammals. No husbandry or species-specific factors were identified as risk-factors.

- Bilateral Harderian gland abscesses (diagnosed at necropsy), with no other cases reported in hamsters (Zaffarano *et al.*, 2015).

- Cutaneous botryomycosis, which was not amenable to surgical or antibiotic treatment and resulted in euthanasia (Grosset *et al.*, 2014). This complex condition is rare and not specific to hamsters, nor is it known to be associated with any particular husbandry factors.

- Severe papillomatosis in *P. sungorus*, which resulted in euthanasia, but was previously unknown to occur in such a widespread, multifocal form in hamsters (Casanova *et al.*, 2017), Spain.

- Neoplasia is common in rodents and case reports included treatment of squamous cell carcinoma (Martorell *et al*., 2005), surgical excision of a subcutaneous myxosarcoma (Wong *et al.*, 2021) and anaplastic sarcoma of the cheek pouch (Rainwater *et al.*, 2011), which was surgically excised, but later recurred.

A review of neoplasia in hamsters in Germany was recently undertaken (Rother *et al.*, 2021), which included 177 hamsters which had been submitted to university facilities for necropsy. This useful guide to the most common tumours and survival time in hamsters does not represent a full view of the incidence of tumours in different species, since the submission rate of histopathology samples from all tumours that occur, and the number of pet hamsters in the population, is unknown.

1.2.4. **Chinchillas**

The long-tailed chinchilla (*Chinchilla lanigera*) is farmed for fur, as well as its use as a pet and in zoos. Infectious disease is reported here only where it occurs in captive animals and where the climactic conditions are similar to Scotland, since flora are likely to reflect local conditions. The RSPCA website provides advice to owners (RSPCA, 2022a).

a) Transport and handling

With gentle handling by experienced keepers, chinchillas can be trained to voluntarily step onto a person's (gloved) hand and to enter a transport crate, but they are more alert and active in the presence of humans and not all chinchillas are receptive towards handling, requiring two or more attempts at catching (Baskir *et al*., 2020). The proportion of chinchillas, which accepted handling and carrying readily or resisted, was not quantified in this study.

b) Behaviour

Abnormal, repetitive behaviours in farmed chinchillas include, but are not limited to, fur-chewing (Ponzio *et al.*, 2007; Franchi *et al.*, 2016; González *et al.,* 2018; Święcicka, 2018). This behavioural response to captivity is of financial importance to the fur industry and was therefore studied in this environment, but could indicate poor husbandry in pets.

c) Housing requirements

An investigation into the care of pet chinchillas in Germany found that 62.5% of the chinchillas are housed in cages that were too small (below minimum recommended) (Bläske *et al.*, 2019). Key concerns in the welfare of pet chinchillas include the need

to be kept socially with their own species, provision of adequate dietary fibre for gastrointestinal health and to avoid dental problems (Nikoletta *et al*., 2019). Preference testing demonstrated that chinchillas prefer to drink from open water dishes and they have a lower water requirement than guinea pigs and degus (Hagen *et al*., 2014)

d) Nutrition

Chinchillas are from arid climates and have a modest daily water intake of 2–12ml/ 100g body weight at ambient temperature. Chinchillas drink much more when fed on an exclusively hay diet (3.48 ± 1.31ml/g) than a mixed (1.17 ± 0.49) or pelleted diet (1.47 ± 0.49), so normal urinary output should be assessed in the light of what and how much the chinchilla is eating (Wolf *et al.*, 2020).

e) Health and disease

A case report (Smith *et al.*, 2010) described a 12-year-old chinchilla with a salivary gland carcinoma. (Crossley and del Mar Miguélez, 2001) demonstrated systematic dental abnormalities in pet chinchillas; cheek tooth lengths of clinically normal and captive bred animals with dental disease (average 7.4mm and 10mm respectively) were significantly elongated compared with wild-caught chinchillas (5.9mm average), which is attributable to an inappropriate diet. This study has not been replicated in the UK in the past two decades.

“Veterinary care of chinchillas” (Saunders, 2009) describes common problems of pet chinchillas, including fractures, fur slip, bite wounds, non-infectious conjunctivitis, matted fur, fur ring and paraphimosis, alopecia and fur chewing, heatstroke, heavy metal toxicity, electrocution, hyperthyroidism, diabetes mellitus (occasional) neoplasia (few reports), urinary tract disease (infrequent), gastrointestinal disorders and infectious diseases. The prevalence of these diseases is not reported, and the risks associated with conditions encountered during breeding, trade and keeping are not known. The prevalence of cardiopathy is unknown; a small study found that three of a group of 20 chinchillas had audible murmurs, (Linde *et al.*, 2004).

Summary: Rodents

Guidance on the care of these rodents is available in veterinary literature and on the RSPCA website. The extent to which their specific nutritional, behavioural and other husbandry needs are being met by pet owners is not evident in the literature.

Chipmunks

- Chipmunks in captivity require an environment with horizontal branches, which gives them opportunities for climbing and leaping.

- Wild chipmunks are stressed by human handling, but their response to humans when kept as pets is not published.

- The Siberian chipmunk now cannot be owned in the UK, so research should focus on the needs of other species, such as *Tamias striatus*.

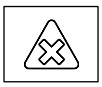
Degus

- High prevalence of dental disease suggests captive degus are not receiving appropriate diets.
- Inappropriate diets are also likely to cause metabolic syndrome.

- The behavioural needs of pet degus and their provision are not known.

Dwarf hamsters

- High requirements for activity (especially at night).
- Social, but express territorial aggression.



- Evidence of paw damage associated with inappropriate bedding and cage materials in Syrian hamsters may also affect dwarf hamsters.
- Dwarf hamsters may be predisposed towards neoplasia.

Chinchillas

- Chinchillas are susceptible to dental disease, if not fed an optimum diet. Severe dental disease requires regular, invasive, surgical treatments.

- Chinchillas demonstrate fur-chewing as a response to poor environments.
- Chinchillas can be conditioned to voluntarily accept human handling.

- Breeding and keeping of hystricomorphs, such as the chinchilla, should focus on avoiding both congenital and acquired causes of dental malocclusion.

Key resources

Degus and chinchillas as laboratory animals and pets (Nikoletta *et al.*, 2019).
Chipmunks (RSPCA, 2022)
Degus (RSPCA, 2022)
Hamster factfile (RSPCA, n.d.)
Chinchillas (RSPCA, 2022)
Veterinary care of chinchillas (Saunders, 2009)
Small prey species' behaviour and welfare: implications for veterinary professionals (McBride, 2017)

1.3. Carnivores

The carnivores included in this review are: coatis, *Nasua* spp., leopard cats, *Prionailurus* spp., meerkats, *Suricata suricatta*, ocelots, *Leopardus pardalis*, and servals, *Leptailurus serval*. "Small nondomestic felids in veterinary practice" details the basic husbandry and care of the ocelot, as well as some hybrid species of non-domestic felids (Eckermann-Ross, 2014). The veterinary journal "Veterinary clinics of North America: Exotic Animal Practice" published an article on the nutrition and natural history of the serval and caracal, *Caracal caracal* (Livingston, 2009). The European Association of Zoos and Aquariums (EAZA) does not currently publish best practice guidelines for these species. The American Association of Zoos and Aquariums (AZA) published a "Minimum Husbandry Guidelines for Mammals: Small Felids", (Mellen, 1997). Owing to the non-domesticated nature of these species, they may be subject to dangerous wild animal legislation (ocelot, leopard cat and serval) and therefore must be kept in a secure enclosure, rather than being considered house-pets. Minimum standards described in Mellen (1997) include:

- Enclosure sizes <10kg, 2 x 2 x 2.5m per cat, <20kg, 4 x 2 x 2.5m per cat, with further aerial pathways to encourage climbing. Platforms and hides, as well as logs to sharpen claws.
- Further basic guidelines are described on temperature, light, ventilation, water and sanitation, nutrition and vaccination. None of these requirements is sophisticated, except the instruction to "consider the regular use of a whole prey and/or bones with meat attached both for oral health and to stimulate natural eating behaviours", which may pose hygiene challenges for the non-specialist keeper.

In the absence of species-specific literature, the search was widened to the welfare of small, zoo-housed felids and carnivores.

1.3.1. **Coatis**

Few studies on Web of Science mentioned coatis. One study reported phaeochromocytomas in two coatis (Reppas *et al.*, 2001), neither of which were stated or suspected to relate to conditions relating to life in captivity or any factors relevant to this review. None of the other results had any relevance to domestic or pet coatis.

Only one individual was listed on an exotic pet license, issued from 2014-2018 by APHA (Elwin *et al.*, 2020). In the “Journal of Exotic Pet Medicine” coatis only appeared in relation to advice on tranquilisation (Lennox, 2014).

The term “coati” yielded two case reviews, a case of arterial thromboembolism in a brown-nosed coati, *Nasua nasua*, in Singapore Zoo (Heng and Hsu, 2021) and one pet South American coati, *N. nasua* (in Denmark), with severe dilated cardiomyopathy, which may have been related to an inappropriate, protein-deficient diet (primarily breakfast cereals, small amounts of vegetables, raw chicken and shrimps) (Halck, 2021).

1.3.2. **Leopard cats**

There are two species of leopard cat; the mainland or Asian, *Prionailurus bengalensis*, and the Sunda leopard cat, *P. javanensis*. The Asian leopard cat is hybridised with domestic cats, *Felis catus*, to produce “Bengal” domestic cats. However, searching “Web of Science” did not yield any information on the breeding, transport, captive housing or welfare of leopard cats. 18 results for the term “leopard cat” were found with country/ region as Scotland, England, Wales or Ireland, but none of these studies related to animals being kept in the UK. A study on the handling of captive *Prionailurus bengalensis euptilurus* in Tchernogolvka, Russia, demonstrated an immediate significant increase in serum cortisol, 20 minutes after capture, and handling was associated with an initial decrease in red and white blood cells (Pavlova *et al.*, 2018). Infectious diseases documented include FIV (Feline immunodeficiency virus) (Hayama *et al.*, 2010), clonorchiasis (Choe *et al.*, 2019) and ascarids (Xie *et al.*, 2020), but all of these cases were found in Asia.

1.3.3. **Meerkats**

Meerkat, *Suricata suricatta*, studies were limited to the behavioural ecology of wild meerkats, which inform potential keepers about their normal social structures and social behaviour, but the Web of Science search did not find any evidence for the welfare impact of capture, breeding or life in captivity on behaviour or welfare.

A Pubmed search retrieved an additional article relevant to stress in captivity, comparing zoo populations of meerkats (Scott *et al.*, 2017). Faecal glucocorticoid

metabolites were used as an indicator of stress, and this welfare indicator demonstrated an increase in stress associated with contact with humans (greater visitor numbers) and living in small groups. Meerkats are being kept as pets in the UK as evidenced by sales websites, such as “ukclassifieds.co.uk”. Their social requirements for large group sizes and natural roaming, digging and scent marking render them unsuitable as household pets according to the RSPCA (RSPCA, 2022d).

1.3.4. **Servals**

a) Behaviour

Servals, *Leptailurus serval,* are solitary hunters in the wild, with a home range of 4 km^2 for females to 8 km^2 for males in the Ngorongoro Crater, Tanzania (Geertsema, 1984). Behavioural issues arising from lack of stimulation in captivity, as well as “undesirable” behaviours, such as frequent scent marking and disinclination to bury their faeces and therefore be litter-trained, are reported as issues in these “pet” animals. Their nutritional requirements are not known and therefore estimated based on their similarity to the domestic cat (Livingston, 2009).

b) Health and disease

In a study of ocular disease in captive, non-domestic felids (Nguyen *et al.*, 2022), which included 30 servals, five animals had ocular abnormalities (16.7%), which was roughly equal to the prevalence within felids as a whole (16.3% prevalence over the 25-year period of the study). Corneal ulceration was the commonest ocular abnormality, which is also the case in domestic felids. However, cataracts were diagnosed more commonly than is seen in domestic cats, which may have been secondary to heritable abnormalities, ageing, trauma or nutritional deficiencies. These animals were at a rescue facility in the USA.

Cystinuria is reported as a welfare concern in captive servals in the USA (Cannizzo *et al*., 2017), with a prevalence of 27% from a survey of owners and institutions participating voluntarily in a screening programme. Feline panleucopaenia virus has been detected in captive servals in South Africa (Lane *et al.*, 2016), during an outbreak which included several felid species (including captive ocelots). Although this demonstrates their capacity to carry this virus, it does not mean this is a risk to

captive servals in the UK and vaccines used in domestic cats may be effective in reducing this risk.

1.3.5. **Ocelots**

The behaviour of captive ocelots, *Leopardus pardalis*, was described by (Suárez *et al.* (2017) in the context of visitor impacts on two individuals kept in zoological gardens in southern Spain. Findings indicate that visitor presence had a generally negative effect on diurnal behaviour; during zoo open days ocelots spent more time sleeping and less time walking. Ocelots displayed agonistic behaviour only when visitors were present and spent more time in retreat spaces and hiding places. However, during human presence, ocelots also spent less time performing stereotyped walking.

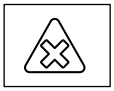
(Cameron-Beaumont *et al.* 2002) studied affiliative behaviour in small Felidae, via questionnaires sent to handlers in 71 zoos in the USA, UK and South Africa and concluded that the Ocelot Lineage (the phylogenetic clade including the ocelot and other small spotted South American cats) had the highest proportion of individuals showing affiliative behaviour and therefore may be preadapted to domestication. No other studies relating to welfare implications of keeping ocelots were described.

Summary: Carnivores

a) Wild carnivores cannot live with humans like a domestic cat or dog and are subject to “Dangerous Wild Animals” legislation, requiring a secure enclosure.

b) Small felids require aerial pathways, platforms, hides and logs.

c.) Servals and ocelots have home ranges of several kilometres in the wild.



d.) Ocelots in zoos react to human presence with more agonistic behaviour (fighting) and hiding in retreat spaces, but they also performed less stereotypical behaviour, which may reflect vigilance towards humans.

e.) Captive servals are vulnerable to corneal ulceration, but its aetiology is unknown.

f.) Capture and handling are stressful for leopard cats, and being in close proximity to humans may cause chronic stress, although this needs more investigation.

g.) No information was found on the conditions and welfare of these selected pet carnivores kept in Scotland, including the breeding and importation of pet animals.

Key resources

The Nutrition and Natural History of the Serval (*Felis serval*) and Caracal (*Caracal caracal*) (Livingston, 2009)

https://www.rspca.org.uk/adviceandwelfare/pets/other/meerkats

Small Nondomestic Felids in Veterinary Practice (Eckermann-Ross, 2014)

AZA Minimum Husbandry Guidelines for Mammals: Small Felids (Mellen, 1997)

1.4. Primates

The keeping of primates as pets is sufficiently rare that they are often treated as a taxonomic group rather than at the species level (e.g., Soulsbury *et al.*, 2009). There are legal restrictions on the importation of primates into the UK, including entry through an appropriate Border Control Post, health certification and a four-month quarantine period for rabies (APHA, 2022). The numbers and species of pet

primates kept in the UK were not known, when reviewed (Soulsbury *et al.*, 2009). A recent DEFRA call for evidence of primates kept as pets in England resulted in an estimate of 1,000-5,000 individuals being kept privately, with common marmosets, *Callithrix jacchus*, being the most prevalent (DEFRA, 2020). However, the true number is unknown, nor is the degree to which primates are being kept in "zoo-like conditions" or as house pets. The DEFRA call for evidence did not reach any individuals keeping primates as pets, but Table 2 of the report summarises a range of physical and psychological issues experienced by primates kept in unsuitable conditions from case studies and academic research.

The removal of teeth and claws is mentioned as not advisable and/or illegal in husbandry advice (Wissman, 2014), suggesting that these are practiced (at least where the author's clinical experience is based in the USA), although no published evidence of this was found. The AVMA has a policy of opposing the removal or reduction of healthy teeth from non-human primates and carnivores kept as pets (avma.org/resources-tools/avma-policies/removal-or-reduction-teeth-nonhuman-primates-and-carnivores). Primates without teeth are relinquished to facilities, such as "primate rescue centres", but figures on the prevalence of this practice are not published. Johnson-Delaney (2008) describes biting as part of the normal dominance signalling by non-human primates, and advises vets that "monkeys bite, they bite quickly and hard, and they will always bite, even if their owners swear they do not". Tooth-brushing, regular dental cleaning and chew toys, coated with sodium hexametaphosphate are recommended aspects of preventative dental care (Johnson-Delaney, 2008).

The social needs of primate species are crucial to their welfare. The "Code of Practice for Privately Owned Primates (DEFRA, 2010) states: "With few exceptions, they live in complex societies that can comprise tens of individual animals." The early life period is also highlighted as important for the development and welfare of primates, which makes them remarkable among species typically regarded as suitable pets: "In relation to their total life history, primates have long infant and juvenile phases, with social independence occurring long after nutritional weaning". The code of practice goes on to describe welfare-assessment methods available to owners of primates and requires keepers to be "registered with a veterinary practice

that has specialist knowledge of the species kept". Marmosets and tamarins, Family Callitrichidae, although not considered a danger to humans "cannot be considered pets, and require specialised knowledge, ownership should be preceded by hands-on experience with primates, and breeding should not occur unless offspring can be placed with owners able to provide suitable care". Detailed guidance is given for what the behaviour of primates should look like (avoiding excessive aggression, appropriate sleeping and resting patterns, low anxiety around food, a wide range of foraging behaviours, appropriate defence and escape behaviours, a full range of physical activities, etc.).

The AZA provides a care manual for lemurs (*Eulemur* spp.) (Campbell *et al.*, 2013), which represents a compilation of current knowledge provided by a variety of experts in the genus. Although publicly available, the document "is intended solely for the education and training of zoo and aquarium personnel at AZA-accredited institutions". The USDA (United States Department of Agriculture) provides animal care aids (practical information is presented in simple language in an A4 poster format) on various aspects of primate care relevant to private keeping of primates, in particular their social needs, providing appropriate enrichment, rearing infants and juveniles and dealing with psychological distress.

While the current review focusses on the behaviour and welfare associated with keeping exotic animals as pets, it should be noted that the illegal pet trade directly threatens the wild population of lemurs in Madagascar (LaFleur *et al.*, 2017).

Many species (including marmosets and tamarins) do not require dangerous wild animal licenses and compliance with dangerous wild animal licensing is reported to be low, although this information is not recent (Greenwood *et al.*, 2001). There is strong objection by veterinary organisations to keeping primates as pets: "We can think of no circumstances where a primate would benefit from being kept privately as a pet. They are unsuitable to be kept as companion animals." British Veterinary Association and British Veterinary Zoological Society" (BVA and BVZS, 2020).

1.4.1. **Bushbabies**

a) Transport and handling

Relocation stress has been studied in northern greater bushbaby, *Otolemur garnettii,* (Watson *et al.*, 2005) in the context of a planned relocation between universities 90 miles apart (by road). The home cages were relocated into the new environment and cage-mates were kept together. On the day of relocation a near ten-fold increase in cortisol from baseline was observed. Faecal cortisol had returned to normal when the next sample was taken at seven days after moving.

a) Behaviour

The Senegal bushbaby, *Galago senegalensis*, is nocturnal primate, known to vocalise frequently. Schneiderová *et al.* (2016) studied vocalisations of lesser galagos, *G. senegalensis,* and reported regular attention/ alarm calls. Loud vocalisations were infrequent, but “could be emitted repeatedly in long series lasting for several minutes”. Alarm vocalisations increase in captive conditions and are associated with environmental and social disturbances (Zimmermann, 1989; Boinski *et al.*, 1999). Bushbabies increase production of loud calls before and at dawn (Schneiderová *et al.*, 2016). Self-injury, which may reflect redirected or thwarted aggression, is commonly reported in captive non-human primates.

Bushbabies also exhibit stereotypies. In a university laboratory primate facility (Jackson State University Center for Prosimian Studies) a study of 22 northern greater bushbabies (*Otolemur garnettii*) exhibiting self-injurious behaviour compared with 11 control animals demonstrated a positive effect of daily L-tryptophan treatment on self-injury and stereotyped behaviours (McCoy *et al.*, 2009) However, bushbabies exhibiting self-injury did not have significantly lower baseline serotonin than control animals, demonstrating the harmful behaviour is likely to be a response to circumstances rather than individual differences in neurophysiology. Classical music was tested as a form of auditory enrichment for eight *O. garnettii* (Hanbury *et al.*, 2009), which were exhibiting stereotypic behaviour in a laboratory colony of bushbabies, University of Southern Mississippi. The music did not influence either stereotypy or grooming behaviours. Bushbabies experience handling stress, even when caught and restrained regularly by experienced animal handlers. In a study at the University of Mississippi, the use of food reinforcement was not successful in

reducing the negative emotional response to restraint, which was reflected by increased tympanic membrane temperature (Hanbury *et al.*, 2013).

c) Housing requirements

Bushbabies are arboreal (Rosenson, 1972) and require branches to climb. In a study of environmental enrichment for Galago *senegalensis* at Paignton Zoo Environmental Park (Clark and Melfi, 2012), artificial termite mounds and gum feeders were successful in encouraging species-typical behaviours, although bushbabies also responded to auditory stimuli (rainforest sounds) by moving away into the nest boxes, which may indicate neophobia (fearful of sounds that were not familiar, despite their ecological relevance). Like all bushbabies, Moholi bushbabies, *G. moholi*. are nocturnal (Rosenson, 1972) and while they should ideally not be disturbed during the day, in a zoo exhibit they were substantially more active when housed under red lighting than blue lighting. However, only two individuals were tested and the female bushbaby gave birth during the experiment (Fuller *et al.*, 2016). It is possible that inappropriate levels of blue light will have detrimental welfare effects on captive bushbabies, but further research is needed to establish ideal lighting conditions.

d) Nutrition

A study of nutrient intake and availability in 11 captive O. *garnettii* established that an insectivorous diet had higher non-digestible fibre, crude protein and dry matter digestibility to a frugivorous diet (Smith *et al.*, 2020). Diet has been studied from an anthropological viewpoint rather than assessment of the nutritional adequacy of diets provided to privately owned bushbabies.

e) Health and disease

The search elicited few studies of disease in bushbabies. An article in “Microbiology society” journal reported that an isolate of *Pasteurella* B species (as found in dog and cat bites) was found in a Moholi bushbaby, *Galago moholi*, at Copenhagen Zoo (Christensen *et al.*, 2012). A single case report of a fibroepithelial tumour, called “Phyllodes-like” mammary tumour, was diagnosed after euthanasia of an 11-year-old captive northern greater galago O. *garnettii* (Jones *et al.*, 2016).

f) Mortality

Debyser (1995) reviewed prosimian juvenile mortality (from conception until weaning) in zoo and research populations from articles published during the period 1972- 1992. Mortality of *G. senegalensis* is estimated as 28-28.6% (captive population) and of G. *moholi* as 25.3- 61.6%. These figures are based on data from 1982-1900 (table III, Debyser, 1995).

