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Review

Are the key welfare models effective for exotic pet animals?

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Abstract
The Five Freedoms, Five Domains, Five Welfare Needs, and other similar models or principles, are key aspirational or outcome-led frameworks aimed at safeguarding animals under human custodianship, and are widely used in legislation, guidance documents, and protocols. We aimed to investigate the effectiveness of these animal welfare models as intended protections. Our study considered three informational tiers of relevance for guidance: Tier 1, key welfare models and principles governing legislation; Tier 2, formal secondary guidance; and Tier 3, welfare outcomes. We conducted a literature review of key welfare models, as well as reports of persistent animal welfare problems associated with exotic pets, and collated available examples of relevant legislation and their implementation. Of the 91 studied regions that adopted animal welfare models, the following were directly or closely aligned with: Five Freedoms n = 64, Five Welfare Needs n = 26, Five Domains n = 1. We identified the following numbers of welfare concerns for animals kept in trade and private home situations: invertebrates n = 21, fishes n = 27, amphibians n = 26, reptiles n = 43, birds n = 22, mammals n = 43. Despite the frequent adoption of one or other model or principle, animal welfare concerns and problems were regularly identified in relation to both commercial and home environments across all animal classes. We recommend that animal welfare is assigned priority over traditional pet selling or keeping practices through the adoption of modernised animal welfare models, underpinned by evolving scientific knowledge and precautionary principles, that aim to promote animal-centric preferred life quality.

Keywords Five Freedoms · Five Domains · Five Welfare Needs · Exotic pet · Companion animal · Wild animal · Animal welfare

1 Introduction

The Five Freedoms [1], Five Domains [2], Five Welfare Needs [3], and other models, such as the three ethical concerns (Freedom, Feelings & Function) [4], are key established, influential, aspirational or outcome-led approaches aimed at safeguarding welfare for animals under human custodianship [1–7]. Animal welfare models are used by governments and legal frameworks (e.g., [8, 9]), teaching (e.g., [10]), husbandry guidance documents (e.g., [8]), other protocols (e.g., [11, 12]), and policy statements (e.g., [13]). Relatedly, a recent major investigation into the Five Freedoms and their impact on farm livestock in The Netherlands concluded that the model is out of date with modern welfare science, and that legislative improvements are required to include more positive and holistic outcomes for animals [14].

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For this report we summarise key animal welfare models and examine available materials regarding the management of pet invertebrates, fishes, amphibians, reptiles, birds, and mammals within pet commercial and home environments. This project aims to review the application of animal welfare models within the exotic pet sector, and, in particular, to consider how effectively the Five Freedoms, Five Domains, Five Welfare Needs and other key animal welfare principles serve exotic pet welfare. Relatedly, our study aims to examine three tiers of relevance: key welfare models and principles that are used by governments and other formal legislators (Tier 1), availability of formal secondary guidance that interprets welfare models and principles to instruct specific obligatory husbandry practices (Tier 2), and welfare outcomes to estimate the possible effectiveness or otherwise (e.g., benefits or disbenefits to animal welfare) of their application in both commercial and private home situations (Tier 3).

Throughout, we have adopted a precautionary principle, which allows for presumption in favour of animal welfare where evidence is lacking [15, 16]. For example, the precautionary principle is increasingly applied across a breadth of reasonable situations, such as sentience and welfare [17–20], development of positive lists regarding species for trade and keeping [15, 21, 22], biodiversity conservation [23, 24], public health protection [16], and is otherwise enshrined in related national and international legislation [15–17, 19, 21–23]. Accordingly, the precautionary principle is a permissive, rather than prohibitive, approach that seeks to provide pre-emptive safeguards and alternatives to prospective bans.

1.1 Animal welfare models

The following sections summarise the key animal welfare models as well as other welfare principles. Whilst the historical introduction of the models follows the Five Freedoms (1979), three ethical concerns (1997), Five Welfare Needs (2005), Five Domains (2015, 2020), the arrangement herein will vary according to chronological development and frequency of citation or use where relevantly discussed.

1.1.1 Five Freedoms

The Five Freedoms model (Table 1) was published in 1979, to offer a concise foundation for animal welfare protections [1]. Since then, the Five Freedoms have been incorporated into many welfare provisions, laws, guidance documents, and assessment protocols.