1.4.2. **Capuchin monkeys**

EAZA produces “best practice guidelines” for keeping captive capuchins (Souvignet *et al.*, 2019). There are two different subfamilies in the Family Cebidae, the squirrel monkeys (Saimirinae) and the capuchins (Cebinae). According to the RSPCA, the commonest captive capuchins in the UK are the black-capped or tufted capuchins, *Sapajus apella*. Capuchins are subject to “dangerous wild animal” legislation.

a) Transport and handling

In laboratory and zoo-housed capuchins, negative associations with routine husbandry procedures, including space restriction, can create stress and fear, which in turn can lead to the expression of stereotypic behaviour (de la Barrera Cardozo *et al.,* 2021). Therefore, using positive reinforcement training can allow capuchins to associate tasks, such as moving to a crate with a reward, thereby increasing predictability and reducing stress (Brando *et al.*, 2021).

b) Behaviour

Capuchins are diurnal and live in family groups in the wild, including “Single-male or age-graded group of 10-20 individuals. The Margarita Island capuchin groups (S. *apella*) are smaller: 4-6 individuals.” (Souvignet *et al.*, 2019). Capuchins with a more sociable and active personality may be more resilient to stressful experiences, such as relocation, measured in terms of faecal glucocorticoid metabolites (Ferreira *et al.*, 2020). In common with other primate species, the social needs of this species are challenging to meet. “Capuchins need to be kept in groups, however their social structure results in eventual evictions of group members. Therefore, keeping those animals implies having sufficient enclosures to accommodate evicted animals in appropriate conditions.” (Souvignet *et al.*, 2019).

c) Nutrition

Capuchins are frugivore-insectivores (Mittermeier *et al.*, 2013). Energy is provided by the fruits and the proteins are provided by small animal prey (insects).

d) Health and disease

Infectious diseases have been studied in the context of captive capuchin monkeys in Ecuador (gastrointestinal parasites; (Martin-Solano *et al.*, 2017) and Brazil (trypanosomatids; (Aysanoa *et al.*, 2017), but parasitic burdens are highly specific to climate and location and we cannot use these studies to infer disease or health status of the UK population of captive and/ or pet capuchins. No data are available on welfare in transport, although a single study advertised a transport cart cage for laboratory use (Lowery *et al.*, 2001).

1.4.3. **Lemurs**

Lemur species kept commonly as pets include ring-tailed lemur, *Lemur catta,* black-and-white ruffed lemur, *Varecia variegata* and brown lemur, *Eulemur fulvus*. Dangerous wild animal licenses are required for i) Indriidae ("leaping lemurs"), including the indri, *Indris indris*, sifakas, *Propithecus* spp., and woolly lemurs, *Avahi* spp. and ii) Lemuridae (except the gentle lemurs, *Hapalemur* spp. and the broad-nosed gentle lemur, *Prolemur simus*).

a) Transport and handling

A single study on transport stress was found (Volfová *et al.*, 2019). Two female black-and-white ruffed lemurs, *Varecia variegata,* were transported 202 km between zoos in individual transport crates. This form of transport can be considered a mild stressor, with a decrease in some forms of comfort behaviour in the new environment compared to pre-transport (sunning, scratching, stretching and allogrooming) and an increase in faecal glucocorticoid metabolites, which was evident two days after transport.

b) Behaviour

Aggression within lemur groups is a topic of interest for ethologists (Roeder, Duval and Gosset, 2002), particularly because lemurs in the wild and in captivity perform post-conflict affiliation and in some cases reconciliation (Colmenares, 2006; Palagi

and Norscia, 2015). From a welfare perspective, aggression is part of the behavioural repertoire of captive lemurs, and owners need to correctly treat bite wounds. A recent study of ring-tailed lemurs from five British zoos evaluated bite-wound management in lemurs (n=88) living in troops of 10 or more (Ceccolini *et al.*, 2021). Over the study period (2015-2019), 211 bite wounds were observed and 51 required surgical treatment. When presented with a food source within a marked area, red-fronted lemurs, *Eulemur rufus*, were more socially tolerant than ring-tailed lemurs (Fichtel *et al.*, 2018), and captive lemurs were more likely to tolerate others feeding at the same time than their wild counterparts, but total rates of aggression were not impacted either by species or by setting.

The behaviour of free-roaming, captive-born and mother-reared ring-tailed lemurs, *Lemur catta*, at Fota Wildlife Park, Ireland was largely unaffected by the presence and number of visitors. They chose to interact infrequently with visitors (this was observed during 1.03% of observations), and rarely reciprocated when visitors tried to feed, frighten, or approach them. Their overwhelming response, to ignore humans' attempts at interactions, suggest that unfamiliar humans are not regarded as socially relevant to lemurs, but that in this environment they are able to habituate to human presence. When visitors were present at feeding times (crowned lemurs, *Eulemur coronatus*) in Newquay Zoo (Jones *et al.*, 2016), the lemurs performed significantly less aggression, compared with feeding occasions when only the keeper was present. The implications for pet ownership are not clear; lemurs gradually increased their attention towards visitors over time, which may show an initial wariness followed by desensitisation, so lemurs explored visitors once they were used to being fed in their presence.

38 ring-tailed lemurs at Duke Lemur Center (USA) were assessed for "allostatic load", using biomarkers to estimate the level of chronic stress they experienced in captivity (all the lemurs were over one year old at the time of sampling). Increased time spent indoors, and living in a small group both increased allostatic load, suggesting these factors have a significant, negative influence on welfare (Seeley *et al.*, 2021). An increase in faecal glucocorticoid metabolites was observed in captive black-and-white ruffed lemurs, *Varecia variegata,* when the level of disturbance

exceeded that associated with daily husbandry, e.g., relocation (involving handling and capture), or construction work near to their enclosure (Volfova *et al.*, 2020).

Lemurs are highly curious and are attracted to novel objects. Feeder enrichments are common and effective in increasing the amount of time spent performing behaviours observed in the wild. For example, whole rather than chopped food increases the time spent feeding (Kerridge, 2005) and presenting food which requires lemurs to manipulate containers increases simulated foraging and general activity (Sommerfeld *et al.*, 2006; Dishman *et al.*, 2009; Shapiro *et al.*, 2018; Fernandez and Timberlake, 2019). Different types of feeder design are more suited to different lemur species. Shapiro *et al.* (2018) tested three types of enrichment and concluded that the "bottle feeder" was most engaging for ring-tailed lemurs, whereas a "hanger" was more appealing for red ruffed lemurs, *Varecia rubra*, whereas Coquerel's sifaka, *Propithecus coquereli*, used both types of enrichment more than the food bowl, but had no preference between the two. Positive reinforcement training, carried out at "Parco Natura Viva", Italy by animal trainers, following a structured habituation and training programme, resulted in decreased aggressive and increased affiliative social interactions (Spiezio *et al.*, 2017).

c) Housing requirements

No studies compared the effect of enclosure size on lemur welfare, but there were zoo studies on environmental enrichment. As lemurs are highly arboreal, branches for climbing should be provided, which need to be cleaned and varied regularly. Aerial nest-boxes have been used in zoos (Campbell *et al.*, 2013). Although Baker *et al.* (2018) found that a range of new smells (lavender, peppermint, coconut, and morio worms, *Zophobas morio*) added to an enclosure had a generally stimulatory effect on activity as well as resting behaviour, there was no significant difference between the type of odour presented. In contrast, a trial at Dudley Zoo (Vaglio *et al.*, 2021) found that the use of oils (benzoin, lavender, lemongrass) as a putative "enrichment" resulted in a significant decrease in social behaviour and increase in faecal glucocorticoid levels in captive red ruffed lemurs. This suggests that lemurs are sensitive to different types of scent, and care is needed to avoid inadvertent negative effects on welfare by introducing new scents.

The natural habitat of lemurs (Madagascar) is warmer than Scotland, with an annual mean minimum and maximum temperatures of 12.4–34.2 °C (Sha *et al.*, 2020), compared to Scotland (average mean minimum and maximum approximately 5-15°C). In a study of primates at Guangzhou Zoo (lowest mean temperature 9.9°C), lower temperatures were not associated with a change in activity levels in ring-tailed lemurs, but this species dedicated most time to thermoregulation behaviour (sitting hunched, or huddling with others). However, in response to food scarcity in the wild, reduced activity, torpor and hibernation are part of the normal behavioural repertoire of mouse and dwarf lemurs, Family Cheirogaleidae (e.g., Goodman's mouse lemur, *Microcebus lehilahytsara* (Karanewsky *et al.*, 2015)). This winter hibernation is still expressed in the zoo environment and during this time the lemurs sleep in same-sex groups (Karanewsky *et al.*, 2015). Fat-tailed dwarf lemurs, *Cheirogaleus medius*, hibernate 3-7 months per year in the wild and will enter a state of torpor when husbandry conditions are adjusted so that it is cooler (10-15°C) and food is restricted (Blanco *et al.*, 2021). AZA guidance states: "When temperatures fall below 18.3 °C (65 °F) heat sources (as described below) should be provided. When temperatures fall below 8.9 °C (48 °F), animals should be housed indoors only." The provision of shelter and heat sources that are sufficient for all animals to have access regardless of their social status, ventilation and back-up systems in case of faults with the buildings, are described. However, in agreement with the lack of information on lighting found in this review, "little research has been conducted on the light intensity requirements of *Eulemur* species. Some *Eulemur* holding institutions report the use of UVB light bulbs or vita-lights to supplement exhibit lighting, particularly in the case of animals housed without access to natural lighting. More research is needed in this area."

d) Nutrition

Lemurs are frugivorous and, when given the choice, will select foods which are high in carbohydrate and in particular sucrose (Fernandez and Timberlake, 2019; Hansell *et al.*, 2020). The diet of these primates in captivity often affects gut microbiota negatively, due to the feeding of plants selected for higher sugar content and lower fibre than would be encountered in the wild. Supplementation of romaine lettuce resulted in enrichment of microbial populations associated with fibre digestion, and increased foraging behaviour (Greene *et al.*, 2020). Across 13 European zoos body

weights of ruffed lemurs, *V. variegata*, were significantly higher than wild populations, and 46.5% of captive individuals were categorised as obsese (Schwitzer and Kaumanns, 2001). Obesity may reduce life-span. In contrast, chronic calorie restriction in grey mouse lemurs, *Microcebus murinus*, (on average 71kJ/day compared with 105kJ/day in controls) was reported to extend lifespan (initial results showed an increase of 22% in lifespan, (Pifferi *et al.*, 2018), but there was also an associated accelerated loss of cerebral grey matter.

Lemurs can progressively accumulate iron in their digestive organs, which can result in toxic effects on the liver and premature death (Andrews *et al*., 2005). Prevalence of iron storage disorders vary across lemur species, with a lower prevalence in *L. catta* (16.7% haemosiderin-positive on necropsy) compared with other species such as *Varecia variegata* (50% positive) and *Eulemur coronatus* (57.1% positive) (Wood *et al.*, 2003; Glenn *et al.*, 2006). Dietary interventions (increased vitamin C, reduced iron and increased tannins) have been shown, using transferrin saturation tests, to reduce iron serum levels (Wood *et al.*, 2003).

e) Health and disease

The diet of captive lemurs is likely to be an important factor in the rate of tooth wear, which in turn affects welfare and mortality. Although these variables were not systematically compared, two populations of zoo lemurs were studied and those which had annual veterinary and dental examinations, tooth cleanings and more varied and fibrous, “leaf-eater” diets (Indianapolis Zoo), had much lower levels of dental wear than lemurs with less veterinary intervention, and which were predominantly fed on tamarind fruits (at the Bezá Mahafaly Special Reserve in Madagascar BMSR) (Cuozzo *et al.*, 2010). Compared with grey mouse lemurs in the wild, those in a captive setting (a breeding colony, housed in a cage measuring $2m^3$ and containing three plastic tubes and three nesting boxes, (Némoz-Bertholet *et al.*, 2004), had weaker grip strength and began to decline in strength at a younger age than wild lemurs (Hämäläinen *et al.*, 2015).

Studies of infectious disease existed mostly for wild populations in Madagascar (Spencer and Irwin, 2020). In relation to captive ring-tailed lemurs (L. catta), there is evidence they can become infected with *Echinococcus multiocularis*, spread to

wildlife parks by foxes, *Vulpes vulpes* (Umhang *et al.*, 2013). Five cases of E. *multiocularis*, including one animal which had alveolar echinococcus diagnosed at necropsy, detected in at Parc Animalier de Sainte-Croix in France demonstrate the potential for *L. catta* to host this parasite and therefore pose a serious risk to human and animal health. Therefore, routine anthelmintic treatment (as in pet dogs and cats) is necessary for lemurs in close contact with humans, but there have been no cases of domestically acquired cases of *E. multiocularis* in the UK (https://www.gov.uk/guidance/echinococcus-multilocularis-how-to-spot-and-report-the-disease). Widespread use of antibiotics in Madagascar has affected the abundance of anti-biotic resistance genes in wild lemurs (Bornbusch and Drea, 2021). Resistance is present even in wild populations with little human disturbance, but in captive lemurs the antibiotic resistance genome was considerably enriched. These captive animals were housed either in LRC (Lemur Rescue Centre, Madagascar) or DLC (Duke Lemur Centre, United States) and the type of resistance found depended on the most commonly used antibiotics in the respective countries. In a case study of an illegally owned pet ring-tailed lemur in Madagascar, streptomycin-resistant M. *tuberculosis* was isolated (LaFleur *et al.*, 2021).

f) Mortality

In Coquerel's sifakas, *Propithecus coquereli*, housed at the Duke Lemur Center (1990-2015), the median age of death in animals that lived longer than 30 days is 10.3 years and the most common causes of deaths were stillbirths (64.7% of deaths in the perinatal group), enteritis-colitis, failure to thrive (in the perinatal period) and protozoal infections *(Cassady et al.*, 2018). Even where breeding programmes are managed in order to retain genetic diversity, breeding colonies show genome-wide inbreeding effects. Homozygosity makes *L. catta* more vulnerable to disease, in particular parasitism, and more likely to die prematurely, compared to more heterozygous individuals (Charpentier *et al.,* 2008).

1.2.4. **Marmosets**

Marmosets belong to three genera: *Callithrix* spp., *Mico* spp. and *Cebuella* spp. According to the RSPCA report "Do you give a Monkey's?" (RSPCA, 2016), marmosets are the most commonly kept primate in the UK, comprising chiefly common marmosets, *Callithrix jacchus*, Geoffroy's marmosets, *C. geoffroyi*, and their

hybrids. EAZA publish best practice husbandry guidelines for the Callitrichidae (Ruivo and Stevenson, 2017). This taxonomic group include 61 species and subspecies: 22 marmosets, *Callithrix* spp., *Mico* spp. and *Cebuella* spp., 34 tamarins, *Saguinus* spp. and *Leontocebus* spp., four lion tamarins, *Leontopithecus* spp., and Goeldi's monkey, *Callimico goeldii*. Common marmosets in the wild live in scrub, swamps and tree plantations. Infants are weaned at two months old and reach sexual maturity at 12 months old for females and 16 months old for males. Their most active period is early morning and late evening (Ruivo and Stevenson, 2017).

A key health consideration relevant to human contact with marmosets and tamarins, is that herpes simplex virus, highly prevalent in the human population, is fatal to callitrichids (Ruivo and Stevenson, 2017). In addition, mice can carry viruses, which cause lymphocytic choriomeningitis (callitrichid hepatitis), therefore feeding "pinkies" or exposure to wild mice, *Mus musculus*, is not recommended (Ruivo and Stevenson, 2017).

a) Breeding

In laboratory-bred marmosets humans may have to intervene to supplement feeding, which is disturbing for the mother. Handfeeding of triplet offspring did not affect cortisol or behaviour changes in response to a stressful procedure (capture, handling, weighing and release into a new clean cage). However, this procedure increased agitated locomotion (Ash, Smith and Buchanan-Smith, 2021). The management of dystocia using techniques, such as the use of oxytocin or forceps, often leads to complications and so timely use of caesarean section is recommended (Ruivo and Stevenson, 2017). This highlights the importance of liaising with specialist veterinarians before any planned breeding. Detailed instructions on the hand-rearing of callitrichids is published in veterinary journals and available at: www.exoticpetvet.net/primate/callitrichid.html. This is based on the expertise and experience of a veterinary surgeon (Wissman, 1999), an avian/exotic specialist vet, who co-owns a sanctuary for marmosets and tamarins. Data are not presented about the success of breeding marmosets and tamarins in domestic settings (i.e., outside zoos). The issues raised include potential for rejection, trauma and even cannibalism of offspring by inexperienced parents. Where marmosets are reared without their

parents, there is a need for intensive and specific feeding and infant-carrying by owners acting as “substitute” parents. The tendency for callitrichids to give birth at night increases the risk of owners missing dystocia cases. Short intervals between births increases the risk of infant mortality (Frye *et al.*, 2022).

b) Transport and handling

Moves between exhibits in the same building, between indoor exhibit buildings and between all zoo buildings were analysed for their effect on weight in captive callitrichids (Kaplan and Shelmidine, 2010). In marmosets, relocation was associated with at least 5% weight loss in 44% of cases and more rarely weight gain (6%). Similar figures were observed for tamarins, with 35% of housing events resulting in a 5% weight loss or greater, and 6% with weight gain.

c) Behaviour

Marmosets and tamarins in zoos may be hand-reared, but are still nervous and handling is not recommended. Stress associated with restraint can even lead to death during or just after capture (Ruivo and Stevenson, 2017). Keepers are advised to maintain “neutral relationships” to reduce fear in animals, when capture is necessary, and the effect of their distress on others in the social group. Bites to human handlers can be deep, and teeth can be damaged if handling is rough, e.g., pulling away from the marmoset if it bites into a glove during restraint. A lack of hiding areas with reduced visibility to visitors is a risk factor for developing marmoset wasting syndrome (Cabana *et al.*, 2018).

The welfare of non-breeding females kept in single-sex groups may be negatively affected by the restriction of their behavioural repertoire. Rearing young is an important part of social life, and therefore euthanasia of surplus offspring may be carried out in zoos. The justification for this is related to exhibiting zoo animals in conditions that reflect their true behaviour to the public. Greater understanding of the costs and benefits of breeding, particularly for females, is an important avenue for future research. Multiple births are more usual than single births, and twins increase the risk of neonatal mortality. In zoos, larger litter sizes (often triplets) are more common than in the wild, because nutrients are more easily available. Neonatal mortality (death before 30 days of age) was multifactorial, and included birth

problems, poor maternal care and infectious disease. Rearing of infants by several members of the social group (helpers) may be an important factor in infant survival (Anderson and Dennis, 2018) and participation in caring for younger siblings is a means of learning about parental care.

d) Housing requirements

EAZA best practice guidelines are available for housing standards in zoos (Ruivo and Stevenson, 2017), including a recommendation to allow outdoor access, to provide minimum humidity of 60% and an indoor temperature of 18 ^{o}C, natural substrates, nest boxes, nesting material, ropes and plants. A list of toxic and non-toxic plants is included.

e) Nutrition

Marmosets are morphologically adapted to eating plant exudates and in the wild are found in forests in the Neotropical region of South America. Pygmy marmosets, *Cebuella* spp., are particularly specialised for gouging plants in order to produce exudates, and their diet is primarily exudate, insects and spiders. *Callithrix jacchus* is highly exudativorous, and *C. geoffroyi* is less reliant on exudates than *C. jacchus*, but is still well adapted for tree gouging. Gums are a poor source of energy, but important for the provision of calcium, magnesium, potassium and iron (Ushida *et al.,* 2006). A review of the nutritional management of marmosets in seventeen research colonies found that gastrointestinal disease was the most common clinical illness and obesity was common (on average 20% of the institute's population). The report is related to the diet of experimental animals and one of the concerns is that captive diets may be unnecessarily varied, which is not a concern for pets. The overall finding is that clinical illness is likely to relate to poor diet, but there is a lack of evidence to inform the ideal marmoset diet. The authors summarise the state of knowledge on marmoset nutritional management as reliant on "anecdotal or historical precedence, animal food preferences, or published reports that focus on the role of a limited number of very specific diet components in relatively small numbers of animals".

Laboratory marmosets are fed either once (59% of institutions) or twice (41%) daily, with additional treats used for training. A base diet is provided, with fruit as

supplemental food, most also use protein sources, vegetables and/or grains, 42% use dairy products and 18% use Arabic gum as enrichment or as a reward, which provides an important source of calcium. Food deprivation (inadvertently feeding marmosets either three hours or six hours after their normal feeding time) resulted in significant increases in serum cortisol and an increase in body temperature (tympanic membrane temperature) (Pereira *et al.*, 2020).

1.4.5. **Tamarins**

Tamarins belong to two genera: *Saguinus* spp. and *Leontocebus* spp. The EAZA best practice guidelines (Ruivo and Stevenson, 2017) provide a rich source of information on the care and behaviour of tamarins.

a) Behaviour

Social groups are composed of several females and males, usually with a single breeding female. Tamarins are arboreal and diurnal, and their communication is based on vocalisations and scent marking. Their foraging behaviour is well described (Ruivo and Stevenson, 2017) and appropriate enrichment for zoo-housed tamarins has been studied (Franks *et al.*, 2013). In zoo tamarins, feeding insects (mealworms) increased time spent climbing compared with fruit (raisins) and a puzzle feeder was effective in increasing foraging time and general activity (Sanders and Fernandez, 2020).

b) Housing requirements

Free-ranging tamarins are more active, whereas those socially housed in cages express more affiliative and agonistic behaviour. At Jersey Zoo the “caged” treatment consisted of male-female pairs, which had access at all times to indoor sheds (either 3.7 m^2 × 2.2 m or 7.2 m^2 × 2.4 m) and outdoor spaces (40 m^2 × 4 m high or 14.5 m^2 × 3 m high). Leaping and running are more often observed in the free-ranging tamarins, suggesting these are curtailed when there is not enough space.

c) Nutrition

Tamarins and lion tamarins (*Leontopithecus* spp.) feed on fruit and insects, with small amounts of flowers, other invertebrates and small vertebrates and fungi. In contrast to marmosets, they are not adapted to gouging plants for exudates and

these constitute a smaller part of their diet. Tamarins rely on natural sources of exudates or steal from the gouges made by marmosets.

d) Health and disease

Urinary neopterin is a candidate biomarker predicting poor survival, which could be used as a non-invasive welfare measure in marmosets and tamarins (Sacco *et al.*, 2020). The natural diet of tamarins and marmosets does not include gluten, but it is sometimes included in captive diets and is associated with gastrointestinal disease such as “wasting marmoset syndrome” (similar to human coeliac disease (Cabana *et al.*, 2018).

e) Mortality

Neonatal mortality of tamarins at Cleveland Metroparks Zoo from 1990 to 2014 was 48.9% for Geoffroy’s tamarins (*Saguinus geoffroyi*), 45.9% for golden lion tamarins (*Leontopithecus rosalia*) and 59.3% for pied tamarins (*Saguinus bicolor*) (Anderson and Dennis, 2018). Factors relating to the complex requirements for parental care are discussed in the general introduction. In adult tamarins, colitis and enteritis are leading causes of mortality, and may be related to suboptimal temperatures, parasitism, stress and dietary inadequacy, although more research is needed to confirm this.

1.4.6. **Squirrel monkeys**

The Web of Science search found no publications referring to the welfare of pet squirrel monkeys, *Saimiri* spp.

a) Breeding

Squirrel monkeys reared with and without their mother showed significant differences in behaviour. Nursery-reared monkeys were less active and attentive and had slower motor development than those reared by their mother. Behaviour was analysed at two and six weeks old only (Bahia *et al.*, 2011).

b) Behaviour

Squirrel monkeys readily participated in voluntary positive reinforcement training (clicker training) in a zoo environment. This technique can be used to reduce the

stress associated with routine procedures, even intramuscular injections (Gillis *et al.*, 2012).

Dominance structure is characterised by a linear relationship between the dominant (large) male and the rest of the social group ranked below him. Between lower ranked animals, differences in dominance and aggression are much less marked and several animals can occupy the same rank (Pinheiro and Lopes, 2018). In mixed-species groups, squirrel monkeys are less aggressive than capuchins. Enclosure design can improve affiliative and reduce aggressive encounters between individuals of different species (Buchanan-Smith *et al.*, 2013). Changing the distribution of food can alter the dominance structure of a group (Bashaw, McIntyre and Salenetri, 2011).

Unwanted attention by juveniles of their own species (play invitations) causes chronic raised cortisol levels in adults, (Soltis *et al.,* 2003). Housing conditions (particularly isolation or pair housing) can be a greater influence on behaviour than enrichment. Several studies have presented enrichment to squirrel monkeys, but not observed a reduction in stereotypy (Spring *et al.*, 1997; Fekete *et al.*, 2000).

c) Nutrition

Squirrel monkeys consistently prefer food with a higher energy content (Laska, 2001), which may negatively influence health if food presentation is not tailored to ensure they consume a complete diet.

d) Health and disease

Squirrel monkeys are susceptible to toxoplasmosis, which can be fatal (Nishimura *et al.*, 2019; Carme *et al.*, 2009). No studies were found to suggest a high susceptibility to diseases associated with captivity.

Summary: Primates

Bushbabies

- Bushbabies exhibit a strong stress response to handling and relocation.
- Require a complex, arboreal environment, may exhibit neophobia (in zoos).
- Frequent vocalisations, especially before and at dawn, loud alarm calls.

- Stereotypic behaviour and self-injury indicate distress in captivity.

Capuchin monkeys

- Live in large family groups, from which evictions can occur.

- Routine husbandry procedures in captivity can cause stress and fear.

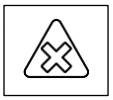
Lemurs

- Arboreal and need branches to climb on, which can cleaned and varied.
- Adapted to a warm climate and natural sunlight (require UVB).
- Social and use biting as a means of resolving disputes.

- Living in small groups and living indoors increases chronic stress.

Marmosets

- Breeding is high-risk; multiple births and may require caesarean sections.
- Handling is stressful for marmosets in zoos and chronic exposure to humans, without hiding places, contributes to the debilitating “marmoset wasting syndrome”.



- Gastrointestinal disease and obesity are common in laboratory marmosets.

- Optimum diets are not well understood and may require plant exudates. The welfare impact of not being able to express parenting behaviour is unknown.

Tamarins

- Normal behaviour of free-ranging tamarins includes running and leaping, which are curtailed when space is restricted even in zoo enclosures.
- Infant care is complex, with high levels of juvenile mortality in a zoo population

- Gastrointestinal disease is a major contributor to adult mortality in captivity. Potential causes include husbandry factors (cold, stress, parasitism)

Squirrel monkeys

- A preference for high energy food puts squirrel monkeys at risk of obesity.
- Living in isolation is associated with a greater risk of stereotypies.

- The natural behaviour of squirrel monkeys (and primates in general) is altered by hand-rearing and the consequences of this for stress-coping are unknown.

Key resources (primates)

EAZA Best Practice Guidelines for Callitrichidae (Ruivo and Stevenson, 2017)

Code of practice for the welfare of privately-kept non-human primates (Defra, 2010)

Nonhuman Primate Dental Care. (Johnson-Delaney, 2008)

“Do you give a monkey’s” The need for a ban on pet primates (RSPCA, 2016).

The welfare of primates as pets in England: call for evidence Summary of responses and way forward (DEFRA, 2020)

EAZA best practice guidelines: CAPUCHIN MONKEYS (Souvignet *et al.*, 2019).

AZA Eulemur care manual (Campbell *et al.*, 2013).

1.5. Marsupials

Sugar gliders (*Petaurus breviceps)* and Bennett’s wallabies (*Notamacropus rufogriseus*; formerly *Macropus rufogriseus*) are two of the most common pet marsupials encountered by veterinary surgeons in the USA (Brust, 2009). Wallabies are herbivorous foregut fermenters with a chambered stomach (Munn, Banks and Hume, 2006). Sugar gliders have a large caecum, which is the site of gum fermentation (Brust, 2009).

1.5.1. **Sugar gliders**

A Web of Science search yielded only 11 search results relevant to keeping sugar gliders as pets.

a) Breeding

No information was found on the conditions of sugar gliders in breeding facilities. Two articles were published on the topic of surgical castration (scrotal ablation) (Cusack *et al.*, 2017; Malbrue *et al.*, 2018). Both techniques, using a “LigaSure” device (Cusack *et al.*, 2017), and electrosurgery (Malbrue *et al.*, 2018), were found to be safe and effective in the small cohorts tested (five and eight males respectively).

b) Housing requirements

The RSPCA “Handle with Care” report (RSPCA, 2004) identifies aspects of the natural behaviour of sugar gliders that pose particular difficulties for private ownership of sugar gliders in captivity. Sugar gliders are social and nocturnal (zoo sugar gliders (Dierenfeld and Whitehouse-Tedd, 2018) slept from 6am to between 7-9pm). A challenge to the captive housing of sugar gliders is their arboreal nature. As the name suggests, their behavioural repertoire involves gliding. The 2004 “Handle with Care” report highlights the fact that sugar gliders rarely come down to the ground from tree canopies, and “can glide for as far as 45 metres between trees”. Heat should be provided at 21-32 ^{o}C, so that the provision of an adequate tree canopy, along with an appropriate climate to encourage levels of activity observed in the wild, is extremely challenging.

Guidance on the care of sugar gliders was published in “Seminars in Avian and Exotic Pet Medicine” (Booth, 2003), most of which is based on the experience of a specialist veterinarian working with Australian native species and knowledge of their natural history, rather than published studies of captive animals. The author recommends that housing less than 2m x 2m x 2m is inappropriate, which should include a nest box, vertical and horizontal branches, raised feeding stations and sleeping quarters. Housing of sugar gliders is described as commonly “in small bird cages, with a suspended pouch provided as sleeping quarters”, which the author states may be appropriate as long as supervised exercise is given regularly outside the cage.

c) Nutrition

Sugar gliders are described as facultative gummivores; they are adapted to a low-moderate protein diet and obtain calcium and other minerals from gums. They mainly eat insects, spiders and plant exudates in the autumn and winter (Brust, 2009). Their main energy source is from non-foliage plants, including saps, manna, necor, resins, honeydew, lerp and plant gels (Dierenfeld *et al.*, 2006), and this natural diet is difficult to replicate in captivity (Dierenfeld and Whitehouse-Tedd, 2018). Disorders related to inappropriate diet may include obesity, osteodystrophy, malnutrition and dental disease (Ness and Booth, 2004). This review did not find any information on

the incidence of these diseases in the pet population. Hypocalcaemia results in fractures, paresis, paralysis and ataxia (Brust, 2009).

Feeding trials were carried out on nine male sugar gliders (4-9 months old) over the course of two months with three animals per treatment. The findings demonstrated that sugar gliders selectively eat preferred ingredients from mixed diets, consuming most (75-100%) of the high energy foods: meat (chicken and meal worms) and fruit mixes, and consuming least of the vegetable component (38-51%). Variation within trial groups was high (two gliders in group C lost weight and the third had the greatest weight gain overall). Therefore, it is not possible to conclude which diet was most likely to result in obesity. Health and mineral status were measured, but sample size restricted the conclusions that could be drawn about the impact of each diet.

A larger trial was carried out of three diets fed to 12 gliders using a cross-over design, so that all animals experienced all diets. The diets are described in detail (Dierenfield and Whitehouse-Tedd, 2018) and briefly summarised in Box 1.

Box 1: Three diets for sugar gliders, analysed by (Dierenfield and White-house Tedd, 2018)

Diet 1: Liquid formula and a mix of fruit and vegetables.

Formula (from powder): Dried honey, dried egg product, dried whey protein concentrate, bee pollen, soya protein concentrate, vegetable oil, cereal grains, and vitamin and mineral premixes.

Produce mix: Peas, green beans, carrots, lima beans, green peppers, cucumber, papayas, strawberries, raspberries, blackberries, bok choy.

Diet 2: Home-cooked ingredients plus protein and calcium supplements

Orange juice, honey, water, two cooked eggs, chicken or turkey jarred baby food, yoghurt, bee pollen

Produce mix (as for diet 1).

Protein Supplement: Whey protein, soya protein, processed cereals, maltodextrin, dextrose, mannan oligosaccharides, β-glucans, lysine, methionine, vegetable oils, omega-3 and -6 fatty acids, carotenoids, taurine, vitamins and minerals.

Calcium carbonate powder

Diet 3: Pellets and gravy

Pellets: Ground whole cereal grains, soya meal, flax meal, corn gluten meal, whole dried eggs, dried whey, fish meal, minerals, vitamins, microbial enzymes and probiotics.

Gravy: Dried honey, dried egg product, dried whey protein concentrate, bee pollen, soya protein concentrate, vegetable oil, cereal grains, vitamins and minerals, water.

Diet 2 caused weight gain and diet 3 caused weight loss, whereas weight did not change significantly during the feeding of diet 1. Weight gain on diet 2 was associated with a greater dry matter intake (per body weight) and caloric intake, compared with diets 1 and 3. Across all diets, protein digestibility was similar to natural diets. The authors advise that the protein level of these diets is still likely to be higher than necessary for good health. Mineral digestibility varied for magnesium and phosphorus (higher in diets 1 and 2 than diet 3), and iron and zinc digestibility was higher in diet 2 than diet 3. Only diet 3 provided appropriate Ca and P

concentrations and ratios, whereas Diet 1 and Diet 2 were both low in Ca relative to P, and high in K, likely due to the fruit content. Notably, none of the diets contained gum. The authors conclude that these diets are likely to support good health and, compared with insect feeding, the constituents are more reliable in nutritional value. Commercially formulated ingredients seemed to provide more appropriate Ca: P ratio than the more home-cooked rations (diets 1 and 2).

1.5.2. **Wallabies**

Few studies were found on Web of Science.

a) Transport and handling

Wallabies are vigilant towards zoo visitors and it may be that humans are perceived as predators (Meade *et al.*, 2021).

b) Health and disease

In the USA pet wallaby population the most common infectious gastrointestinal disorders are macropod progressive periodontal disease (MPPD, or “lumpy jaw”), candidiasis, toxoplasmosis, campylobacteriosis and Tyzzer’s disease. Parasites are often diagnosed but seem to not cause clinical disease (Brust, 2009).

MPPD is a serious, often fatal disease in captive wallabies, with a prevalence in European zoos of 4.9 cases/100 animal years and in Australia of 5.7 cases/100 animal years (Rendle *et al.*, 2020). Bacterial infection is involved, in particular *Fusobacterium necrophorum*. Feeding and husbandry affects the likelihood of MPPD, and cold climates are cited as a risk factor (Oliphant *et al.,* 1984), but Rendle *et al.,* (2020) found that the prevalence of cases in Australian and European zoos was not affected by geographical region. There is a link between relocation to a different enclosure or between zoos and MPPD. Therefore, transport or relocation stress is a possible risk factor (Rendle *et al.*, 2020). This review did not include any studies which included behavioural or physiological parameters of stress around relocation in wallabies, but a link between stress and MPPD has been shown in kangaroos (Sotohira *et al.*, 2017). A risk factor for the entry of bacteria is the feeding of “spiky” food, or the occurrence of periodontal disease, which is common in wallabies (associated with feeding large amounts of soft, sticky food) (Brust, 2009).

Summary: Marsupials

- The dental health of captive marsupials is a concerning issue and the feeding of an appropriate diet is difficult due to their seasonal variation in feeding behaviour in the wild, including facultative or obligatory consumption of plant exudates.
- The environmental and behavioural needs of sugar gliders are not compatible with living in small spaces; adequate cage sizes must be combined with being taken out regularly for exercise.

Key resources

"Handle with care" report (RSPCA, 2004)

Sugar Gliders (Booth, 2003)

Evaluation of three popular diets fed to pet sugar gliders (*Petaurus breviceps*): Intake, digestion and nutrient balance. (Dierenfeld and Whitehouse-Tedd, 2018)

2.0. Birds

The birds covered in this review are: Parrots (African grey parrots, Amazon parrots cockatoos, eclectus parrots, macaws and ring-necked parakeets), finches (except for canaries), and birds of prey (barn owls, eagles, eagle owls, Harris' hawks, and lanner, saker and peregrine falcons).

The Pet Food Manufacturers' Association estimates there are 30,000 indoor pet birds in Scotland (from 2019 using average figures over three years) (Pet Food Manufacturers' Association (PFMA), 2021), with an average of 1.6 birds in 20,000 bird-owning households. Therefore, although the distribution of birds per household is not stated, it is very likely that the social needs of birds are not being met in captivity. Parrots have long lifespans and the Oasis Sanctuary (USA) has requests for help in rehoming 1000 to 1500 parrots per year, partly because the birds can outlive their owners, who purchase pets in retirement ("the need for rescue and sanctuary in the 21st century), but also because owners find their birds "too destructive, time consuming, loud or expensive", because of changes in

relationships, new babies and new jobs (Oasis Sanctuary Foundation Ltd., 1997-2006).

Birds are not included on “positive lists” in Europe, except in Croatia, Luxembourg and Malta. A scoring system was developed to inform beginner or unqualified pet keepers of exotic animals about how difficult they are to keep (Easy, Moderate, Difficult or Extreme, or “Emode”) and scores have been calculated for some of the species in this review (Warwick *et al.*, 2018) (Table 2), which indicate the majority are very challenging pets. In comparison, rats (*Rattus norvegicus*) were assigned a score of 10 points and fall into the category “easy to moderate”. The parrots in this review are listed in CITES Annex A and therefore all captive bred birds require closed leg-rings with unique identifying numbers. Pets do not need to be registered, but any commercial activity must be certified by DEFRA.

Table 2. Selected “EMODE” scores calculated on the website www.emodepetscore.com, describing the level of difficulty required to keep birds as pets.

Type of bird	**POINTS (+ 5 points if a household member is vulnerable)**	**Category**
African grey parrot, *Psittacus erithacus*	33	Extreme
Amazon parrot, *Amazona* spp.	33	Extreme
Umbrella cockatoo, *Cacatua alba*	38	Extreme
Blue-and-yellow macaw, *Ara ararauna*	33	Extreme
Hyacinth macaw, *Anodorhynchus hyacinthinus*	33	Extreme
Gouldian finch,	23	Difficult

Chloebia gouldiae		
Zebra finch, *Taeniopygia guttata*	18	Moderate to difficult
Harris' hawk, *Parabuteo unicinctus*	23	Difficult

There are fundamental questions about the keeping of birds in captivity. The act of placing a bird in a cage may be sufficient to cause stress, unless the enclosure is so large and well equipped that the bird does not perceive it as captivity (Graham, 1998). The ideal enclosure may exceed the means of the average private owner. Flight and socialisation are particularly challenging natural behaviours to accommodate in captivity (Engebretson, 2006).

2.1. Parrots

Statements from the Parrot Welfare Trust (in the interim report) identified some key areas of concern, where owners' lack of understanding or failure in provision result in suffering. These can be summarised as: Nutritional deficiencies (especially vitamin A and calcium), unbalanced diets (macro- and micronutrients), over-feeding, failure to provide UVB lighting and air purification, and failures in biosecurity. Causes of psychological suffering include inadequate cage sizes and wing clipping. The list of illnesses linked to poor husbandry is extensive: Respiratory infections, fungal infections, seizures, weakness, difficulty laying eggs, liver disease, muscle wastage/inability to fly, obesity, chlamydiosis, Psittacine Beak and Feather Disease (PBFD), avian bornavirus and food toxicities. The Parrot Society provides care sheets and publishes a magazine, both of which are only available to members (www.theparrotsocietyuk.org).

A review of environmental enrichment for parrots (Rodriguez-Lopez, 2016) found that most studies evaluate enrichment in terms of its effects on activity budget (e.g., increasing activity or stimulating foraging) or reducing abnormal behaviours. Foraging activity is markedly reduced in captivity. Wild parrots spend around 40%–

75% of their waking time searching for or accessing food, compared with 42 mins. in captive orange-winged Amazon parrots, *Amazona amazonica* (Rozek and Millam, 2011). Beyond these functions, enrichment should allow parrots control over their environment, and to fulfil their social needs, e.g., social play (Diamond and Bond, 2003). Studies carried out in a laboratory setting (Mettke-Hofmann, 2000; Garner *et al.*, 2003; Meehan *et al.*, 2003; Fox and Millam, 2004; Meehan *et al.*, 2004; Lumeij and Hommers, 2008; Kim *et al.*, 2009; Rozek *et al.*, 2010; Webb *et al.,* 2010; Rozek and Millam, 2011; van Zeeland *et al.*, 2013; Cussen and Mench, 2015) may be more applicable to pet parrots than enrichment studies in zoos, since social deprivation, exposure to human handling and space restrictions are very relevant to both the laboratory and the home. Meehan and Mench (2002) carried out regular handling of their Amazon parrots, so they would be suitable to rehome as pets after the experiment.

2.1.1. **African grey parrots, *Psittacus erithacus***

a) Behaviour

Feather destructive behaviour is an abnormal repetitive behaviour, which constitutes a major welfare problem, frequently observed in pet African grey parrots, *Psittacus erithacus* (Greenwell and Montrose, 2017). This problem has been attributed to a lack of adequate resources to develop coping skills. An active/ bold personality type may predispose individuals to developing FDB (van Zeeland *et al.*, 2013). Secondary to self-mutilation, opportunistic bacterial infection can be serious and chronic. Positive resolution can be achieved in almost all cases with appropriate care, but can take up to 21 months to achieve (Abou-Zahr *et al.*, 2018).

Aggression was observed in both parrots that bonded to a human and those that did not, and mostly in birds between four and seven years of age. Inappropriate hand-rearing practices (such as feeding chicks with tubes) or early painful experiences can lead to a fear of humans, which leads to biting (Welle and Luescher, 2008), and territorial aggression is also seen (Gaskins and Bergman, 2011). A large survey (103 pet *P. erithacus* over three years of age of known origin) explored the risk factors associated with different types of hand-rearing, parent-rearing and wild-capture. Hand-rearing was associated with greater aggression, whereas wild-caught birds had poorer health and more abnormal behaviour. Captive parent-rearing appears to

be a balanced approach between the extremes of hand-rearing and wild capture, but the time at which birds are separated from their parents is critical, and parent-rearing was associated with a greater risk of the juvenile behaviour of demanding food directed at owners extending into adulthood (Schmid *et al.*, 2006). Owner behaviour (aggression or shouting towards the bird, often in response to unwanted behaviours) can exacerbate aggression.

A lack of social and cognitive stimulation is an issue in pet African grey parrots, and FDB may arise as a consequence of frustration and suffering caused by a lack of appropriate company and stimulation. Owners should not acquire an African grey parrot, if they cannot spend a minimum of four hours per day with the pet; the risk of feather picking decreased by nearly 90% when birds interacted with humans for more than four hours per day (Gaskins and Hungerford, 2014). Pair-bonding can be challenging, if a new parrot is introduced to an established pair. However, social isolation, as associated with shorter telomeres (Aydinonat *et al.*, 2014), indicates these birds are suffering chronic stress.

b) Housing requirements

In common with other parrots foraging is a major part of their natural behavioural repertoire and can be stimulated using feeding enrichments. Eleven types of foraging enrichment were compared (van Zeeland *et al.*, 2013) and the longest foraging duration was around two hours per day, which was achieved with a “Plastic foraging device consisting of four opaque cups that can be hung from the ceiling and need to be unscrewed” and a “Honey-comb transparent acrylic feeder (W × L = 8 × 18 cm), in which a cardboard box filled with food can be placed”.