Table 1 Five Freedoms

Freedom	Provision
1. Freedom from hunger and thirst	By ready access to fresh water and a diet to maintain full health and vigour
2. Freedom from discomfort	By providing an appropriate environment including shelter and a comfortable resting area
3. Freedom from pain, injury, or disease	By preventing animals from getting ill or injured and by making sure animals are diagnosed and treated rapidly
4. Freedom to express normal behaviour	By providing sufficient space, proper facilities, and company of the animal's own kind
5. Freedom from fear and distress	By ensuring conditions and treatment, which avoid mental suffering

Derived from [1, 6]

1.1.2 Five Domains

The Five Domains model (Table 2) was published in 2015 [2], and updated in 2020 [25] to include behavioural interactions with the environment, other (non-human) animals, and humans (Domain number 4), and was designed to provide robust assessment not only against conditions with negative welfare implications, but also to promote positive welfare states, including feelings [2, 5]. The Five Domains in part refines the basis of the Five Freedoms to produce a model that focuses on specific criteria including nutrition, environment and health, and is aimed at achieving positive affective states with the overarching principle of securing 'a life worth living' for all animals [7, 26].

Table 2 Five Welfare Domains

Physical/Functional Domains							
Survival-related factors						Situation-related factors	
1. Nutrition		2. Environment		3. Health		4. Behaviour	
Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
Restricted water & food; poor food quality	Enough water & food; balanced and varied diet	Uncomfortable or unpleasant physical features of environment	Physical environment comfortable or pleasant	Disease, injury and/or functional impairment	Healthy, fit and/or uninjured	Behavioural expression restricted	Able to express rewarding behaviours
Affective Experience Domains							
5. Mental State							
Negative experiences				Positive experiences			
Thirst Hunger Malnutrition Malaise Chilling/overheating Hearing discomfort	Breathlessness Pain Debility Weakness Nausea Sickness Dizziness	Anger Frustration Boredom Helplessness Loneliness Depression Anxiety Fearfulness Panic Exhaustion		Drinking pleasures Taste pleasures Chewing pleasures Satiety Physical comforts	Vigor of good health & fitness Reward Goal-directed engagement	Calmness In control Affectionate sociability Maternally rewarded Excited playfulness Sexually gratified	
Welfare Status							

Reproduced from [7]

1.1.3 Five Welfare Needs

The Five Welfare Needs model (Table 3) was published in 2005, and proposed to provide enhanced protections above the Five Freedoms to raise welfare quality protection principles from aspirational to outcome-led [3].

Table 3 Five Welfare Needs

1. Need for a suitable environment
2. Need for a suitable diet
3. Need to be able to exhibit normal behaviour patterns
4. Need to be housed with, or apart, from other animals
5. Need to be protected from pain, suffering, injury, and disease

Derived from [3]

1.1.4 Three ethical concerns

The three ethical concerns (Freedom, Feelings & Function) model (Table 4) was published in 1997 [4]. Development of the Three Fs resulted from an investigation of three commonly expressed ethical concerns and concepts regarding quality of life for animals, notably what freedoms it has, how it feels, and how it functions.

Table 4 Three ethical concerns (Freedom, Feelings & Function)

1. Freedom: that animals should lead natural lives through the development and use of their natural adaptations and capabilities
2. Feelings: that animals should feel well by being free from prolonged and intense fear, pain, and other negative states, and by experiencing normal pleasures
3. Function: that animals should function well, in the sense of satisfactory health, growth and normal functioning of physiological and behavioural systems

Derived from [4]

1.1.5 Other welfare principles

The key models described above present various structured protocols designed for assessing, improving, or securing animal welfare. However, numerous other scientific principles have been conceived that offer standalone criteria that do not present as specifically described models, but are in use nonetheless (Table 5).