2.1.2. **Amazon parrot**

EAZA has produced best practice guidelines for the Ecuadorian Amazon parrot, *Amazona lilacina* (Pilgrim and Biddle, 2016), but it is unlikely that enclosure design, rearing and handling advice is going to be applicable to owners of Amazon parrots, unless they have the space and means to provide zoo-like conditions. The guidelines highlight the importance of disease screening, which is relevant to parrot importers and breeders of all species.

a) Behaviour

The University of California, Davis has a research centre for Parrot Wellness and Welfare. A colony of orange-winged Amazon parrots has been the focus of a number of studies on enrichment (Meehan *et al.*, 2003; Meehan *et al.,* 2004; Kim *et al.*, 2009; Rozek *et al.*, 2010; Webb *et al.*, 2010). This work elucidates the link between social isolation, lack of environmental complexity and foraging opportunities on poor psychological wellbeing and the incidence of stereotypical behaviour. Early experience in chicks, but not necessarily rearing method, has an important influence on the neophobia of adult parrots (Fox and Millam, 2004).

b) Nutrition

Complete pelleted diets are readily available for pet parrots in the UK, which are formulated to provide appropriate energy requirements as well as adequate levels of vitamin A and calcium: phosphorus ratios (Brightsmith, 2012). However, pellets can be perceived as monotonous, may be unappealing and feeding a high-seed diet is preferred by some owners, which can result in selective feeding and nutrient imbalances. A small study (seven adult parrots, fed a mixed diet with a higher proportion of seeds (25%), consumed less calcium, sodium and iron, and more than the recommended amount of fat. At lower levels of seed feeding (18%), fat consumption was still above recommended levels. Amazons, which were given mostly pellets (75%) with 25% fresh produce, consumed a recommended balance of nutrients. In recent nutrition studies for Amazon parrots, palatability of processed foods was tested, which should improve uptake (Di Santo *et al.*, 2019; Werneck *et al.*, 2020).

c) Health and disease

Atherosclerosis is a common disease of both African grey and Amazon parrots, and a common cause of sudden death among parrots submitted for necropsy (Fricke *et al.*, 2009). This literature search did not find any more recent estimates of the incidence of these diseases, since Bavelaar and Beynen analysed the causes of atherosclerosis in parrots (Bavelaar and Beynen, 2004). As in humans, atherosclerosis is linked to plasma cholesterol and has genetic, dietary and lifestyle-related causes. Abnormalities in heart dimensions are associated with obesity in blue-fronted Amazon parrots, *Amazona aestiva* (dos Santos *et al.*, 2020).

2.1.3. **Cockatoos, Family Cacatuidae**

a) Behaviour

Behavioural issues were the most common results of the Web of Science search, including a study of visitor behaviour in zoos (Collins and Marples, 2015). Citron-crested cockatoos, *Cacatua sulphurea citrinocristata*, became more social in the presence of visitors, when housed near a zoo playground. Facial expression of positive welfare is associated with feather ruffling over the cheeks and nape (Bertin *et al.*, 2020).

Cockatoos, in common with other parrot species, express abnormal repetitive behaviours in response to the captive environment. Simple materials that are easily accessible in the UK, but which can significantly decrease stereotypical behaviour, are fresh grass and millet discs (Fangmeier *et al.*, 2020). Cockatoos, along with African grey parrots, are at most risk among parrots for feather-destructive behaviour, according to a multi-country survey of 42 cases and 126 controls (Gaskins and Hungerford, 2014). This finding was replicated in UK populations; a survey of 310 cockatoos found that 42.4% of cockatoos had expressed feather-destructive behaviour at some point during their life (Jayson, Williams and Wood, 2014). Most (62.9%) plucked more than one body area. Being acquired from a pet shop had a considerable influence on feather-plucking, with cockatoos from pet shops having a six-fold greater risk than those bought from private breeders. Keeping the cage against a wall increased the risk of feather plucking. Being male, having owners that were away for more than one week, being regularly sprayed with water and command training were also risk factors. For both cockatoos and African grey parrots, 50 potential causes were tested and most were found to be insignificant influences on the incidence of feather-pecking. Veterinary treatment may be required for the treatment of feather damage caused by owner feather trimming (Welle, 2019).

b) Mortality

In Canada over a period of 19 years, when causes of mortality in more than 20 different genera of captive psittacine birds were analysed (Gibson *et al.*, 2019), cockatoos were not significantly more affected by any of the categories of disease

than any other parrot genus. Non-infectious, metabolic causes of death were most common, such as atherosclerosis, gout and haemosiderosis. Haemorrhage, congestion, degenerative diseases (such as atrophy and necrosis) were commonly diagnosed. The most common infectious causes of death included bornavirus, polyomavirus, circovirus, *Mycobacterium* spp., *Chlamydia* spp., *Macrorhabdus ornithogaster* and *Aspergillus* spp.

2.1.4. **Eclectus parrot, *Eclectus roratus***

Of 16 search results on Web of Science using the terms defined in this review, 13 were health-related, two were related to breeding in wild eclectus parrots (Heinsohn *et al.*, 1997; Heinsohn and Legge, 2003) and one studied the nutritional intake of nestling eclectus chicks in Indonesia (Rachmatika *et al.*, 2020).

a) Behaviour

Eclectus parrots feature in studies of feather-plucking (Garner *et al.*, 2008; Horie *et al.*, 2012; Grosset *et al.*, 2014), a condition which is discussed in general terms in section 2.0.

b) Health and disease

The literature was sparse and dominated by case reports of diagnosed conditions in a single parrot (disseminated coelomic xanthogranulomatosis, (Donovan *et al.*, 2022); intracoelomic teratoma, (Mayer *et al.*, 2021); mycobacteriosis, (McRee *et al.*, 2017); osteoma, (Cowan *et al.*, 2011); complications after orthopaedic surgery (Harris *et al.*, 2007); immune-mediated haemolytic anaemia (Johnston *et al.*, 2007); and ventricular diverticulum (De Voe *et al.*, 2003). Eclectus parrots are amongst those most affected by Psittacine Beak and Feather Disease in Taiwan (Lin *et al.*, 2021). They can also host microfilaria parasites (Huang *et al.*, 2017), although this study was also from Taiwan and there is no evidence to suggest microfilaria is a problem in UK parrots.

2.1.5. **Macaws**

a) Breeding

Formulas available for hand-rearing parrots do not match the crop contents of wild chicks. Although they have comparable energy content, they may be lacking in

minerals and electrolytes, including potassium, magnesium and manganese (Cornejo *et al.*, 2013). Overall, formulas for hand-rearing vary between brands and although research is continuing, e.g., the characterisation of fatty-acid profiles appropriate for feeding young chicks (Cornejo *et al.*, 2021), more work is needed to ensure such diets are standardised and provide the appropriate balance of nutrients (but see Schmid (2006) for evidence on the outcomes of hand-rearing parrots).

b) Behaviour

Macaws share characteristics with other psittacine birds, including the expression of stereotypical behaviours (de Almeida *et al.*,2018), in the captive environment, which are exacerbated by lack of appropriate enrichment. Physical, feeding and cognitive enrichments all stimulate activity (Miglioli and Vasconcellos, 2021), although no significant relationships were found in this study between enrichment and reproductive success. Among parrots, macaws are particularly large and easily capable of injuring their owners.

c) Nutrition

Veterinary investigations have defined physiological values of vitamins A and E in psittacines, including macaws (Torregrossa *et al.*, 2005); haematology and biochemistry values for hyacinth macaws, *Anodorhynchus hyacinthinus* (Kolesnikovas *et al.*, 2012); haematological values of green-and-red macaws, *Ara chloropterus* (Vieira *et al.*, 2021).

2.1.6. **Ring-necked parakeet**

Ring-necked parakeets, *Psittacula krameri*, are the only parrot species successfully free-living in the UK. The only WoS results from the pre-defined search terms related to free-living parakeets in the UK (Newson *et al.*, 2011; Sa *et al.*, 2014; Heald *et al.*, 2020), France (Pisanu *et al.*, 2018) and Portugal (Rocha *et al.*, 2020).
Avihepadnavirus has been identified as a cause of liver disease in young birds in Poland (Piasecki *et al.*, 2013). *Chlamydia psittaci*, isolated from swabs of multiple organs in psittacine birds, including suburban populations of ring-necked parakeets in France (Pisanu *et al.*, 2018), is an important cause of disease and of particular concern as a zoonosis (Gibson *et al.*, 2019).

Summary: Parrots

- The dietary needs of parrots require not only nutritional, but behavioural understanding of the species, which may require a concerted effort to overcome selective feeding.

- Aggressive or reactive biting can escalate negative interactions between parrots and their owners and become a barrier to giving parrots the appropriate amount of positive, active time out of their cages.
- Parrots' behavioural responses to a lack of appropriate social and mental stimulation are very dramatic and can result in intractable, distressing feather-damaging behaviour.
- Atherosclerosis can cause severe cardiac disease, including sudden death, and although dietary factors play an important point in mitigating this, parrot breeders should also avoid selecting for individuals predisposed to this condition.

- The effect of relinquishment and rehoming on parrots should be investigated, as these are long-lived, demanding pets, vulnerable to the consequences of becoming unwanted pets.

Key resources

EAZA Best Practice Guidelines, Ecuadorian Amazon Parrot (Pilgrim and Biddle, 2016)

Prevalence and risk factors of feather plucking in African grey parrots (*Psittacus erithacus erithacus* and *Psittacus erithacus timneh*) and cockatoos (*Cacatua* spp.). (Jayson *et al.*, 2014)

The gray matter: Prevention and reduction o).f abnormal behavior in companion gray parrots (*Psittacus erithacus*) (Greenwell and Montrose, 2017.)

The welfare and suitability of parrots as companion animals: A review. (Engelbretson, 2006).

The Parrot Society www.theparrotsocietyuk.org

2.2. **Finches**

The most commonly kept species of pet finch in the UK is the zebra finch, *Taeniopygia guttata*. These are also common laboratory animals, e.g., in studies of song learning, flight, navigation and foraging (Patterson and Fee, 2015). The Association for Avian Veterinarians provides a basic care guide for "companion birds" (AAV, 2019), which, for finches, has few specific recommendations, but highlights the need for spaced-apart perches to allow hopping and flying, the benefit of keeping finches socially and encourages owners to provide long, large enclosures for flight, and social companions. Wild capture of finches in the UK is illegal, but according to the RSPB is still common (RSPB, n.d.).

a) Behaviour

Finches form pair-bonds and are prolific breeders (RSPCA, 2011). Fear is also a concern, if birds are not used to humans. The effect of isolation on finches (other than canaries) is not published, but canaries, *Serinus canaria*, have a more positive cognitive bias, if housed socially rather than alone (Lalot *et al.*, 2017). Zebra finches score 18 EMODE points (23 if a family member is vulnerable), whereas Gouldian finches (*Chloebia gouldiae*) score higher (23 points) due to being "an especially sensitive species".

b) Housing requirements

The RSPCA provides a guide to housing and care of zebra finches (RSPCA, 2011). This guide provides references, including "The Zebra Finch: A synthesis of field and laboratory studies" (Zann and Bamford, 1996). Popular pet songbirds, such as zebra finches and Gouldian finches, are adapted to the climate of Australia, but no published studies were found on the effect of a colder climate on their welfare. Acute, loud noises cause short-term disruption of birds' behaviour (at least 15 minutes after a fire alarm, (Corbani *et al.*, 2021). Bathing water is an important resource for zebra finches, as demonstrated by (Krause and Ruploh, 2016). Without the opportunity to bathe for 30 days, finches had a higher basal cortisol plasma concentration.

c) Nutrition

Finches' natural diets vary seasonally and they require grit to aid digestion (Patterson and Fee, 2015). Publications on nutrition are often in the context of development (from an ecological research angle, in relation to song learning (Lovell *et al.*, 2011; Yamada and Soma, 2016) or reproduction (Blount *et al.*, 2003; Blount and Matheson, 2006; Noguera *et al.*, 2017), rather than demonstrating a relationship with good health or clinical disease.

Summary: Finches

- Owing to their popularity and use in research, information is available on appropriate aviary design and social needs, which can allow finches to perform normal behaviours.
- Finches can habituate to human presence, but require company of their own kind.
- Finches form stable breeding pairs therefore allowing this normal social behaviour is difficult as uncontrolled breeding is usually not compatible with pet ownership.

- Evidence of the welfare of finches kept in domestic situations other than aviaries is lacking. Finches kept in small cages which do not allow for flight, or kept in social isolation are at risk of poor welfare, but this has not been investigated.

Key resources

Basic care guide for companion birds (Association for Avian Veterinarians, 2019).

Zebra finches: good practice for housing and care (RSPCA, 2011).

2.3. **Birds of prey**

This review did not elicit evidence about the welfare of birds of prey in private ownership in Scotland. EAZA publish guidance on falconry demonstrations (Habben and Parry-Jones, 2016), including aviaries, transport, tethering, training, free flight

and breeding. This evidence is a result of a collaboration between zoo experts and representatives of the Hawk Conservation Trust.

2.3.1. **Barn Owl, *Tyto alba***

The Barn Owl Trust (Barn Owl Trust, 2021) does not recommend keeping barn owls as pets, nor for falconry birds. They state many reasons why barn owls do not make good pets: Stroking their feathers reduces natural waterproofing, they are not suitable to be kept indoors, mostly inactive unless hungry, can show persistent juvenile calling for food or aggression if imprinted to a human "parent" and during the breeding season, and males can be very noisy at night. Untamed barn owls prefer to be away from people and stay out of sight. Owls are not easy to train with food, and they are nocturnal and once they are fed, prefer to rest and digest their food. Flying off while wearing ankle straps can cause the bird to become trapped and die. Additional considerations include unwanted breeding, difficulty in finding holiday care and the relevant legislation for keeping the species: It is illegal and unethical to release a captive barn owl. Reference values are established for haematology and blood biochemistry parameters in healthy barn owls (Szabo *et al.*, 2014; Agusti Montolio *et al.*, 2017, 2018).

2.3.2. **Eagles, Family Accipitridae and 2.3.3. Eagle owls, *Bubo* spp.**

There were few studies relevant to the welfare of captive eagles or eagle owls in the Web of Science search. A retrospective study of pododermatitis (bumblefoot) in rehabilitated raptors in the USA reported an incidence of 52 cases per 100 bird-years at risk between 1980- 1990 and this disease was described as being "one of the most common and potentially serious afflictions of captive raptors" in the proceedings of an American veterinary conference held in 2001 (Forbes, 2001). A lower prevalence has been reported from Spain, data on 2004 raptors admitted to a wildlife rehabilitation centre (Madrid) included 8.8 cases/ 100 bird-years at risk. Accipitridae were more at risk than raptors from the Falconidae and Stringdae families. No studies reported on the prevalence of infectious diseases among captive eagles in the UK, but a study of adenoviral disease outbreaks in a UK bird "collection" identified a previously unknown virus, "raptor adenovirus", which was causing deaths, including of two owls (Zsivanovits *et al.*, 2006). Successful surgical treatment of a calcified lesion in a captive-bred tawny eagle, *Aquila rapax* (calcinosis

circumscripta) was described (Sabater *et al.*, 2016). Another case report by the same author reports that intussusception, an emergency intestinal obstruction requiring surgery, is rarely reported in raptors (Jones *et al.*, 2004). A golden eagle, *Aquila chrysaetos*, presented with acute trauma during exercise, leading to spinal fracture and spinal cord compression, and was subsequently euthanased (Fraga-Manteiga *et al.*, 2013).

2.3.4. Harris' hawks, *Parabuteo unicinctus*

Feather-destructive behaviour is reported in Harris' hawks more commonly than in other captive raptors (Smith and Forbes, 2009). An article published in the USA (Jones, 2004), describes behavioural aspects of captive birds of prey. Harris' hawks, used for falconry, can pose a risk to immune-compromised humans (see appendix 1). Evidence for the welfare of captive Harris' Hawks in the scientific literature is lacking.

a) Breeding

The early period when the young bird is in the nest involves imprinting, when it learns to recognise parents and siblings, and then later learning about future mates. A long period of daily socialisation is required in order for raptors to imprint (i.e., accept) a human as a surrogate parent or mate. The sensitive period varies according to species and nocturnal birds imprint later in development than diurnal birds. Food-begging, screaming and aggression are described as commonly occurring behaviours, which make raptors challenging in captivity. No recent reviews or case reports of behavioural issues were found (Jones, 2004).

b) Housing requirements

The British Falconers' Club recommends that a Harris' hawk is the most appropriate bird to begin training for a novice falconer, but that they do not make good pets, and ownership should follow careful consideration and study. Owning a hawk involves dedication of considerable time, accommodation, daily feeding of raw food, training, and crucially, the continuous assistance of an experienced falconer.

c) Health and disease

Atherosclerosis, which can lead to hypertrophy of the left ventricle, and in the most extreme cases, sudden death by myocardial infarction (Legler *et al.*, 2017), is reported in Falconiformes (diurnal birds of prey) and Strigiformes (owls) (Jones, 2013), but the prevalence of this disease in UK populations has not been recently reported (Mitchinson and Keymer, 1972). The risk factors for this disease are thought to be associated with captive diets, obesity and lack of exercise (Jones, 2013). Similarities between this condition in humans, raptors and owls, include an increased risk associated with elevated blood cholesterol. Birds fed a diet of day-old chicks rather than rats and mice were at a higher risk of having increased serum cholesterol (Legler *et al.*, 2017).

2.3.5. **Falcons, Falconidae**

a) Transport and handling

Lanner, *Falco biarmicus*, and saker falcons, *Falco cherrug*, at a rehabilitation centre in Jordan were most commonly presented due to illegal ownership and confiscation at the port of entry (five of seven lanner falcons, six of 10 Saker falcons). Three lanner falcons had coccidiosis; other reasons for rehabilitation were sporadic incidences of trauma or disease (Al Zoubi *et al.*, 2020).

The effect of transport on blood-cell values was tested in peregrine falcons, *Falco peregrinus,* and Harris' hawks, *Parabuteo unicinctus* (Parga *et al*., 2001). Peregrine falcons, which were accustomed to transport, did not show any significant changes in blood-cell parameters after one hour of transport, and for those which were untrained, their heterophil/ lymphocyte ratio increased (suggesting this was more stressful for the untrained birds). Among Harris' hawks, more blood changes were observed; the untrained birds showed leucopaenia, lymphopaenia and eosinopaenia, whereas trained birds had monocytosis.

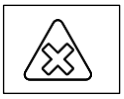
b) Health and disease

Outside the UAE (United Arab Emirates) (Lierz *et al.*, 2002) and Kuwait (Tarello, 2008), no studies on the health or welfare of saker falcons were found since 2001. In the Czech Republic, one hybrid saker falcon x gyrfalcon (*Falco cherrug* x *F. rusticolus*) and one Harris' hawk died during an outbreak of West Nile virus

encephalitis (Hubálek *et al.*, 2019). Falcons can become ill due to aspergillosis, which is often secondary to immune suppression or concurrent bacterial infection. A review of appropriate treatment regimes was carried out (Krautwald-Junghanns *et al.*, 2015). Supportive therapy alongside antimycotic drugs is necessary in most cases. Protozoal diseases, *Caryospora* spp., also affect falcons and owls.

Summary: Birds of prey

- Taming birds of prey to make them amenable to living around humans, by handling them as chicks, is not always successful and can result in adults, which are unsuitable for release and have poorer welfare in captivity.
- Free flight gives birds of prey the exercise and expression of normal behaviours they need, and evidence for the provision or absence of this opportunity in the pet population is unknown.



- Based on the information provided by hobbyist organisations, there are significant risks to bird welfare, if ownership is entered into without the appropriate expertise and guidance, and some species are not suitable as pets.

- There was no evidence on the welfare of birds of prey kept as pets in Scotland.

Key resources

EAZA Falconiformes and Strigiformes Taxon Advisory Group Husbandry and Management Guidelines For Demonstration Birds (Habben and Parry-Jones, 2016).

3.0. Fishes

The fishes covered in this review are cichlids, Order Cichliformes, clownfishes, Subfamily Amphiprioninae, Koi carp, *Cyprinus rubrofuscus*, and Siamese fighting fish, *Betta splendens*. The welfare issues of fishes on their journey to the home aquarium are not often measured at the species level and some general issues are outlined here.

a) Transport and handling

The scale and sustainability of the ornamental pet trade is outside of the scope of this review, but is explained in a recent publication (King, 2019). Captive-breeding of marine oriental fishes is mainly carried out in non-EU countries, such as Indonesia, the Philippines, USA and Sri Lanka. Imported fishes from third (non-EU) countries into the UK are accompanied by a packing list, which details the species and their quantities, but this information is not available in a repository (King, 2019). Overall rejection rates of wild-caught marine aquatic fishes are suggested by King (2019) to be lower than the 24.2% in a six-month period figure stated in a small study from Papua New Guinea (Militz *et al.*, 2016), with the rationale that countries with more established industries have more experienced operators and divers paid by the number of fish they catch that are subsequently exported, but more quantitative data are needed to confirm this. A recent estimate of the number of marine ornamental fishes imported into the UK between 2012 and 2014 is 1.4 million (Defra, 2015). The average transport time for ornamental fishes sold in the UK is 24 hours (Vanderzwalmen *et al.*, 2021). Therefore, welfare in transport is a pressing issue relevant to all ornamental marine fishes. Ornamental fishes are subject not only to deterioration in water quality, because of the build-up of waste products of the fishes being transported, but to abrupt changes in water at different stages of the supply chain (Vanderzwalmen *et al.*, 2021). In addition to issues of water quality and temperature, handling is a profound stressor (Portz *et al.*, 2006), and in cichlids, packing into plastic bags, is associated with a four-fold rise in cortisol in the subsequent two hours, which continued to increase until six hours post-packing (Wu *et al.*, 2021). Sedatives and tranquilisers are used routinely (Crosby *et al.*, 2010), but doses used may not be standardised, evidence based and safe. Dried soybean root (*Glycine tomentella*) was demonstrated to reduce cortisol at four hours post simulated transport in orange-spotted grouper, *Epinephelus coioides*, blood parrot cichlids, *Amphilophus citrinellus* x *Vieja melanurus*, and koi carp (Wu *et al.*, 2020, 2021).

(Baldisserotto *et al.*, 2014) studied the effect of transport on cardinal tetras (*Paracheirodon axelrodi)* under normal commercial conditions for a 24-hour journey between Barcelos and Manaus, Brazil. Mean survival was 99.5%, with no significant effect of treatment with salt water, tetracyclines or Amquel®, which are commonly used in the transport of commercial fishes to reduce transport stress. Whole body

cortisol increased during the initial three hours and this increase was mitigated by the addition of any/all additives (however, the massive increase in Na+ and Cl- influxes, and the potential to develop antibiotic-resistant pathogens suggest these additives should not be used routinely). After this time cortisol decreased back towards baseline by 24 hours after treatment, suggesting that the processes associated with catching, loading, change in water and/or changes in the social environment have a greater effect on the level of stress experienced by fish compared with the journey duration and associated water quality issues. Transport in sealed plastic bags leads to the accumulation of CO_2 and consequent drop in pH, whereas fish in open containers are subject to a slower decrease in pH and are less stressed.

DEFRA do not provide specific guidance for the welfare of fish during transportation (www.gov.uk/guidance/animalwelfare#animal-welfare-during-transport). The most recent guidance follows Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes (T-AP), 2005). Owing in part to the large range of species covered, the guidance requires secondary information in order to be effective, i.e., “appropriate training of stock-people and the use of professional advice on species-specific requirements”, and limited in specificity (containing terms such as: “where possible, pH shall be kept stable”, “it is essential that carbon dioxide levels are kept low”, “enclosures should be regularly cleaned”. The standing committee report recommended “research on the development of husbandry systems, which fully respect the biological needs and welfare, including health, of fish”, with specific areas to target, such as pain perception and food deprivation.

Sources of information for pet owners signposted by (King, 2019) (Assistant chief executive of the Ornamental Aquatic Trade Association (OATA) Ltd., UK.), include OATA, www.thepetcharity.org, and www.practicalfishkeeping.co.uk.

3.1. **Cichlids, Cichliformes**

a) Behaviour

Cichlid species are the focus of fundamental ecological research into aggressive behaviour (e.g., Nijman and Heuts, 2011; Alward *et al.*, 2021). Cichlids are territorial

and fight for dominance, after which overt aggression is much reduced. Social defeat is known to be acutely stressful for subordinates (Sloman *et al.*, 2001), but the longer-term effect on welfare of being housed with a dominant conspecific is not known.

b) Housing requirements

Contrary to the expectation that enrichment would lead to greater territorial aggression, the presence of enrichment can reduce aggression in a resident-intruder test (Nijman and Heuts, 2011). Chemical communication is important for the maintenance of stable dominance relationships, and even replacing only 25% of tank water is enough to elicit aggression between freshwater angelfish, *Pterophyllum scalare,* and replacing 50% of tank water resulted in an increased in aggression lasting over 24 hours (Gauy *et al*., 2018).

c) Mortality

Concerns about the mortality of fishes in transport were reported in the interim report. Mass mortality events may be caused by pre-transport infection with gastrointestinal parasites (*Enterogyrus* sp. and *Aeroomonas jandaei*) (Assane *et al.*, 2021) in combination with transport stress.

Summary: Cichlids, Cichliformes

- The breeding and transport of cichlids exposes them to a range of risk factors for poor welfare, of which handling is the most stressful component.
- The social environment is another potential source of welfare problems, and owners must be cautious of disrupting stable relationships when introducing new fish or during routine cleaning.

- The welfare of cichlids has been investigated in laboratory studies, but the conditions of cichlids in the pet trade and in private ownership is much less reported.

Key resources

Less water renewal reduces effects on social aggression of the cichlid *Pterophyllum scalare* (Gauy *et al.*, 2018)

3.2. **Clownfishes**

a) Capture and breeding

It is estimated that 90% of all clownfish (*Amphiprion* spp. and *Premnas* spp.) are bred in captivity (King, 2019). Fears that children's films featuring clownfishes increased demand for wild-caught clownfishes were not substantiated by research, and a similar claim regarding blue tang fish, *Paracanthurus hepatus*, was also shown to be unfounded (Veríssimo *et al.*, 2020). Breeding clownfishes successfully involves a thorough understanding of the breeding structure of wild groups and several search results were related to clownfish reproduction (Fobert *et al*., 2019; Phillips *et al.*, 2020). *Amphiprion ocellaris* is protoandrous and its social environment determines the sex of group members. Several articles focused on factors affecting sex determination (Iwata *et al.*, 2008; Iwata and Manbo, 2013; Phuc Thuong *et al.*, 2017; Iwata *et al.*, 2019; Iwata *et al.*, 2019). Clownfish social groups centre on a host sea anemone. Monogamous pairs are collected for breeding. When mated pairs are not available, mixed groups, including sexually immature groups, of fish can be collected and breeding pairs will form. The sea anemones, with which the clownfishes are associated, also need to be transported, and should be kept in separate transportation containers (Madhu *et al.*, 2006). Red Sea clownfish (*Amphiprion bicinctus*) is one of the most commonly exported ornamental fish from Saudi Arabia, as is Clark's anemonefish (*Amphiprion clarkii*) from Sri Lanka (Wood, 2001).

b) Conditions in commercial premises

Husbandry studies often focus on productivity and profitability as outcomes, without mentioning or measuring welfare *per se* (Chambel *et al.*, 2015). Stress is considered to contribute towards poorer survival in fish (Sharm and Chakrabarti, 1998) and researchers may assume that where growth and survival are depressed, welfare is also likely to suffer. Stocking density has a significant influence on the survival of juvenile clownfishes measured over the course of four months (Chambel *et al.*, 2015). In this laboratory study, survival was 100% when the stocking density was 0.5 fish per litre, and as low as 82.5+/-1.9% at densities up to three fish per litre (survival values were not stated for 1, 2 and 3 fish per litre). Higher stocking densities also depressed growth, with significant decreases in length and specific growth rate. Varying the type of commercial diet fed to the fish did not significantly decrease their

survival rate over a four-month study period, running parallel to the stocking density trial. However, the survival rate of fish in the nutrition trial was as low as 68.89+/-2.22%, whereas when only stocking density was varied, fish received a mix of all four diets. In the nutrition trial, stocking density was one fish per litre, which might indicate that individual commercial diets are in some way insufficient to meet their full nutritional needs. In a laboratory study, survival of larvae from hatching to 13 days after hatching varied from 60 to 66% (Nass *et al.,* 2016).

c) Nutrition

The nutritional needs of marine ornamental fishes are less well studied than those of fishes farmed for food, and the complete diets available are not tailored to the needs of particular species (Craig *et al.,* 2017; Vargas-Abúndez *et al.*, 2019). Clownfish larvae differ in their ability to consume large prey from a young age. Clark's anemonefish is particularly precocial and when fed brine shrimp nauplii from day two post-hatching, and began to metamorphose one day sooner than when feeding commenced on day four or six (Nass *et al.*, 2016). Under laboratory conditions, 300 juvenile *Amphiprion ocellaris* were fed four different diets for 106 days, including a novel insect diet, black soldier fly, *Hermetia illucens*, larvae and all survived for the duration of the study (unless sacrificed for analysis), (Vargas-Abúndez *et al.*, 2019).

3.3. **Siamese fighting fish**

The welfare issues facing pet Siamese fighting fish, *Betta splendens*, have been reviewed by (Pleeging and Moons, 2017) and are summarised here. A review of stress and welfare in ornamental fishes (Stevens *et al.*, 2017) provides a suggested list of further research priorities.

a) Behaviour

Behaviour-based welfare indicators are lacking, but the building of bubble nests by males is considered to indicate that the water temperature is sufficient. Males are highly competitive and territorial, and housing males together may result in fatal aggression.

b) Housing requirements

Betta splendens is adapted to living in warm water, with a low pH and low oxygen saturation; they have a high tolerance to oxygen levels as low as 0-2 ppm. Species-specific sensitivity to ammonia due to waste products is unknown. Therefore, assessment of water quality, and procedures for water filtration and cleaning for hobbyists are based on recommendations that are not substantiated by the scientific literature. As a result, fish may be inadvertently subjected to toxic effects of high doses or chronic exposure to inappropriate conditioning products.

c) Nutrition

Betta splendens is carnivorous, feeding on mosquito larvae in its natural habitat. Experimental evidence has shown that feeding animal proteins is important for growth, although plant proteins are less risky for introducing mycotoxins. Amount as well as quality of protein is important, with an optimum protein level for young fighting fish of 31-35% protein. Overfeeding leads to deterioration in water quality. The nutritional needs of adult *Betta splendens* are not well understood and more guidance is needed.

d) Health and disease

The relationship between disease and welfare, particularly infection with *Mycobacterium* spp., is not clear. Mycobacteria are prevalent in *B. splendens* and often isolated from dead

and dying fish (Zanoni *et al.*, 2008), but it is not known if they are the primary cause of disease, or if infection is only secondary to poor health.

Summary: Perciformes

- It is important for owners to be aware not to house males fighting fish together.

- Based on laboratory studies, inappropriate nutrition and overstocking are likely to increase mortality in transport and on commercial premises.

- Little information has been published for *Betta splendens*, such as optimum nutrition and water quality. Therefore, they are at risk of health problems due to poor water quality or excessive or inappropriate use of chemicals.
- Information on *Betta splendens* may be available from general information on "ornamental marine fishes", but is not species-specific.
- Successful captive breeding of clownfishes is a complex process and the feeding of larvae is still subject to uncertainty over when to transition to larger prey.
- No information on the welfare of clownfishes as pets in home aquaria was found.
- Basic requirements of clownfish, such as stocking density and nutrition, are receiving increasing attention, but studies of behavioural needs are only focussed on reproduction.

Key resources

Potential welfare issues of the Siamese fighting fish (*Betta splendens*) at the retailer and in the hobbyist aquarium. (Pleeging and Moons, 2017).

3.4. **Koi carp**

Most of the published literature on Koi carp, *Cyprinus rubrofuscus*, found on the Web of Science, using the search terms relevant to this review, concerned viral infections (25 of 47 results). A review of the welfare of common carp, *Cyprinus carpio*, was carried out by the European Food Safety Authority (Algers *et al.*, 2008). Koi carp can be used in hydroponics (e.g., the production of cannabis) in a dual system, where fish are used as a cheap source of nitrites (via bacterial filtration) (Love *et al.*, 2014).

The long lifespan of Koi carp make them attractive due to the reduced need for restocking and associated biosecurity concerns (Maitland *et al.*, 2022).

a) Transport and handling

Netting, grading and transport are stressful events, and the best way to reduce stress is to expedite these procedures. Stressful procedures increase respiration rate and oxygen demand, which can cause acute stress and asphyxia, e.g., at harvesting (measured in rainbow trout, *Oncorhynchus mykiss* (Van Raaij *et al.*, 1996). Sudden changes in light intensity and spectrum during harvesting, grading and transport are potential welfare issues. To maintain water quality during transport, measures already undertaken are: "(i) addition of atmosphere of pure O_2, (ii) ammonia neutralization or removal procedures, (iii) addition of buffers to the water, (iv) pre-transport fasting, (v) addition of salt or seawater dilution to reach isosmotic salinity, (vi) reduction in temperature, (vii) use of anaesthetics and (viii) addition of probiotics." Grading is stressful and it is recommended to only grade common carp twice a year (Algers *et al.*, 2008). Feed restriction prior to transport may reduce resilience to stress, increased competition and aggression (studied in salmon, although not in carp), and hunger is a welfare issue in itself. In an addendum to Algers *et al.* (2008), Broom highlights that assessments of welfare commonly used by producers are incomplete and only take into account growth, feed intake and mortality. Representative sampling of individuals is advised to assess fin damage, health status and the effect of exposure to repeated stressors (which may include changes in light or pressure), to gain a greater understanding of chronic stress.

Long transport duration is associated with extreme elevation in pH due to excretion of ammonia. Oxygen can be supplemented more easily to avoid hypoxia. Additional water quality issues include concentrations of NH_3, NO_2, NO_3, pH, dissolved oxygen and CO_2.

The use of metomidate (a tranquiliser that inhibits enzymes involved in cortisol and aldosterone synthesis) to reduce transport stress (and increasing saleability of the fish after being transported for 24 hours) was evaluated. Outcome measures were: Plasma cortisol and glucose, appearance (graded from 1-5, where lower grades were awarded if fish had severe fin damage, hyperaemia, clamped fins and/or scale loss) and behaviour (graded from 1-4 where negative "behaviours" were rapid

respiration, hiding and loss of buoyancy). Neither transport nor metomidate influenced behaviour scores, whereas at the higher doses of metomidate (3.0 and 4.0 mg/L) an increase in cortisol, following transport, was not observed. Koi carp treated with 0 or 4.0mg/L metomidate had significantly worse appearance, so that intermediate doses (3.0mg/L) were recommended. The authors acknowledge that inhibiting cortisol may not reduce stress, but rather the ability to respond to stressors (Crosby *et al.*, 2010).

b) Behaviour

In polyculture, koi carp can attack the eyes of goldfish, *Carassius auratus* (Oladi *et al.*, 2017), causing obvious negative welfare, but the literature search did not find any concerns quantifying aggression or fin damage between koi carp. The effect of human presence on koi carp is an important factor in their welfare as pets, yet the human-animal bond is poorly researched in fish. Koi carp (seven adults) in an aquaponics learning centre were studied, after an initial period of habituation and handfeeding, to determine whether they would voluntarily interact with humans. The study also sought to understand whether these interactions vary according to individual personality differences or could instead be driven by a general fear of humans or general attraction towards novelty or disturbance (Fife-Cook and Franks, 2021). Fish voluntarily approached and stayed near to the person's hand when it was in the water, and individuals varied in their preference to be near the human. However, the carp spent more time close to the human hand in sessions before they had been fed than 20-30 minutes afterwards, so these results could be due to fish associating human hands with the presentation of food rather than any sense of social interaction. Nevertheless, it demonstrates that koi carp can learn to perceive humans positively. Domestic strains of carp appear to be less efficient at consuming live, swimming prey, and less cautious and slower to attack prey. Domestic strains were also more likely to be found in the upper layers of the water than the feral carp, which inhabited the bottom of the water column. These findings suggest that koi carp are adapted to living around humans and being provided with food (Matsuzaki *et al.*, 2009) and that domestic strains which escape captivity are at a disadvantage compared to wild strains, even if the environment is favourable.

c) Conditions in commercial premises

Increasing stocking density (2.8kg/m^3) of koi carp fingerlings in an aquaponic system negatively affected growth and body length, and increased catalase activity, and levels of glucose and cortisol, compared with fish kept at 1.4kg/m^3 (Nuwansi *et al.*, 2021). Carp are able to tolerate a wide range of temperatures, but enter a state of torpor at colder temperatures (Algers *et al.*, 2008). Often a minority of carp will grow exceptionally fast and become larger than the rest of the population ("shoot carp"), leading to a right-skewed distribution and potential welfare issues, including cannibalism in juvenile populations (van Damme *et al.*, 1989) and smaller individuals suffer because they are outcompeted for food (Barki *et al.*, 2000). In a study of koi carp used in a hydroponics system, the presence of "shoot carp" was not affected by stocking density, average fish weight, cohort size, feed rates, feed-conversion rate or specific growth rate (Maitland *et al.*, 2022). High levels of food competition are thought to encourage shoot carp and a narrow range of sizes may increase competition, whereas adding some larger individuals may dampen the propensity for future shoot carp to emerge. Interestingly, no aggression or cannibalism was observed despite the appearance of shoot carp in every group (Maitland *et al.*, 2022). It may be argued that grading is an ineffective way of preventing the negative consequences of food competition and improving feed provision may be a better focus to resolve the problem of smaller individuals losing out.

d) Health and disease

Cyprinid herpesvirus 3 (cyHV-3), which causes koi herpesvirus disease (KHVD), commonly affects farmed and wild carp (Bocklisch *et al.*, 2006; Negenborn *et al.*, 2015), leading to mass mortality events (Garver *et al.*, 2010; Rahmati-Holasoo *et al.*, 2021; Tolo *et al.*, 2021). The virus is imported into the UK via the ornamental pet fish trade (Wood *et al.*, 2022) and is spread via direct contact prior to the symptomatic phase of the disease (Tolo *et al.,* 2021). Below water temperatures of 16°C the disease is suppressed (Yuasa *et al.*, 2008), but the virus may persist in a latent state after recovery from clinical illness. Koi carp are most at risk of contracting and spreading the disease, if they are mixed during exhibitions and at mating periods (Uchii *et al.*, 2011). Another important cause of mortality is carp oedema virus (CEV) (Lovy *et al.*, 2018), and co-infections with CyHV-3 and CEV can

occur in carp populations (Padhi *et al.*, 2019; Sauerwald *et al.*, 2020; Toffan *et al.*, 2020; Tolo *et al.*, 2021).
Other important diseases identified in this review affect the swim-bladder. Inflammation and mortality can be caused by bacteria, such as *Proteus hauseri* (Kumar *et al.*, 2015), *Aeromonas hydrophilia/ caviae* group and *Shewanella xiamenensis* (Sirri *et a*l., 2020), *Spaerospora dykovae* (Chang *et al.*, 2016) and a range of other bacteria, have been isolated from koi carp suffering from “sinking disease”, including *P. aurigonosa* and streptococci (Yasumoto *et al*., 2021). *Trichodina mutablis* (a protozoan) and *Dactylogyrus* sp. (gill fluke) may not be primary causes of mortality, but can heavily infest ill fish or those kept in poor environments (Kritsky and Heckmann, 2002). Fish lice (*Argulus* spp.) can infect fish, even when kept in ponds considered within the recommended range of water quality by veterinarians (Mayer *et al.*, 2013), and can be effectively treated with lufenuron. Importations of live fishes from non-EU countries should be issued with aquatic animal health certification, pertaining to the supplying country’s disease status. These certificates require inspection within 72 hours of loading, with no clinical signs of disease, and must originate from a country or area which is free of KHVD (among other notifiable diseases), or be subject to quarantine. Importers are required to demonstrate a biosecurity measures plan.

The incidence of internal tumours (neoplasia) in koi carp, examined in Switzerland (belonging to 353 keepers), was affected by husbandry (Knüsel *et al.*, 2015). Higher risks were associated with indoor/outdoor systems (rather than indoor only), larger ponds (although this may be conflated with larger, more expensive fish being more likely to receive veterinary attention), keeping more than 20 koi carp per pond and increased use of praziquantel, formalin/malachite green and potassium permanganate.

The search term “koi carp” and “pain” yielded a single result (Harms *et al.*, 2005), which investigated behaviour as an indicator of post-surgery pain (and the efficacy of analgesia provided intra-operatively). These indicators included general activity level (caudal-fin beat rate), speed of response to feeding (visually orienting towards and consuming pellets of food) and vertical position in the water column. Studies citing Harms *et al.* (2005) included an experiment comparing two opioid analgesics in koi

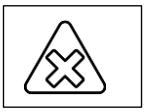
carp (Baker *et al.*, 2013), which expanded on these behavioural measures, to include “percentage of time fish performed swimming movements in a 2 minute period”, interactive behaviour (orienting towards an observer and food pellet) and hiding behaviour, as well as food consumption and position in the water. Guidelines for the evaluation of pain in koi carp, outside the experimental surgical setting, are lacking. The use of computer vision (using visual images to detect abnormal behaviour in real time) is still experimental (Hümmer *et al.*, 2019), but can identify group behaviour patterns, such as shoaling, feeding, resting, mobbing and hiding.

e) Nutrition

Vijayagopal *et al.* (2015) investigated the suitability of diets for koi carp, because commercially available diets were not formulated or based on scientific literature on the nutritional requirements of these fish. They specifically investigated the optimum protein (marine protein and soy flour) levels for 150mg koi carp fry, in terms of growth (over 12 weeks) and whole-body fatty acid and amino-acid composition. Diets containing 400-450g protein/kg increased growth rate, compared with diets containing only 250-350g/kg (Vijayagopal *et al.*, 2015). The administration of sodium propionate to koi carp is improved by the use of gelatine micro- and nano-particles, as indicated by several immune system parameters (Sarkheil *et al.*, 2021). Vitamin E supplementation enhanced growth, fertilisation
and hatching (Betsy *et al.*, 2021).

Summary: Koi carp, *Cyprinus rubrofuscus*

- There is some evidence that koi carp are more domesticated (suitable for living around humans) than common carp and they may choose to interact with humans, if handled appropriately.



- The factors which are detrimental to welfare in transport of common carp are likely to also be relevant to koi carp; water quality, handling stress, aggression and food restriction, and mitigation of these requires more research.
- Strategies to manage “shoot carp” (i.e., grading) are harmful and may be ineffective. Adequate stocking density and food availability is important to reduce aggression.
- Use of tranquilisers, which reduce the ability to respond to stressors, may harm welfare and fail to reduce behavioural signs of distress; more evidence is needed.
- Viral diseases, such as koi herpesvirus, are threats to welfare and cause mass mortality, as well as persistent, latent infections. Therefore, improvements in biosecurity are fundamental to improving conditions for koi carp in the pet trade.

- No assessments on the welfare of koi carp in private ownership were found.

Key resources

Standing Committee of the European Convention for the Protection of Animals kept for Farming Purposes, 2005).
Biosecurity and the ornamental fish trade: A stakeholder perspective in England (Wood *et al.*, 2022).

4.0. Reptiles

The reptiles covered in this review are: Ball (royal) pythons, *Pythion regius*, Burmese pythons, *Python bivittatus*, bearded dragons, *Pogona* spp., chameleons, Family Chamaeleonidae, corn snakes, *Pantherophis guttatus*, garter snakes, *Thamnophis* spp., green iguanas, *Iguana iguana*, tegus, *Salvator* spp., and tortoises, *Testudo* spp.

Captive reptiles are often considered as a coherent group and statements about their welfare made at the level of Class (Moszuti *et al*., 2017; Whitehead *et al.*, 2018). Some broad issues are covered, which are common to several reptile species, and then descriptions are given of what is known for the key species targeted in this review. Human health concerns (zoonoses), relating to reptiles as pets, are included in Appendix 1.

The RSPCA commissioned research into the motivations of beginner reptile owners (White and Barber, 2017). The motivation for acquisition of a reptile varied across the key age groups defined by the research, and included media influence (children), a change in lifestyle to becoming able to keep a pet that they had always wanted (20-30s) and being left a pet by a friend or relative that was no longer wanted. Common reasons to give up a reptile included relationship break-up, death of the owner and cost of keeping. Being passed between owners is cited in the RSPCA study as a risk factor for owners being ill-informed about the animals' histories and needs. Reptiles can be considered easy-to-maintain, hardy pets, which are suitable for people who do not have the space or time to commit to a traditional pet. Respondents felt that they had a lack of information about signs of illness, found information inconsistent (when online sources varied) and agreed that signs of ill-health in reptiles could be difficult to spot; they can look well when they are not.