Table 5 Summary examples of other animal welfare principles or models

Principle/Model	Summary description	Sources
Human-centric (caretaker responsibility-led)		
Quality of life	Implies human presumptive assessment of animals and outcomes probably consistent with good welfare	[27]
Controlled deprivation	Controlled deprivation recognises that regardless of enrichment, captive animals probably experience inferior conditions when compared to nature. Essentially, even the best captive conditions equate to a basic "life-support system" rather than meeting holistic biological needs	[28]
Positive and negative states	The promotion of positive states (favourable feelings, stimulation, pleasure, comfort, quiescence, good mental, emotional and physical health, good welfare) and avoidance of negative states (thwarting of positive states, stress, pain, suffering, understimulation, unfavourable stimulation and poor welfare)	[7]
Our control, our responsibility	In nature, animals have control over their own welfare, whereas in captivity, humans are in control of their welfare and thus hold high responsibility	[29]
One Welfare, One Biology	A paradigm in which environment, animals, and people are considered interconnectedly	[30–32]
Crypto-overcrowding	The inability for all animals in an enclosure to simultaneously use any facility or furnishing. For example, all animals must be able to occupy a water vessel or basking site at the same time	[33]
Animal-centric (choice-led based free will of animals)		
Motivation and preference	The ability to express preferences—to choose according to motivation. For example, habitat selection or performing exploratory behaviours	[34]
Control over environment	Welfare is linked to the animal's control over its interactions with the environment and, thus, homeostasis and survival. Animals lacking control over their environment frequently develop a raft of negative states, including stereotypies, aggression, sedentarism, learned helplessness, hyperactivity, exploratory and escape activities, stress, immunosuppression, and disease	[34, 35]
Sentience	Sentience recognises and embraces the capacity to perceive and feel subjectively, including positive, neutral and negative experiences (such as pleasure, enjoyment, rest, pain, and suffering), as well as to experience consciousness and self-awareness. Potentially relevant to all animals	[20, 29, 36–43]
If it leaves, does it come back?	If opening the cage door results in the animal leaving and returning, then captive conditions and welfare may be favourable (or is it merely dependent on basic provisions?). If the animal does not return, then welfare may be unfavourable	[44]

1.2 Pet trading and keeping

The keeping of animals as pets or companions has a history extending at least 17,000 years [45], although in recent decades the trading and keeping of both wild and domesticated species has increased dramatically to include at least 13,000, almost exclusively exotic (wild, non-native, non-traditional, or non-domesticated) forms [46]. Despite various models aimed at ameliorating problems pertinent to the trading and keeping of exotic pets, major animal welfare issues have long persisted, and even multiplied (e.g., [13, 44, 46–73]).

From the literature, it is clear that there are significant welfare issues regarding exotic pets, and a general lack of knowledge of, or disregard for, their needs. For example, a survey of knowledge regarding reptiles among 50 pet shop managers in the United Kingdom found that information generally was highly limited, and only 8% of staff were able to advise on signs of ill health indicators [74]. Despite general commercial availability and keeping of diverse species, for many animals with highly specialised needs, acceptable care is considered to be rare [13]. A survey within the British veterinary profession found that 81% of practitioners expressed concern that the welfare needs of exotic pets were not being met, with 58% of animals not having their Five Welfare Needs provided [75]. In particular, the survey found that of the Five Welfare Needs, respondents considered that the need for a suitable environment (92%), a suitable diet (85%), and protection from pain, suffering injury and disease (62%) was often not provided. Similar findings were reported from Ireland, where it was found that over 80% of veterinarians were prepared to treat exotic pets, but both owner and veterinarian lacked knowledge of the species, as well as access to resources [76].

A study of over 26,000 animals at wholesaler facilities in the USA found a cumulative mortality for invertebrates, amphibians, reptiles, and mammals to be 72% within six weeks, which was confirmed by industry experts to be within standard mortality rates for the wholesale sector [49]. Invertebrates included scorpions, tarantulas, and millipedes; amphibians included frogs, toads, newts, salamanders, and caecilians; reptiles included freshwater turtles, tortoises, lizards, and snakes; and mammals included hedgehogs, hamsters, mice, rats, prairie dogs, spotted squirrels, guinea pigs, short-tailed opossums, flying squirrels, chinchillas, wallabies, sloths, kinkajous, coatimundis, lemurs, and agoutis. Scientific, veterinary, and forensic investigations determined that all 26,000 animals had suffered significant welfare problems arising from poor husbandry.

Amphibians and reptiles represent particularly serious concerns. A study of 1,533 amphibians and reptiles displayed and sold at pet expos (shows or markets) in three countries (Germany, Spain, and the United Kingdom) recorded (during one-minute observation intervals) frequent stress-related behaviours, notably: interaction with a transparent boundary 27.5%; hyperactivity 11%; hyperalertness 1.8%; rapid body movement 2.1%; flattened body posture 2.4%; head-hiding 4.6%; inflation of the body 0.5%; and other significant signs (e.g. rostral lesion) 1.0% [77]. Another study of 480 tortoise keepers in Morocco found that despite the species being indigenous, keeper knowledge about the animals was generally limited, which raised welfare concerns [78]. Furthermore, a study of pet suppliers at wildlife markets in Morocco found that over 88% of the 2,113 observed animals were kept in conditions that did not meet the Five Freedoms [79]. In Australia 251 snake owners were surveyed, revealing that less than half had enclosures large enough for snakes to fully stretch [62], which is a behaviour essential to health and welfare [33, 67, 80], that just over half used enclosure sizes consistent with elementary government guidance, and 40% failed to identify basic behaviour among their snakes [62]. A survey of knowledge among reptile pet keepers in Portugal found that whilst 68% scored very good to excellent for knowledge of behaviour, only 15% met four basic reptile care needs (temperature, lighting, diet and refuge), and 43% met two or fewer needs. In addition, behavioural indicators of captivity stress and poor welfare were regarded as normal by around 25% of respondents, which may have been attributable to the common frequency of such behaviours being misinterpreted [64]. A survey of 188 frog and turtle owners in Australia found that whilst both positive and negative welfare indicators were identified, less than 20% of owners had enclosures that met the minimum standards set out by government [81].