Onekind (2016) produced a report investigating online adverts of pet reptiles, and whilst this review focusses only on published evidence of welfare harms, it is easily evident from online sales sites that unreliable information is abundantly available. Animals are sold privately as "second hand" rather than going through rehoming centres, thereby missing the benefit of health checks and behavioural evaluations to ensure successful placement (limited evidence from sales sites is given in Appendices 1 and 2).

Warwick (2014) made a strong case against the keeping of reptiles in captivity. Crucially, the severe spatial restriction inherent in keeping reptiles in vivaria is directly responsible for stress-related poor welfare and behavioural expression of this lack of consideration for their behavioural needs. Information available at UK pet stores to reptile owners was reviewed (Williams and Jackson, 2016), highlighting a

lack of information about humidity (62% gave no information about humidity requirements and UV light (no seller recommended using a UV light for snakes, only 35% for leopard geckos, *Eublepharis macularius*, and 80% for bearded dragons)). Although sellers sometimes recommended buying a UV bulb, no further information about the right type of bulb and the need to check and replace them was given.

a) Behaviour

Assessment of new animal-based welfare indicators is made harder by the lack of existing valid, repeatable, and objective indicators against which to validate them. Therefore, testing the preference and the importance of the preference to the individual (Broom, 1988) may be a suitable solution. There is a widely held expectation that it is normal for snakes to be sedentary in captivity (Azevedo *et al.*, 2021) based on the assertion that they are only active in the wild to obtain food, but no longer have the need to explore if their food is provided. In other captive animals, it is acknowledged that providing food, without also providing for the behavioural need to forage, has a harmful effect on welfare (e.g., in parrots, van Zeeland *et al.*, 2013).

On the contrary, Spain *et al*. (2020a) make the argument that the Madagascar giant hognose snake, *Leioheterodon madagascariensis*, is morphologically adapted to root through leaf litter for prey, and therefore that burrowing is an important part of its behaviour. Behaviours indicating negative and positive effects in reptiles are listed in Warwick *et al.* (2013), based on Warwick (1995). Behavioural indicators of affective state are not well understood, e.g., Augustine *et al.* (2022) investigated “rate of tongue-flicking” as a putative welfare indicator in snakes, based on the premise that this behaviour is associated with increased alertness, which is energetically costly.

There are few experimental studies, which have evaluated the change in behaviour in reptiles after a change in environment or exposure to novelty (Bashaw *et al.*, 2016; Moszuti *et al*., 2017; Londoño *et al.*, 2018; Spain *et al*., 2020b; Hoehfurtner *et al.*, 2021; Hollandt *et al*., 2021).

b) Veterinary care

The use of standardised questionnaires to collect an individual reptile's history is recommended (Mitchell, 2010), but the collection of a detailed history from owners may be thwarted by the causal acquisition of animals over the internet and where individuals have had multiple previous owners, despite the necessity for owners to record and/ or remember detailed relevant information about the reptile's current and previous living circumstances. The use of appropriate restraint is important to avoid injury to veterinary staff as well as the reptiles and their owners. Physical examination can be carried out following a checklist, but abnormalities can be missed by those not familiar with the species they are handling. Access to veterinary services for those owning exotic pets is an issue identified a study in the Republic of Ireland, which compared owners of exotic pets (32 respondents) with other types of pet (83 respondents) (Goins and Hanlon, 2021a, 2021b). Only 50% of exotic pet owners consulted a vet in 2019. Comparable figures were not provided for other domestic species, however the PDSA "Pet animal wellbeing" report stated that in the same year, 78% of dog owners and 61% of cat owners said their pet had regular booster vaccines (implying at least annual veterinary health checks) (PDSA, 2019).

In a review of diagnosis and management of disorders of the digestive system (Mans, 2013), plain radiographs were of limited use, and contrast radiography is recommended, although barium sulphate is associated with significant risks and iodinated contrast media should not be administrated to dehydrated animals. Ultrasonography can be a useful tool in the detection of ileus (a condition in which the intestines do not move correctly), with a possible risk of misdiagnosis due to the slow transit time of the normal reptile gastro-intestinal (GI) tract. Disorders of the periodontal cavity may be more amenable to diagnosis by less specialised veterinary surgeons, and prevalence of dental disease is around 50% in UK bearded dragons (Mott *et al.,* 2021). Inappropriate diet (containing fruit), over- and underweight animals, and poor husbandry are identified as the main risk factors for dental disease. The high prevalence of dental disease in bearded dragons (cf. UK dog population (12.5% prevalence of disease in a study of 22,333 dogs (O'Neill *et al.*, 2021)) is related to poor husbandry

4.1. Squamates

4.1.1. **Ball (royal) pythons**

Warwick (2014) raises the following concerns about the welfare of *Python regius* kept as pets. Ball pythons are nocturnal/crepuscular and particularly subject to photo-invasive environmental stress. They require complex naturalistic environments, and consideration of the following: space, temperature, chemical cues in the artificial environment, diet and nutrition, handling stress, veterinary medical issues, captivity-stress-related behavioural problems, interaction with transparent boundaries, hyperactivity, hypoactivity, disposition-related voluntary hypothermia, social stress, and behaviour-related self-injury and disease. No studies were identified, which measured transport stress in this species. The absence of information about the welfare of wild-caught and ranched snakes is highlighted by Green *et al.* (2020).

a) Capture or breeding

Two recent reviews have been published on the topic of ball python welfare (D'Cruze *et al.*, 2020; Green *et al.*, 2020). The welfare of ball pythons at expositions around Europe and North America, including one in Doncaster, UK (28 vendors selling 427 snakes) demonstrate a general failure to meet RSPCA standards (adequacy of mobility/space, shelter, water, substrate and hygiene), but it is not clear how the UK vendor ranks (D'Cruze *et al.*, 2020). Ball pythons, kept as pets, are imported from West Africa, where they are farmed for the pet trade or "ranched" (eggs are taken from the wild and hatched on farms (Green *et al.*, 2020)).

b) Behaviour

FBH (2014) provides broad guidelines for owners to assess the welfare of their animals. The authors recognise that information available on the internet is not always reliable and updated and recommends the source "Reptile & Amphibian Information Portal: http://www.raaip.org.uk" as "constantly kept under review by a panel of experts and updated as appropriate". Unfortunately, this site no longer exists; searching for "Reptile & Amphibian Information Portal" did not find this source. The good practice guidelines (FBH, 2014) advise owners to watch for the following signs:

“They may hide away, refuse to feed, become restless, aggressive or lose their normal colouration. There may also be direct signs of illness, such as swellings, discharge, breathing difficulty, diarrhoea, sores, weight loss or gain, sensitivity or constipation or problems with dysecdysis (skin-shedding).”
“Behaviour problems can include persistent aggression, escape behaviour (e.g., snout-rubbing), repetitive behaviour and lethargy.”

The size of housing for ball pythons, which may live up to 20 years, is a source of debate. The RSPCA care sheet states “A royal python needs a vivarium which allows it to fully stretch out.”(RSPCA, 2019b). The lack of published evidence, describing how snakes experience their captive environment, is highlighted in a review of evidence for reptile sentience (Lambert *et al*., 2019).

c) Conditions in commercial premises

A rack system is often used for pythons, with shelves and bins arranged as drawers (Hollandt *et al*., 2021), with heat provided in the form of pads or cables. This system is usually sparse and contain a hiding place and water bowl, with newspaper, rodent litter or bark mulch as litter. They may also contain artificial plants, tree branches and a basin to provide the opportunity for bathing. There is concern from experts that this set-up does not provide for the full behavioural repertoire of pythons, e.g., hiding in various places, climbing, burrowing and lack of adequate light provision. Where opportunities are provided in a terrarium, bathing, basking and climbing were expressed by ball pythons (Hollandt *et al.*, 2021). In contrast, racks may increase feeding, and therefore growth and earlier reproduction. The rack system was associated with greater abnormal behaviour (pushing the mouth against a barrier) and more time resting in the hiding place than in a terrarium. The behaviour “resting outside of the hiding place, stretched out” tended to be more common in terraria. Ten snakes in the rack system pressed their snouts against the rack system and appear to try and widen them using burrowing movements. This behaviour was not displayed when they were returned to terraria after the experiment. No difference in feed refusal was found between housing systems. Therefore, it is concluded that the rack system is not appropriate housing (Hollandt *et al.*, 2021).

d) Nutrition

Pythons may refuse to eat dead prey and therefore feeding of live rodents is the only alternative (Hollandt *et al.*, 2021). No other articles on nutrition of ball pythons were found.

e) Health and disease

Evidence of insufficient hygiene and litter standards is prevalent in videos of ball pythons in commercial premises (D'Cruze *et al.*, 2020). A large exotic pet breeder in Texas, USA was investigated in 2013 and the conditions were found to be catastrophic (Ashley *et al.*, 2014), with extremely high levels of mortality ("3,500 deceased or moribund animals (12% of stock), mostly reptiles, were discarded on a weekly basis") associated with improper housing and husbandry, (deaths in snakes were due to trauma, caused by overcrowding, crushing, fighting, damage due to improper handling and cannibalism), infections, dehydration, emaciation, and hypothermic stress.

This "spider head shake" is a genetic disorder of the central nervous system, which occurs in "spider ball snakes" as a consequence of selection for their colouring. Rose *et al.* (2014) reviewed the evidence for welfare costs associated with uncontrolled muscle spasms and muscle weakness, which occur due to this condition, particularly around feeding. The review concludes that although this is perceived as frustrating and uncomfortable, more research is needed to understand the experience of snakes affected by this condition. However, "freedom from disease" is a central component of animal welfare and relevant to welfare legislation protecting animals from suffering.

Ball pythons appeared in two studies relevant to their emotional experience, but welfare assessment did not investigate this (one study of "wobble" syndrome concluded that this deformity was likely to be frustrating for "spider morph" snakes (Rose and Williams, 2014)). Not being able to perform a motivated behaviour, such as feeding, could be defined in a functional sense as frustration, but it is not known if these snakes suffer associated mental distress. The second example uses delayed feeding as an indicator of pain (James *et al.*, 2017). The treatments, which provoked this behaviour (chemical noxious stimulus or surgical incision), are known to activate

pain pathways in afferent nerves (C-fibres), and surgical incisions, which cause tissue damage in tissue supplied by afferent nerves, are a recognised source of pain.

4.1.2. **Burmese pythons**

The Web of Science search found only two relevant articles on Burmese pythons, *Python bivittatus*; a report on mites in pet Burmese pythons in Malaysia (Mariana *et al.*, 2011) and evidence for a positive effect of UVB radiation over 10 months in a zoo population (Ouwehand Zoo, Netherlands) on vitamin D-3 synthesis (Bos *et al.,* 2018). In the Journal of Exotic Pet Medicine, Burmese pythons are mentioned in the articles “Selected infectious diseases of wild reptiles and amphibians”, (Schumacher, 2006b) and “Urinary tract diseases of reptiles” (Reavill and Schmidt, 2010).

Inclusion body disease is associated with high morbidity and mortality in captive snakes. The symptoms of this disease in pythons are neurological (incoordination, failure to right themselves from dorsal recumbency) and are incurable. The route of transmission and aetiological agent are not completely clear, although the snake mite, *Ophionyssus natricis*, is considered a vector (Schumacher, 2006a). Ophidian paramyxovirus (OPMV) is present in captive boid snakes, but may be asymptomatic. Symptoms include loss of appetite, respiratory tract disease and, in extreme cases, seizures. Transmission is likely via respiratory secretions and no treatment is available.

Information on welfare of pet Burmese pythons was not evident in the literature, although these animals are available for sale online (see Appendix 2). Changes in circumstances and no longer having space are reasons cited for selling Burmese pythons. The welfare impact of relinquishment/ changes in ownership over the lifespan of these pythons has not been studied.

4.1.3. **Bearded dragons**

a) Breeding

Bearded dragons, *Pogona* spp., in the UK are bred in captivity and breeders import animals from Europe and the USA (e.g., “dragonmorphs.co.uk”). Siviter *et al*. (2019) found that hot-incubated bearded dragons had slower growth, but were faster at

completing a cognitive task and completed it more often than cold-incubated bearded dragons. The hot- and cold-incubated bearded dragons were placed in novel-object and novel-environment tests, and there was no consistent difference in behaviour according to treatment (Siviter *et al.*, 2017).

b) Transport and handling

No literature was found on the welfare of bearded dragons in commercial settings or in transport. To evaluate the effect of handling duration on the welfare of bearded dragons, three conditions were tested in 13 captive-bred lizards, including less than one minute transfer between rooms, five or fifteen minutes of gentle, calm handling by an experienced handler over a period of four days per week for three weeks (Stockley *et al*., 2020). In a subsequent novel-environment test, bearded dragons which had been handled for 15 minutes demonstrated more tongue flicks than those that were carried for < 1 minute. Minimally handled animals also spent more time close to a novel object than those handled for five minutes, while the 15-minute treatment was intermediate. The authors referred to previous studies of bearded dragons in novel-object and novel-environment tests (Moszuti *et al.*, 2017; Siviter *et al.*, 2017) and concluded that their results (more tongue flicks, less time close to the novel object) indicated aversive or anxiety-like responses to handling (Stockley *et al.*, 2020), despite neither of the former studies demonstrating an association between behaviour in the test arena and any other measure of stress or affective state. The lack of validation between measures so far limits the use of novel-object or enrichment tests, or tongue-flicking as indicators of anxiety in bearded dragons. However, tongue-touching could be used to indicate bearded dragon's sensitivity to changes in their environment (individuals may increase or decrease in their responsiveness to novelty according to health or energy status), or to assess the effectiveness of an enrichment item in stimulating exploration.

c) Behaviour

To assess response to novelty as a possible marker of anxious or fearful personality, bearded dragons were presented with a novel or a familiar environment (different substrates: bubble wrap or saw-dust and different wall patterns were used as contextual cues). Behavioural responses to novelty included locomotion, elimination, latency to approach the novel object and reptile-specific measures, such as "tongue-

flicks directed into the air (air-flicks) and tongue-flicks making direct contact with a surface (tongue-touches)". Bearded dragons performed more tongue-touches in the novel compared with familiar environment, but the same number of air-flicks (Moszuti *et al*., 2017). Tongue-flicking in response to a change in environment is an exploratory behaviour, used to sample chemicals from the environment (Cooper, 1994). This behaviour did not correlate with other measures of response to novelty (latency to move, defaecation).

d) Housing requirements

Vergneau-Grosset and Péron (2020) reviewed the effect of UVB light exposure on vertebrates. In contrast with results for other vertebrates, artificial UVB lights enhanced vitamin D production in bearded dragons to a greater extent than natural sunlight (Kroenlem *et al.*, 2011). However, a short lapse in UVB provision is unlikely to be harmful for adults, because the concentration of calcidiol and calcitriol can remain stable for over two months without UVB exposure (Oonincx *et al.*, 2013). UBV exposure is more effective than oral vitamin D3 supplementation in increasing plasma calcidiol, but low serum calcidiol and calcitriol promote the consumption of vitamin-D-rich foods by bearded dragons (Oonincx *et al.*, 2010).

e) Health and Disease

A review of mortality in 36 bearded dragons necropsied at pathology facilities in New York, USA (Crouch *et al.*, 2021) described the most common causes of death as inflammatory (69%) and chronic/degenerative (47%) (N.B. multiple causes were counted in more than one category). Common findings included systemic illness, such as coelomitis and bacterial sepsis, chronic liver disease and hepatitis, pneumonia and chronic nephritis. Crouch *et al.* (2021) did not evaluate the causes of disease. A review of cases presented to a university diagnostic imaging department (Lublin, Poland) found that most bearded dragons were presented for physical changes, deformities, weight loss and inappetence. It is likely that skeletal and coelomic presentations are most commonly represented here because more superficial conditions would not require imaging, but the prevalence of musculosketal injuries (29.33%), both traumatic and developmental deformities, suggests poor bone strength is an issue in this population (Łojszczyk-Szczepaniak *et al.*, 2018).

Moszuti *et al.* (2020) and Gimmel *et al.* (2017) identified choleliths as surprisingly commonly found at necropsy in Germany, which may indicate an increasing trend.

Nutritional secondary hyperparathyroism is common in reptiles in North America and calcium metabolism is also a common cause of constipation due to the role of calcium in gut movement (Wright, 2008). Analysis of bearded dragon clinical cases in Austria and Hungary identified parasitism as a common contributor to gastrointestinal disease, “In 51.92% of the cases of constipation, endoparasites were present, whereas in 38.46% of the cases of constipation, metabolic bone diseases and imbalances in calcium and phosphorus levels were detected”. No similar large case reviews were found in the UK bearded dragon population (Schmidt-Ukaj *et al.*, 2017).

4.1.4. **Chameleons, Family Chamaeleonidae**

There is no “RSPCA Care Sheet” for chameleons, nor AZA (Association of Zoos and Aquariums) animal care manual nor EAZA best practice guidelines. Breeding in captivity is described as relatively easy and successful in veiled chameleons, *Chamaeleo calyptratus* (Diaz *et al.*, 2015), compared with other reptiles within a laboratory setting.

a) Housing requirements

UVB is recommended for panther chameleons (*Furcifer pardalis*); the optimum levels have been defined in terms of reproductive success (290–315 nm), and due to their ability to self-regulate exposure to UVB depending on their vitamin D status, a gradient is recommended (Watson and Mitchell, 2014). Short exposure to high irradiation was not found to be equivalent to longer exposures at mid-low UVB light levels (5–15 mW/cm^2) (Ferguson *et al.*, 2002). A study of UVB lights in a Hungarian veterinary journal, “Magyar Allatorvosok Lapja” (abstract available in English) stated that popular brands of UVB lights, labelled as effective for one year, lost 50% of their irradiation by the 14th week (Nikoletta and István, 2018).

b) Nutrition

Metabolic bone disease can occur due to nutritional deficiencies in vitamin D, vitamin A and calcium, and prevention involves provision of long-low UVB exposure (3–

120 μW/cm$^{2\ 10h/d}$), feeding of insects, gut-loaded with 12% Ca and dusted with 75mg/kg vitamin A and 0.625mg/kg cholecalciferol (Hoby *et al.*, 2010).

c) Health and disease

Infectious diseases reported in chameleons include viruses: Novel herpesvirus (Hellebuyck *et al.*, 2021); iridovirus (Weinmann *et al.*, 2007); ranavirus (Peiffer *et al.*, 2019), endoparasites (nematodes, (Orós *et al.*, 2002); trematodes, (Collicutt *et al.*, 2017); ascarids, (Reitl *et al.*, 2021)), are mostly single-case reports. A study of *Chamaeleomyces granulomatis* fungi in veiled chameleons (*Chamaeleo calyptratus*) in a zoo in Germany suggested this disease is common and fatal (Schmidt *et al.*, 2012), but the route of infection was not established. Parasitic infections in captive chameleons are described as common and guidance on treatment is provided (Stahl, 1997, USA), but no recent reviews on the prevalence of infectious disease in UK captive chameleons were found. Antibiotic resistant *Salmonella* can be isolated from captive veiled chameleons (Barazorda Romero *et al.*, 2015).

d) Mortality

In a study of captive reptile mortality rates in the home (Robinson *et al.*, 2015), a figure of 28.2% mortality within the first year of acquisition was found for chameleons. This figure was a result of randomised-response technique and direct questioning, rather than directly acquired from records and the two methods did not differ significantly in their results. The direct questioning method included the question: “Of the X that you acquired over the last five years, how many died within 12 months of acquisition” and was posed to a sample of attendants at two large meetings for reptile breeders. The breeders also responded to the survey that, based on their own experience, chameleons were “very difficult/ difficult to keep” (41% of respondents), compared to 28.2% rating them easy/ very easy to keep. Panther chameleons have a short lifespan in the wild (less than one year, (Andreone *et al*., 2005), and, therefore in this specific case, the figure of 28.2% chameleons dying within a year of acquisition may not truly reflect poor husbandry. Labord’s chameleon (*Furcifer labordi*) is short-lived; 4-9 months in the wild (Eckhardt *et al*., 2017).

4.1.5. **Corn snake**

Corn snakes, *Pantherophis guttatus*, were the most relinquished snake to the SSPCA (2016- 2020). However, few health, welfare or behaviour issues were reported in the literature.

a) Behaviour

Corn sakes are solitary in the wild and can be kept as single pets. Environmental complexity (beyond the standard enclosure, which contained a rock/cave hide and newspaper substrate and a small water-bowl) increased active behaviour in a study of 15 adult corn snakes, which showed a significant preference for an enriched vs. standard side of an enclosure (Hoehfurtner *et al.*, 2021). A clear preference is also demonstrated for larger enclosures, in which snakes can fully stretch out compared with an enclosure only 2/3 their length. (Hoehfurtner *et al.*, 2021). Corn snakes are obligate carnivores and captive adult snakes are fed on dead (fresh, or frozen and thawed) rats and mice.

b) Health and Disease

A case report of *Kalicephalus* hookworm infection was reported in four corn snakes in the USA (Matt *et al.*, 2020) and a single case of arteriosclerosis, leading to arterial rupture and acute death in a corn snake (*P. guttatus guttatus*), was diagnosed also at a North American veterinary clinic (Zellar *et al*., 2019). No other articles in the Journal of Exotic Pet Medicine concerned the health and welfare of corn snakes specifically. Only five articles resulted from the Web of Science search (including Matt *et al.* (2020)), which may suggest that despite their popularity, pet corn snakes are not regularly presented to veterinarians for health problems.

4.1.6. **Garter snakes**

The RSPCA produces a care sheet for pet garter snakes, *Thamnophis* spp. Garter snakes are diurnal, highly active and non-venomous (RSPCA, 2019a). Captive garter snakes have smaller heads than wild snakes, which limits their ability to catch prey and survive if released into the wild (Ryerson, 2020). Captive garter snake welfare in the UK was not represented in any search results in Web of Science.

Corticosterone can be assayed as a biomarker of stress, which increases immediately after handling in garter snakes, particularly in wild-caught snakes (Aldridge and Arackal, 2005) and was shown to differ in populations from different locations, with the stress response decreasing in older snakes (Gangloff *et al.*, 2017). Snakes collected at different times of year also differ in their glucocorticoid levels (Dayger and Lutterschmidt, 2016). Corticosteroid is not repeatable over time within individuals, and not shown to correlate with heterophil to lymphocyte ratio (a common measure of white blood cell stress response (Sparkman *et al.*, 2014)).

4.1.7. **Green iguanas**

Faecal metabolites of cortisol reflect the level of stress experienced in captive green iguanas, *Iguana iguana*, and this is increased by handling and living in an environment, which does not provide them with the opportunity to climb (Kalliokoski *et al.*, 2012).

Most studies fall into the category “health and disease”, but most conditions have a link to poor husbandry, which are commonly nutritional deficiencies. In common with other captive reptiles, green iguanas suffer from metabolic bone disease. The condition may not be diagnosed until it is severe and difficult to reverse, therefore Zotti *et al.* (2011) developed methods to improve diagnosis, using radiography to analyse bone density. Similarly, novel methods to monitor metabolic disease (plasma protein electrophoresis) were successfully trialled. This technique was more effective in hepatic and renal disease than skin disease, since the systemic diseases were more likely to result in a decrease in albumin:globulin ratio (Knotkova *et al.*, 2019).

Treatment of cryptospirosis can be achieved using potentiated sulphonamides or halofunginone. However, both groups were administered intravenous fluids and hyperimmune bovine colostrum. Therefore, to avoid euthanasia due to the pathology caused by cryptosporidium, intensive in-patient care may be required (Gałęcki and Sokół, 2018). Skin diseases are often caused by poor husbandry, including hypovitaminosis A and systemic disease, which result in protein loss (hypoproteinaemia), but the underlying causes of common conditions such as dysecdysis (problems with skin shedding) are not fully understood. A variety of

infectious causes are described, although since the normal skin flora are not well characterised, diagnosing the underlying cause is challenging (Hellebuyck *et al.*, 2012). (Brown *et al.*, 2006) concluded that mycoplasmas (*Mycoplasma iguanae*) are unlikely to be primary pathogens in green iguanas and may normally colonise the respiratory tract. Green iguanas are also presented to vets due to burns (from inappropriate heat or light fixtures) and trauma. Management of common emergency presentations, including dystocia, renal failure, sepsis, dyspnoea, gastrointestinal foreign bodies, cloacal prolapse and toxicosis, are described by Wellehan and Gunkel (2004), although a recent indication of the prevalence of these conditions was not found.

4.1.8. **Tegus (tegu lizards)**

Tegus, *Salvator* spp., are large, South American lizards, which are available to buy online (e.g., www.bluelizardreptiles.co.uk) and on rehoming sites. However, the Web of Science search yielded only two studies with relevance to their care. Cury de Barros *et al.* (2010) conducted a laboratory study, which concluded that larger, adult tegus were more aggressive than smaller (juvenile) tegus and that at lower temperatures small lizards showed escape behaviour, whereas large lizards stayed inactive in a defensive posture. The second study describes the treatment of malaria (*Plasmodium*) infection with potentiated sulphonamide antibiotics. However, these animals were living in Brazil and malaria is not endemic in the UK.

Three articles in the Journal of Exotic Pet Medicine specifically mentioned tegus in the title, two of which were single animal-case reports (multicentric lymphoma, Saldanha *et al.* (2021) and isolation of antibiotic-resistant *Salmonella*, Giacopello *et al.* (2012)). Recommendations for sedation and pain relief (antinociception) of *Salvator merianae* are given based on a prospective, crossover, randomized study in six captive lizards (Bisetto *et al*., 2018). An abstract from the American Journal of Veterinary Research (Leal, 2017) was found, which evaluated morphine and butorphanol on limb-withdrawal in tegus, concluding that mu agonists provided “antinociception”. The diagnosis of gastrointestinal foreign bodies in reptiles was illustrated by a case of a perforating foreign body (wooden material from the enclosure) in a red tegu, *Salvator rufescens* (Mans, 2013).

In a general article describing reptile dermatological conditions, poxvirus is identified as infecting caimans, Family Alligatoridae, and tegus (Hoppmann and Barron, 2007). Lesions can be diagnosed on histopathology and do not require treatment unless secondary infection is present.

Care guides are not published on the AZA, EAZA and RSPCA websites, and owners are likely to rely on internet sources. Care sheets are provided by hobbyist websites, such as Reptiles magazine: Tegu Lizard Housing and Care Information, Reptiles Lounge, Repitlinks and Reptifiles (summarised in Appendix 3).

Reptifiles website provides the most detailed and extensive “shopping list” of equipment required, including UVB lamp, dual lamp fixture with reflector, LED bar, ceiling mount ceramic socket, halogen heat bulb, flagstone for basking, temperature and hygrometers. The approximate cost of buying (without the tegu or food) is estimated at $2,600, although this can be reduced if the enclosure is hand-made. In addition, guidance for inspecting tegus before buying them includes an eleven-point health check.

Information given by hobbyist websites is inconsistent regarding advice on housing tegus socially, e.g., Reptiles lounge: “Their social skills allow them to cohabitate in one enclosure. The only thing you need is to double everything for two and increase accordingly as you add a tegu”, Reptilinks: “Blue tegus may not play well with others, be extremely careful not to keep two males together. If not breeding, keep two females with plenty of space.”, Reptifiles: “Tegus are perfectly happy living alone. Female and female pairs or male and male pairs can be housed together (although individual personalities mean cohabitation won’t always work).”. Only Reptifiles provided any information on enrichment and included more information about potential negative behaviour, including advice that tegus can be trained (to an extent), can run on two legs, can jump almost a metre straight up, go through a “puberty” like adolescent phase during which they are “thoroughly unpleasant to deal with” and even a tame, adult tegu will bite/scratch/ tail whip, if scared or threatened.

No evidence was available on the extent to which inappropriate rearing, or variation in amenity to “taming” creates problems for tegus, in terms of aggression, anxiety,

injuries, stress-related behaviour problems, lack of exercise opportunities and/or relinquishment.

Another area of concern highlighted by this guidance is the heat, light and exercise requirements of these lizards, which may be possible to fulfil in some areas of the USA where they are popular pets, but exercise outside, and/ or exposure to direct natural sunlight in addition to artificial UVA/UVB and LED lights is important for their welfare. Weather conditions in Scotland may not be appropriate to fulfil this need.

Summary: Snakes and lizards

- Relinquishment of reptiles with long lifespans is likely to affect their welfare. Even if the reptile's health and welfare is not the cause of rehoming, it is likely they are not sold to new owners with the level of oversight and information to ensure a successful placement. Following reptiles across their lives is a challenging avenue for research, but more longitudinal studies may help to formulate regulations for the keeping of reptiles (such as record-keeping and checking in with veterinarians), to ensure that long-term harm is not caused unwittingly.

- For all snakes, pythons especially, housing in small tanks does not represent the opportunity to display a full range of normal behaviours, but the lack of evidence on the welfare effects of confinement (e.g., rates of obesity, activity budgets) results in a lack of awareness of what "normal" should look like.

Tegus

- The success of "taming" tegu lizards is likely to be critical to their successful keeping, and the incidence of aggression is not known.
- The climate in Scotland may not be suitable to provide suitable levels of natural sunlight for tegus to supplement artificial sources. Given their size, enclosures, which provide sufficient heat, artificial light and UVB, but also opportunities for exercise and exploration, are likely to extremely difficult to provide.

- There was very little expert advice or published evidence of pet tegu welfare.

Chameleons

- Detailed knowledge on dietary needs for vitamins and minerals, effective heat, light and UVB for commonly kept reptiles may already be sufficient to prevent deficiencies (or excesses), but owners need to be well informed and fastidious about monitoring conditions.

- Chameleons seem to be at a particular risk of premature mortality in the home, which requires more investigation, but natural lifespans must be accounted for.

Key resources (squamates)

Emergent diseases in reptiles (Wellehan and Gunkel, 2004)
Effect of ultraviolet radiation on vertebrate animals: Update from ethological and medical perspectives (Vergneau-Grosset and Péron, 2020)
Good Practice Guidelines for the welfare of privately kept reptiles and amphibians (FBH, 2014)
Royal python care sheet (RSPCA, 2019)
Garter snake care sheet (RSPCA, 2019)
Corn snake care sheet (RSPCA, 2019)
Bearded dragon care sheet (RSPCA, 2019).

4.2. Testudines (tortoises)

4.2.1. **Hermann's tortoise, *Testudo hermannii***

In the UK, only captive-bred tortoises are legal to keep as pets. A research article from Slovenia (Dovc *et al.*, 2021) on improving the success rate of hatching healthy *T. hermannii* examined the causes of embryonic mortality, finding that after infertility, infection was the most common finding (52.5%), and infectious agents were: *Pseudomonas aeruginosa, Bacillus* sp.*, Purpureocillium lilacinum,* and *Escherichia coli.*

a) Behaviour

Males should be housed singly due to territorial aggression. In captivity, a commonly reported undesirable behaviour is "excessive courtship", involving sexual and aggressive behaviour directed towards other tortoises. Endoscopic removal of the testicles (orchiectomy) was demonstrated to reduce this behaviour to the extent that tortoises could be housed in groups in 59% of cases (Hatt *et al.*, 2019). In eastern Hermann's tortoises, *Testudo hermannii boettgeri*, shell colour was found to predict personality; darker shell patterns were associated with more aggression and boldness in male tortoises (Mafli *et al.*, 2011).

b) Housing requirements

Natural sunlight is important to maintain plasma vitamin D and avoid calcium deficiency. Although Selleri and Di Girolamo (2012) found sunlight to be more effective than mercury-vapour or fluorescent lamps, in the absence of natural sunlight alternative UVB sources, such as those used for other reptiles, could be investigated. A review of the welfare of pet tortoises in Germany was quite optimistic, reflecting owners with a good understanding of the needs of their animals. Most provided the optimum diet and housing (over 75% provided a greenhouse or cold frame with an outdoor enclosure) (Bauer *et al*., 2019).

c) Nutrition

German tortoise owners mostly provided a good diet (approximately 68% of owners fed a diet, consisting of more than 80% grasses and weeds over summer) (Bauer *et al*., 2019). Reliable dietary information for owners is available at: www.thetortoisetable.org.uk (Roberts *et al.*, 2017) . Both inadequate grass/ weeds and tortoises restricted to a terrarium were at higher risk of pyramidal growth syndrome (Bauer *et al.,* 2019). Morin and Priymenko (2018) suggested that owners require more information on appropriate diets for tortoises, as current recommendations only consider selecting foods with an appropriate mineral balance. Optimum levels of vitamin supplementation were tested and over-supplementation of vitamin E, K, B1, B2, B6 and B12 and biotin, combined with less vitamin D was demonstrated to be detrimental to shell strength. The most successful of the two diets contained 50 000 IU/kg vitamin D and both diets contained similar amounts of calcium (Hetenyi *et al.*, 2014).

d) Health and disease

Protozoal infections can severely affect captive tortoises, and the diagnosis and treatment of the key pathogens (amoebae, ciliates, flagellates, coccidia and apicomplexans) are described by Bardi *et al*., 2019) . Amoebae infections, in particular, can lead to chronic diarrhoea and dehydration with a poor prognosis. The most effective prevention for protozoal disease is hygiene and biosecurity. Oxyurid nematodes have a very high prevalence in pet tortoises (43.18%) compared with protozoa such as amoebae (0.005%) (Hallinger *et al.*, 2018).

Investigation of a disease in juvenile tortoises, which has symptoms including soft shells and skeletal deformity, stunted growth and abnormalities affecting multiple organs (including the liver and kidney), found that a picornavirus was responsible; more research is needed into this newly characterised virus (Heuser *et al.*, 2014). Tortoises were included in a veterinary article advising treatment of chelonians as in-patients (Norton, 2005) and the successful application of a novel technique for tissue repair was reported (radio electric asymmetric conveyer (REAC)) (Rinaldi *et al.*, 2013).

Summary: Tortoises, Testudines

- Although the welfare of pet tortoises in the UK has not been surveyed recently, results from Germany suggest a recent trend towards improved conditions and suggest it is possible for owners in a similar climate to provide tortoises with a healthy lifestyle.

- Further directions for research, which would benefit pet tortoises include investigating whether owners have adequate information on parasite control, provision of UVB and nutrient requirements.

Key resources

Occurrence of health-compromising protozoan and helminth infections in tortoises kept as pet animals in Germany (Bardi *et al.*, 2019).

Nutrition and husbandry conditions of Palearctic tortoises (*Testudo* spp.) in captivity. (Bauer *et al.*, 2019).

The Tortoise Table (Roberts *et al.*, 2017).

5.0 Amphibians

Michaels *et al*. (2014) and Burghardt (2013) draw attention to a lack of research into the behavioural responses of amphibians to captive conditions and appropriate environmental enrichment. Shelter provision increased growth rate in Túngara frogs (*Engystomops pustulosus*) and substrate was preferred if the frogs could dig (Walsh and Downie, 2005). Since this review was published, a study on enrichment in African clawed frogs, *Xenopus laevis*, (Ramos and Ortiz-Díez, 2021) was conducted,

and these frogs showed a preference for artificial plants (preferred over plastic pipes, and clear space), which supports the findings of Michaels *et al.* (2014), in finding that plants improve the welfare of red-eyed tree frogs, *Agalychnis callidryas*, (growth rate, diversity of gut bacteria) and that tree frogs show a preference for plants, especially when deprived of access to plants before the choice test.

5.1. **Alpine newt**

The wild introduced population of alpine newts, *Ichthyosaura alpestris*, estimated using photos of alpine newts on social media, is small in Scotland (eight photos identified in total (Allain *et al*., 2021). No papers were found on the welfare of pet alpine newts.

a) Breeding

Alpine newt larvae are very sensitive to UVB radiation and therefore unlikely to survive in shallow water due to the effect of direct sunlight (Nagl and Hofer, 1997).

b) Health and disease

In wild amphibia, pathogenic fungi, such as *Batrachochytrium dendrobatidis*, can deplete wild populations and have been detected in some newt species in Germany (Ohst *et al*., 2013). *Batrachochytrium salamandrivorans* has caused fatalities in amphibian populations in Europe (in the Netherlands and Belgium). According to a recent paper (Allain and Lynn, 2021), no cases of *B. salamandrivorans* have yet been reported in wild alpine newts in the UK (Cunningham *et al.*, 2019), but it has been found in a collection of captive newts at the Zoological Society of London (no species information given; Cunningham *et al.* (2015)). These pathogens are a serious threat to captive and native wildlife, and the use of single-use plastic gloves is necessary to avoid transferring *B. dendrobatidis* between animals (Thomas *et al.*, 2020).

5.2. **Argentinian horned frog, *Ceratophrys ornata***

There were no results on WoS for “Argentinian horned frog” and of the results for “*Ceratophrys ornata*”, four articles were relevant for amphibia in captivity or interaction with humans (Secor, 2005; Trudeau *et al.*, 2010, 2016; Deutsch *et al.*, 2021). There are several common names for this type of frog; searching “ornate

horned frog" and "pac-man frog" each identified one additional paper; a metabolic study of estivation (Groom *et al*., 2013) and isolation of an unusual *Brucella* variant (Soler-Lloréns *et al.*, 2016). The terms "South American horned frog" and "Argentine wide-mouthed frog" did not yield any relevant results.

a) Capture and breedings

Deutsch *et al.* (2021) investigated the impact of the pet trade on local (Argentine) horned frog populations. In Argentina, Uruguay and Brazil, people who had had contact with the species mostly had negative attitudes towards *C. ornata* and those with negative attitudes felt so strongly that most (67%) killed the frog when they encountered it. Most frogs owned as pets in this region of South America were wild caught, with the rest mainly from unlicensed breeders or a university facility. Only one licensed breeder of *C. ornata* was found in Argentina.

Trudeau *et al.* (2010) tested a new commercial product for the hormonal manipulation of reproduction in captive frogs, finding a potential benefit to welfare using injectable hormones, which required only one injection per individual, reducing handling stress compared with other methods.

b) Nutrition

Secor (2005) conducted an experimental study of the process of aestivation. This is a process by which *C. ornata* can reduce gut activity during periods without food, and then when fed (rodent meals), they upregulate nutrient absorption, gut mass and intestinal transport rates.

5.3. **Fire-bellied toads, *Bombina* spp.**

A contributing factor to this toad's negative reputation in its native environment and likely unsuitability as a conventional "pet" is the secretion of a toxin, which causes skin irritation in humans (see Appendix 1).

a) Housing requirements

The fire-bellied toad may require UVB in addition to dietary calcium and vitamin D, to achieve optimum skeletal structure. UVB light was demonstrated to enhance serum D3 (Michaels *et al.*, 2015). Although there is a lack of information about metabolic

bone disease in the pet population, provision of UVB light may be important for the husbandry of this toad.

b) Health and disease

As with alpine newts, *B. dendrobatidis* is a risk to health in fire-bellied toads. The prevalence of this pathogen was reviewed by Berger *et al.* (2016). Options for treatment are given in Martel *et al.* (2011).

The understanding of analgesia and anaesthesia is not as far developed in amphibia compared with other animals, and several studies reviewed effective anaesthetics for fire-bellied toads (d'Ovidio *et al.*, 2015; Adami *et al*., 2016a, 2016b).

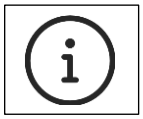
5.4. **Tree frogs, Family Hylidae**

No relevant search results for pet tree frogs were found in the UK or countries with similar pet-keeping practices. No publications were found describing the captive conditions, welfare in transport, handling stress, husbandry, nutrition, incidence of metabolic disease and social behaviour of privately owned tree frogs.

Infectious disease studies were non-UK based, including the detection of ranavirus in a green tree frog (*Litoria caerulea*) in a zoo in Thailand (Pirarat *et al*., 2016).

Summary: Anurans

- Enrichment for amphibians should include plants and shelter, but the behavioural assessment of welfare requires more attention to understand where normal behaviour is suppressed, or abnormal behaviour is expressed.



- *Batrachochytrium* fungi are a threat to wild and pet amphibians.
- There is an absence of scientific literature relating to the reviewed species of frogs and toads in captivity in Scotland. Most studies relate to laboratory conditions.
- The species' requirements for UVB should be established before sufficient information is available to allow responsible pet ownership, otherwise it is possible that anurans are routinely suffering from metabolic disease.

Key resources

The importance of enrichment for advancing amphibian welfare and conservation goals: A review of a neglected topic (Michaels *et al.*, 2014).

Impacts of UVB provision and dietary calcium content on serum vitamin D-3, growth rates, skeletal structure and coloration in captive Oriental fire-bellied toads (*Bombina orientalis*) (Michaels *et al.*, 2015).

6.0. Invertebrates

6.1. **Cephalopods**

The category "cephalopods" includes around 700 living species (Sykes et al., 2017). In Scotland, the main use of cephalopods is for food, which are wild-caught from the northeast Atlantic. Cephalopod culture (captive breeding) is not undertaken around Scotland (Pierce *et al.*, 2010). Publications in cephalopod welfare in captivity are a result of recent concern about the experience of invertebrates in research (Horvath *et al.*, 2013), including the COST Action CephsInAction (FA1301—

http://www.cephsinaction.org/) and Cooke *et al.* (2019). The recognition of cephalopod cognitive abilities and their appreciation by the public for impressive demonstrations of cognitive ability has spurred interest in the suitability of captive environments to fulfil their welfare needs (Mather, 2022).

No cephalopods have been used in animal experiments in the UK in recent years (Speaking of Research, 2020), but since cephalopods kept as pets may be sourced from a similar route as those used in research, information on the welfare of cephalopods in breeding and trade are included here.

a) Breeding

Commercially breeding cephalopods is limited due to high mortality, including massive mortality events of juveniles (Morales *et al.*, 2017), which are linked to difficulties in providing adequate nutrition (Navarro *et al*., 2014).

b) Housing requirements

Several recent reviews explain the health and welfare implications of keeping cephalopods (Jerez-Cepa and Ruiz-Jarabo, 2021) for research and aquaculture (Chancellor *et al.*, 2020). There is a focus on European cuttlefish (*Sepia officinalis*) and the use of cephalopods in research (Fiorito *et al.*, 2015). Husbandry procedures must take into account the fragile nature of cephalopod skin, which is easy to injure, and secondary infections can be fatal. Evidence for traumatic injury, as a consequence of hitting tank walls or fighting, and their mitigation (including softer tank walls, altering sex ratios and decreasing stocking density to reduce aggression) are described in Sykes *et al.* (2019). Noise levels in the laboratory setting can cause acoustic damage (damaged hair cells) in cuttlefish (Sole *et al.*, 2017), and the levels identified as potentially harmful (low frequency sounds up to 400Hz) may inform husbandry in the domestic setting, such as the placement of aquaria near to white goods.

The concept of stress in cephalopods is not new and the National Resource Center for Cephalopods (USA) published guidance (Oestmann *et al.*, 1997) outlining water quality parameters for cuttlefish (*Sepia officinalis*) and squid (*Sepioteuthis lessoniana*) bred for experimental use, particularly with the aim of keeping healthy populations despite the need for transport. The report includes guidance on housing

and handling, identification, common health conditions and their treatments, feeding and the appropriate stocking density to avoid aggression. The use of intramuscular injections should be avoided when antibiotics can be administered in food. Beyond aggression, behavioural signs of illness, such as “changes in chromatophore display patterns or in orientation to other animals in the tank”, may require careful observation by people familiar with the species and individuals. Minimally invasive sampling from the skin surface is an alternative means of assessing stress.

Since no evidence of conditions for pet cephalopods in Scotland was found, an evaluation of the adequacy of water quality in the domestic setting is not known. However, guidelines developed for laboratory animals are available to owners; optimum water quality is defined in Fiorito *et al.* (2015) and recommendations for seawater filtering systems are available (Hanlon *et al.,* 1991). The effect of copper concentration or contamination on health and welfare needs more research (Sykes *et al.*, 2019).

c) Nutrition

The lack of a defined processed diet is identified as a limitation in the successful husbandry of cephalopods (Oestmann *et al.*, 1997). On a simple level, cephalopods’ requirement for protein is high (for *Octopus maya*, nutritional requirements are 80-86% protein, (García-Garrido *et al.*, 2013), requiring live prey from the time they use up larval yolk supplies (Fuentes and Iglesias, 2001; Morales *et al.*, 2017). Octopus larvae require closely balanced amino acids and balanced fatty acid profiles (Navarro *et al.*, 2014). *Octopus vulgaris* has a low ability to digest neutral lipids, which are found in high quantities in sardines, Family Clupeidae (Quintana *et al.*, 2015). Octopus paralarvae fed with *Artemia* enriched with marine phospholipids had better growth at 12 days and survival at 28 days compared with those fed *Artemia* enriched with phytoplankton (Morales *et al.*, 2017).