A review of parrot selling and keeping that considered the biological requirements of these complex birds and the basis of the Five Freedoms, concluded that, in many cases, numerous essential requirements were not being met. Unmet requirements included providing for appropriate veterinary care, sociality, normal behaviour, freedom from physical and thermal discomfort, as well as for freedom from psychological stress [82]. Another study reported owner identified problematic behaviours in birds and rabbits [83]. In the context of the provisions of the Five Freedoms, human-directed aggression by many birds (41%) and rabbits (45%) was recorded. Furthermore, 16% of bird keepers and 19% of rabbit keepers reported providing no exercise for their animals. The study also outlined other concerns, for example, fear of loud noises (birds 27%, rabbits 33%), separation anxiety (birds 15%, rabbits 19%), destructive behaviours (birds 21%, rabbits 37%), and anxious behaviours (birds 21%, rabbits 21%) [83].

A study of Malta's pet trade involving exotic amphibians, reptiles, birds and mammals, found that welfare provisions for these classes was concerning and that new and stringent protocols were required [84]. A survey of exotic pet keepers in Russia found that many supported new controls to protect animal welfare [85].

These issues are not limited to unusual exotic species; it is equally concerning that for even relatively well-known small mammals, which are subject to purportedly solid legal protections in the UK, good welfare is not well established. A study of guinea pigs in UK homes found that over 20% of these social animals were not housed with a conspecific, with overly restrictive spatial environments being common [86]. Although guinea pigs have potential lifespans of around 9 years [86], this study reported an average longevity of 4.1 years. Such deficiencies in providing for relatively well-known and common species may offer some understanding as to the implicit challenges in meeting the needs of less well understood exotic animals.

From these studies, it is clear that concerns are warranted and further investigation is justified regarding the effectiveness of *in-situ* protocols and laws, and whether such approaches are sufficiently stringent or enforceable to protect exotic animal welfare.

2 Methods

We assessed the provisions of key welfare models and principles and their prevalence in worldwide 'primary' legislation (Tier 1) by reviewing a region's Animal Welfare Act or equivalent legislation. Ascertaining the degree to which the legislation incorporated any, or any part of, a key welfare model is open to interpretation. However, we primarily based our categorisation on two criteria in particular: First, certain governments plainly state their adopted welfare model. Second, other governments describe their adopted approach to welfare by listing all or some of the identifiable criteria from a particular model, thus indicating its origins by implication. For example, where provisions reflect (e.g.) 'Freedom from cruelty and neglect', these descriptions equated to (e.g.) Five Freedom 3. In some situations, governments adapt or merge certain criteria identifiable to more than one model, in which cases the predominance of certain criteria led to categorisation.

We also undertook a limited study of international 'secondary' formal guidance (Tier 2) to ascertain the degree to which key animal welfare models, or their components, were incorporated into pet animal welfare codes and regulations. Using Google and Opera search engines (Opera where use of a virtual private network to access sites outside UK was necessary), the search terms included the specific region followed by 'government pet animal care guideline OR legislation OR regulation'; 'government pet establishment guideline OR legislation OR regulation', 'government pet store guideline OR legislation OR regulation'; 'government pet animal care legislation enclosure size dimension'. Through trial and error these terms seemed to come up with the most relevant results. Tier 2 guidance can typically be considered as distinct from Tier 1 provisions by way of its level of detail (i.e., relatively specific husbandry and other management instructions based on taxonomic class, group, or species). However, some examples of formal guidance appear to be based on limited expansions of Tier 1 information (i.e., contain some minimalistic examples of husbandry and/or refer only to a highly limited range of species). In these situations, we have categorised such information as Tier 2a.