The Caribbean octopus, *O. americanus*, is easier to feed, because it will accept thawed food (Bastos *et al.*, 2021). High-temperature processing of food makes it less digestible and specialist processing (lyophilisation) and the development of pelleted diets for commercially farmed cephalopods is still under development (Bastos *et al.*, 2021). Live feeding of “feeder fish” have the disadvantages of creating large

quantities of waste material, which needs to be cleaned out of the tank, is inefficient, toxic metals (copper) can be introduced, and there are ethical concerns around the welfare of the fish and decapods being used as food. However, frozen prey may be more effective sources of environmental enrichment than pelleted food.

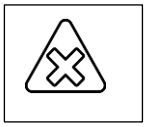
Malnutrition or under-feeding during rearing can weaken cuttlefish cuttlebones and leave them susceptible to fracture. More research on appropriate nutrition for juveniles, especially calcium and magnesium deposition, would elucidate the role early nutrition plays in the development of fractures (Sykes *et al.*, 2017) .

d) Health and disease

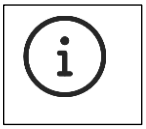
The development of appropriate anaesthetics for cephalopods is a recent (but see (Culloty and Mulvahy, 1992) focus of research, particularly in relation to surgical procedures carried out on experimental animals (Goncalves *et al.*, 2012; Polese *et al.,* 2014; Lopes *et al.*, 2017; Escanez *et al.*, 2018; Wellehan *et al.*, 2020).

Summary: Cephalopods

- Feeding cephalopods is challenging due to their high requirement for appropriate protein, and live feeding live poses issues for the welfare of feeder fish and decapods, and for water quality.



- Farmed and laboratory cephalopods face many challenges to their welfare; they are vulnerable to stress and injury in captive conditions.



- More research is needed into whether the social and behavioural needs of pet cephalopods are being met.

Key resources

Invertebrate welfare: an overlooked issue (Horvath *et al.*, 2013)

Aquarium Maintenance Related Diseases (Sykes *et al.*, 2019)

6.2. **Decapods**

The importance of decapod welfare is a current issue in animal welfare and veterinary medicine, and the legislation to establish the UK Animal Sentience Committee recognised sentience in cephalopods and decapod crustaceans Animal Welfare (Sentience) Bill [HL] - Parliamentary Bills - UK Parliament (BVA, 2021). However, their ownership as pets is not evident in published literature. Although live decapods (such as shrimps, crabs and lobsters) can be sold over the internet in the UK (Source: Crustacean Compassion), these are largely intended for cooking rather than pets.

The WoS search results included evidence on some basic principles of decapod welfare in relation to crustaceans traded for meat (Fossati, 2019), which are briefly described here.

a) Capture

Factors contributing towards mortality in capture (becoming tangled in fishing nets) were analysed in a case study at a Hawaiian Kona crab, *Ranina ranina,* fishery (Wiley *et al.*, 2020). After injury, crabs were transported to a laboratory to assess the consequential level of mortality. An entire limb being pulled off (due to getting trapped in a net), increased mortality almost eight-fold compared with a limb being cut cleanly off. Crabs taken out of the water and exposed to direct sunlight for two hours had a 16.7% risk of mortality.

b) Transport and handling

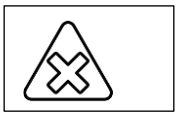
Lorenzon *et al.* (2008) measured a panel of potential biomarkers, which could indicate harmful physiological effects of transport: “glucose, lactate, total protein cholesterol, triglycerides, chloride and calcium concentrations, pH, haemolymph density, and total haemocyte count (THC)”. Transport in air was found to be less disturbing than transport in water, and lactate concentrations remained high in both treatments, suggesting exertion and energy depletion.

The welfare of decapod crustaceans in transport involves a number of physiological processes, which must adapt to artificial conditions, causing weakened ability to deal with disease challenges, and failure to cope with acute stressors may increase mortality. These factors, explained in detail in Lorenzon (2008), are briefly:

- Starvation prior to transport, leading to depletion of energy stores (including protein catabolism)
- Low oxygen and high ammonia concentrations (both exacerbated by high stocking densities)
- Emersion and air exposure, gill drying
- Temperature changes
- Handling
- Interactions with other animals
- Reduced total haematocyte concentration, leading to immunosuppression

In the green shore crab, *Carcinus maenas*, all of the handling techniques assessed in a laboratory study (gentle transfer in containers without physical touching, 10 minutes emersion or 10 minutes emersion with shaking (Wilson *et al.*, 2021)), resulted in physiological stress responses. Useful indicators of transport stress were identified (oxygen consumption, haemolymph glucose and L-lactate), and these increased in proportion to the severity of the handling procedures. Oxygen consumption can remain high for 14 hours after transport, and the greatest increases are found in crabs, which are physically touched or shaken, with emersion (removal from water) being a lesser factor.

Summary: Decapods



- Capture and transport are stressful to decapods and can cause severe injury. Air transport may be a less disturbing method of transport than water transport.
- Buying crabs as pets (e.g., hermit crabs) is evidently possible due to their listing on UK sales websites, but evidence of their welfare as pets is not published.
- "Cleaner shrimps" are also commonly purchased for aquaria but their welfare is so far overlooked.

Key resources

Crustaceans and snails as food and new challenges for ensuring ethical behavior toward invertebrates (Fossati, 2019)

Effects of handling during experimental procedures on stress indices in the green shore crab, *Carcinus maenas* (Wilson *et al.*, 2021)

Stress effect of two different transport systems on the physiological profiles of the crab *Cancer pagurus* (Lorenzon *et al.* (2008)

6.3. **‘Tarantulas’, Family Theraphosidae**

The EAZA Terrestrial Invertebrate TAG produces best practice guides for the Montserrat tarantula, *Cyrtopholis femoralis* (Garcia *et al.*, 2021), which outlines some unknown factors about this tarantula’s normal biology (such as lifespan, diet, seasonality and clutch size). Key factors to provide in captivity are appropriate substrate for burrowing and high humidity. Veterinary care articles are available online, although original sources of evidence are not cited (Netisingha, 2019). Housing requirements include enclosures, which allow for climbing, are quiet and not too bright, and water dishes must be shallow to avoid drowning. Reichling and Gutzke (1998) describe the effect of temperature and feeding on size, and a Web of Science search did not reveal any information relating to the welfare of pet tarantulas at any stage in their life in captivity.

Summary: Tarantulas, Family Theraphosidae

- Guidance on husbandry is available to owners for the Montserrat tarantula, *Cyrtopholis femoralis,* which has apparently quite simple needs, but more investigation of its normal behaviour in a more complex or wild environment is warranted.

- No additional information on tarantulas from WoS or veterinary journals was found.

Key resources

Best Practice Guidelines for the Montserrat arantula (*Cyrtopholis femoralis*) (Garcia *et al.*, 2021)
When your pet has eight legs (Netisingha, 2019).

Conclusion

The published evidence for the welfare of exotic pets in Scotland has mostly been collected on animals in zoos and laboratories, or from farmed fishes, cephalopods and decapods. Data on health and disease in pet animals are mostly individual case reports in veterinary clinics. However, more investigation and reviews have been carried out, where behavioural problems occur in commonly kept species (e.g., African grey parrots) and are obvious and distressing to owners (e.g., aggression, feather-damaging behaviour).

The supply of exotic pets in Scotland is largely dependent on captive breeding, which is generally considered preferable to capture from the wild, as the risk of disease and parasitism is lower, the impact on wild populations is less and young can become familiar with humans at an earlier stage. The evidence assessed in this review indicates that wild-caught exotic pets are not common in Scotland, but information on the illegal wildlife trade (with a focus on conservation) may be available and is outside of the scope of this review, if studies do not analyse the welfare of the traded animals. The importation of captive-bred animals from outside the UK, which are transported long distances (especially in the case of fishes) is regulated to some degree (e.g., by IATA), but has rarely been investigated, with notable exceptions e.g., ball pythons (Green *et al.*, 2020). Captive breeding presents several risks: Lack of genetic diversity which amplifies the presence of congenital diseases (e.g., African pygmy hedgehogs, lemurs, ball pythons), dystocia (e.g., marmoset, tamarins, green iguanas), difficulty in replicating breeding environments (clownfishes) and providing for the nutritional requirements of young (e.g., macaws, clownfishes and koi carp fry).

The sources targeted in this review (mostly published papers in scientific journals and care guides developed by experts) include very few data on conditions in commercial premises, except where data are held and made available by public bodies (such as APHA and DEFRA), or investigations have been carried out by welfare organisations. Parental care of captive-bred offspring is often preferable to hand-rearing and this is well understood in primates and parrots, but in birds of prey imprinting of birds onto humans is considered important to allow training. Early

removal from parents can result in behaviours that are difficult to manage, such as loud and persistent calling for food, or aggression directed towards owners. Carnivores, which have not been domesticated, do not exhibit neoteny (retention of juvenile characteristics into adulthood) and therefore show adult behaviours, such as scent-marking, aggression and fear of humans. However, no objective assessments of the welfare of wild carnivores in private ownership were found.

Transport stress, where reported, is mostly due to restraint and can be reduced with preparation, including positive reinforcement and calm handling by familiar individuals. This is appropriate when animals travel with their owners, but not when animals are moved by courier or in mass transit (e.g., wild-caught fishes, cephalopods and decapods). Studies of the effect of human presence on stress in non-domesticated species often only happens in zoos and laboratories, although fear of humans is mentioned anecdotally in advice by hobbyist organisations on taming (e.g., birds of prey, squamates). Where it is well known that animals are not amenable to handling, or likely to benefit from interacting with humans, this is reflected in advice provided by the RSPCA.

The social needs of group-living animals may be complex and it is widely accepted that social animals should not be kept singly. In some cases the welfare of animals kept in isolation in laboratories has been assessed (e.g., African grey parrots, squirrel monkeys), whereas in others the isolation of individuals in captivity (especially males) has not been investigated (e.g. African pygmy hedgehogs, Siamese fighting fish, tegu lizards, Hermann's tortoises).

Case reports of health and disease often focus on rare and novel findings, rather than giving an overview of the prevalence of disease in the pet population. Broadly, veterinary care guides are more informative than published studies in understanding the common conditions affecting each species, but the lack of specific data means that information on what is common may not be recent or may only represent a snapshot of admissions to a single veterinary centre. Establishing links between poor husbandry or lack of understanding of the species kept as pets, as well as signs of disease and behavioural indicators of poor welfare, are frustrated by lack of data collection on the conditions in which animals are kept.

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Appendix 1: Zoonotic disease

Animals	Zoonotic disease	References
African pygmy hedgehogs	Hives (contact urticaria) Fungal skin infections - *Trycophyton erinacei* - *Trichophyton mentagrophytes* Salmonellosis - Including antibiotic resistant strains	(Rosen, 2000), (Weishaupt *et al.*, 2014) (Frantz *et al*., 2020) (Perez *et al*., 2021)
Bushbabies	*Pasteurella* B	(Christensen *et al.*, 2012)
Lemurs	Bite wounds *(*intraspecific aggression*)* *Echinococcus multiocularis* (tapeworm) Antibiotic resistance (gut microbes) *Mycobacterium tuberculosis*	(Ceccolini *et al.*, 2021) (Umhang *et al.*, 2013) (Bornbusch and Drea, 2021) (LaFleur *et al.*, 2021)
Psittacine birds	*Chlamydia psittaci*	(Ornelas-Eusebio *et al.*, 2016; Pisanu *et al.*, 2018; Gibson *et al.*, 2019; Jayson *et al.*, 2019)
Eclectus parrots	Microfilaria	(Huang *et al.*, 2017)
Harris' hawks	*Campylobacter jejuni* *Debaryomyces hansenii* (pathogenic yeast causing severe disease in immune-compromised humans)	(De Luca *et al.*, 2018) (Cafarchia *et al*., 2006).
Reptiles	Salmonellosis -pathogenic and drug-resistant - *Salmonella* isolated in 80% of reptile-owning households (Sweden)* - Increased risk due to live food** *Campylobacter*	(Weiss et al., 2011) (Lowther et al., 2011) *(Wikström et al., 2014) Kiebler et al., 2020; Zajaç et al., 2021). (Dróżdż et al., 2021) **(Marin et al., 2021) (Masila et al., 2020)
Fire-bellied toads	Toxins cause minor dermal injuries	(Harkewicz, 2004) (Forrester, 2018)

According to Health Protection Scotland, the most reported non-foodborne zoonotic organisms in Scotland 2015- 2019 were *Borrelia burgdorferi* (total 1084 cases) and pasteurellosis (1024) (Public Health Scotland, 2020). The number of *Salmonella* cases, deriving from pet reptiles, was not identified in the report. Despite the ubiquity of *Salmonella* spp. carried across a wide range of animal, which associate with

humans, serovars isolated from reptiles are suggested to be more resistant to human serum and there may be an increased risk of multi drug-resistant *Salmonella* serovars in reptiles. Resistant isolates belong mostly to the subspecies *S. enterica enterica*.

Appendix 1 References

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Appendix 2: Selected information from websites selling reptiles and amphibians

Ball pythons

Advice on enclosure size recommends vivarium sizes that do not allow snakes to fully extend:

- "You are best providing your snake with a vivarium or terrarium that is roughly just over half their size in length" ("Swell Reptiles", reptiles.swelluk.com).

The congenital neurological condition "spider wobble" may be perceived as normal.

- "Great snake eats and does everything as he should… He does have the typical spider head shake at feeding time" (Ball python for sale in Scotland (as of 28/02/22) on "Morph Market").

On the sales site, "Morph market", with adverts from across Europe, including 16 Scottish locations, 18,206 ball pythons were available for sale (28/02/2022). Ball pythons on this website are traded chiefly on the basis of their colour (under the heading "Genes and Traits"), and within the description of each individual is their sex, age (juvenile or adult) and a brief description of their diet (e.g., "live mice").

Burmese pythons

- "As the python grows it will need to be upgraded to a much bigger enclosure. A male may be okay in something aroun (sic) 7x2x2ft but females could need something even bigger", Northampton reptile centre.
- Descriptions of Burmese pythons on general purpose sales sites (Preloved and Gumtree, accessed 01/03/2022) highlight the priorities in owners' perceptions of good health and welfare are chiefly determined by feeding, defecating and shedding.
- "I've done the boring bit for you getting her to this size. She will probably hit 11ft with a sensible feeding regime, if you push the envelope with the food this girl will get VERY large". (Pets4homes)

Amphibians

- "an excellent frog to keep in captivity if you like a low maintenance and easy to care for animal", (Horned frogs, Reptiles Cymru)
- "The best breeds to start with are often the horned frog and fire salamander". (Pets at Home)

	Reptiles Magazine	Reptiles Lounge	Reptilinks	Reptifiles
Behaviour	"become puppy-dog tame, form strong bonds with their keepers, and they adapt easily to life in captivity". Handle from hatchlings. Avoid staring directly into their eyes or making sudden moves with your hands. Be gentle, calm and talk softly. Spend time together in a small room and just sit with your pet while letting it roam. [Argentinian tegus] "often become very docile when kept in a stable setting and with the attention needed", "appear to	"With constant human interaction they can be domesticated and create a bond with the handler" "**Their social skills allow them to cohabitate in one enclosure**. The only thing you need is to double everything for two and increase accordingly as you add a tegu". "When domesticated, you have the option of allowing them to freely roam about as long as the humidity and sunlight exposure is adequate".	Handle often, Argentine tegus get more docile as they get older. If not used to being handled, can become anxious and lash out… can grow to have an incredibly strong bite. Blue tegus may not play well with others, **be extremely careful not to keep two males together**. **If not breeding, keep two females with plenty of space**. Can be housetrained, red tegus particularly suited to clicker-training to drink from a water dish and toilet outside. Gold tegus harder to domesticate, use	Can be trained (to an extent), can run on two legs, can jump almost 3-straight up. Go through "puberty" like adolescence… "thoroughly unpleasant to deal with". Even a tame, adult tegu will bite/scratch/ tail whip if scared or threatened. Wild-caught tegus are difficult to tame and more likely to harbour parasites and disease. Argentine tegus are calm and easy to tame. Tupinambis (Colombian) tegus more defensive but can be tamed. Tegus are perfectly happy living alone. **Female and female pairs or male and male pairs can be housed together** (although individual personalities mean

	seek human attention and thrive more when kept in a caring environment".		thick mitts or gloves when handling.	cohabitation won't always work).
Nutrition	Ominivorous Hatchlings: insects dusted in calcium. Adults: whole frozen/thawed rodents, lean meat, fish, eggs, fruit and vegetation. Vary the diet, and mix ingredients to encourage eating vegetation.	Omnivorous Diet largely composed of meaty meals with some fruits and veggies. Any raw meat: pinkie mice and boiled eggs. "Zoo menu" tegu and monitor food as a ready-to-use alternative. Red tegus need more fruit and vegetables. A full list of recommended foods is included, owners advised to ensure variety.	Omnivorous Young: mostly insects (recommends "tegu hatchling bundle", which contains ground whole prey and fruit and vegetables) High C:P ratio. Adult: cooked eggs and turkey meat, tropical fruits, "megablend" proprietary food. Special requirements for blue tegus: lean cooked meat and less fruit, ensure Ca supplements. Ground-up rabbit bones (for calcium) and quail eggs (help absorb vitamins A and D). Similar recommendations for gold tegus.	Salvator (Argentine) species are pmnivorous, Tupinambis species are carnivorous. Juveniles: 90% protein, 10% vegetables, occasional fruit. Most of diet= insects. Ault Argentine tegus: 60% protein, 30% vegetables, 10% fruit). Adult Colombian tegus (90% protein, 10% vegetables). Recommend less fruit than wild tegus eat because captive tegus are less active. **Portion size:** "about the size of the tegu's skull". Avoid obesity by sticking to a schedule and encouraging exercise.

		Prey supplemented or gut-loaded with vitamins, other food should be sprinkled with calcium and vitamin D, or rep-cal herptivite given 2x/ week.	Red tegus: more fruit compared with others.	Full list of insects (not wild caught), whole prey, meat (supplemented or dusted with calcium). Eggs and fish should be cooked. Full list of vegetables and plants including list of plants not to give. Commercial diets in addition to rotation of tegu foods. Dog and cat food can be added (canned). When whole foods are given, supplements are not required. If using non-whole food, “repashy calcium plus, arcadia earthpro A, miner-all indoor and herptivite”. Live prey is recommended.

Enclosure size (adults)	At least 6 x 3 x 3 ft, preferably 8 x 4 x 3ft.		6-8ft x 3-4ft x 3ft	8’ x 4’ x 4’ (Argentine) 6’ x 3’ x 3’ (Colombian)
UVB	UVB lighting is mandatory and vital to health (no further specifications) .	10-12 hours of natural sunlight that is not filtered or UV light. 6-month replacement cycle must be done to ensure adequate UVA/UVB	UVB bulbs recommended for gold tegus.	12-14h daily UVB, supplemented by natural sunlight when possible. Fluorescent UVB bulb of high output (specific recommendations). S. merianae categorised as “open or partial sun baskers”, all day UVI 2.6-1.0 (gradient from 2.6 to 0). Need solarmeter 6.5 to measure precise UVI.
Light	Use a 12 hours on, 12 hours light cycle or 4h on, 4h off, 4h on, 12h off.		“All the tegus need proper lighting”, especially important with gold tegus.	Heat bulbs and UVB bulb not enough to provide bright light. Arcadia jungle dawn LED bar, expensive but high output, use one or even two per enclosure to actively light at least half the length of enclosure.
Temperature	100-110F over basking spot, 90-95F at warm end, 75-80F at the cooler end.	Basking spot: 95-100F, warm area 90F, cool spot 80F.		Basking surface 125-135F, warm side 90-95F, cool side 75-85F.

	Heat lamp over basking spot,	Basking spot bulbs, incandescent lights and infrared ceramic heat emitters controlled with a thermostat. Use a thermometer to help maintain temperature.		Turn off all lighting and heat at night. To **monitor temperature, need infrared temperature gun**. Hatchlings: high wattage halogen floodlight bulb for basking spot. Adult: Series of halogen flood lights clustered together. Experiment and use **dimmer switch**
Humidity		Humidity helps tegus shed. **75%-90%.** Use damp moss or substrate Tip-proof water bowl big enough to soak in with easy entry and exit **Misting also helps keep humidity optimum.**	Mist the substrate as needed to maintain the recommended humidity level, but the substrate shouldn't be "overly saturated". Provide a secure screen top and/or vents but avoid too much airflow. "Experiment a little to get things just right".	70-80% Mix water into substrate until uniformly moist (weekly). Mist enclosure (pressure sprayer). Provide cool, humid hide box with damp moss. **Track using digital hygrometer** (one for warm side, one for cool side). Include pool large enough for body

				and tail to fit inside.
Substrate	Cypress mulch, coconut coir or a sand and soil mixture. Depth of about 4” for hatchling, 8” for adults. Not “over dusty or resinous” substrates,	Cypress mulch, coconut fiber. Substrate must allow them to dig/ excavate.		Mix of 40% organic topsoil, 40% reptisoil, 20% play sand. Bio Dude terra firma Reptichip (mulched coconut shell), less dusty than coconut fiber. Cypress mulch (layered on sand/soil mix) 12-24’ depth at least on one side of enclosure
Enrichment		Hide big enough for them to move about inside freely.		“**Minimalistic setups are horribly boring for your pet and do nothing to keep them entertained or make them feel secure**”. Ensure you let them **free-roam regularly** for enrichment and exercise. Hide box/ cave Large water tub Thick substrate

				Large logs/ branches **Live or artificial plants** (live plants **require planning** so not destroyed, artificial plants must be durable, **not placed under heat source and low/ no VOC**). Toys: leaves, boxes, hang whole fruit from the ceiling, hidden food, live insect/ bird/ mammal prey, puzzle balls, rearrange “furniture”, newspaper balls, snake sheds, tunnels.

Appendix 3. Varying information about behaviour and husbandry of tegu lizards available on four websites which were listed as the top search results for “Tegu care guide”

This publication is available at **www.gov.scot**

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