The study included the United States, Canada, Europe (11 countries of which 10 are in the European Union), Australia, and New Zealand. For countries and regions where English is not the official language, unofficial English translations or Google translations were used. Table 6 provides summary examples of use of animal welfare models or principles by region, country, or state (see the Discussion section for more extensive information).

We conducted a literature search using Scopus and Google Scholar search engines and the terms presented in Box 1. The literature review followed the guidelines for rapid reviews [87, 88]. Materials from the animal class-specific searches were reviewed for information describing positive or negative welfare issues associated with commercial or home environments for exotic animals, and observations of images of captive conditions as described or depicted within the reviewed literature, were also performed.

We then compared model provisions and guidance *versus* the presence of reported signs consistent with negative states for animals and apparent welfare outcomes (Tier 3). In principle, if the key welfare models were serving animals well, i.e., adopted and fully implemented as functional systems, then signs of negative states or outcomes should be minimal or absent.

Box 1 Searches

Search	Search strings (since 2000)	Reports remaining after initial assessment	Reports remaining after further reading and removal of duplicates and irrelevant reports	Reports added from authors libraries
General search (i.e., re key welfare models)	Five freedoms AND animal welfare Five Domains AND animal welfare Five Welfare Needs AND animal welfare Three ethical concerns AND animal welfare Three ethical concerns AND function AND animal welfare Three ethical concerns AND feel AND animal welfare	20	13	5
Invertebrates	Scopus: (pet OR "companion animal" AND welfare AND invertebrate) (pet OR "companion animal" AND (morbidity OR mortality AND invertebrate) ("pet shop" OR "pet store" AND (morbidity OR mortality) AND invertebrate Scholar: invertebrate (pet OR "companion animal") ("pet shop" OR "pet store") home welfare mortality morbidity first 5 pages	111	17	2
Fishes	Scopus: (pet OR "companion animal" AND welfare AND fish) (pet OR "companion animal" AND (morbidity OR mortality AND fish) ("pet shop" OR "pet store" AND (morbidity OR mortality) AND fish Scholar: fish (pet OR "companion animal") ("pet shop" OR "pet store") home welfare mortality morbidity first 5 pages	122	17	1
Amphibians	Scopus: (pet OR "companion animal" AND welfare AND amphibian) (pet OR "companion animal" AND (morbidity OR mortality AND amphibian) ("pet shop" OR "pet store" AND (morbidity OR mortality) AND amphibian Scholar: amphibian (pet OR "companion animal") ("pet shop" OR "pet store") home welfare mortality morbidity first 5 pages	79	4	4
Reptiles	Scopus: (pet OR "companion animal" AND welfare AND reptile) (pet OR "companion animal" AND (morbidity OR mortality AND reptile) ("pet shop" OR "pet store" AND (morbidity OR mortality) AND reptile Scholar: reptile (pet OR "companion animal") ("pet shop" OR "pet store") home welfare mortality morbidity first 5 pages	172	6	6
Birds	Scopus: (pet OR "companion animal" AND welfare AND bird) (pet OR "companion animal" AND (morbidity OR mortality AND bird) ("pet shop" OR "pet store" AND (morbidity OR mortality) AND bird Scholar: bird (pet OR "companion animal") ("pet shop" OR "pet store") home welfare mortality morbidity first 5 pages	170	3	1

Search	Search strings (since 2000)	Reports remaining after initial assessment	Reports remaining after further reading and removal of duplicates and irrelevant reports	Reports added from authors libraries
Mammals	Scopus: (pet OR "companion animal" AND welfare AND mammal) (pet OR "companion animal" AND (morbidity OR mortality AND mammal) ("pet shop" OR "pet store" AND (morbidity OR mortality) AND mammal Scholar: mammal (pet OR "companion animal") ("pet shop" OR "pet store") home welfare mortality morbidity first 5 pages	130	14	1
Total number of relevant search reports used: 74 Total number added from authors' libraries: 20				

3 Results

3.1 Key animal welfare models and principles: global use (Tiers 1 and 2)

Table 6 provides summary examples of use of animal welfare models or principles, mainly in legal instruments, by region, country, or state in Northern America, Europe, Australasia, and globally. Of the 91 studied regions, countries, or states that adopted animal welfare models or principles in legislation, the following were directly or closely aligned with: the Five Freedoms $n = 64$, Five Welfare Needs $n = 26$, Five Domains $n = 1$, three ethical concerns $n = 0$. While prospective and likely incomplete, our search for further formal secondary husbandry regulation found 35 (out of 91) regions adopting examples of formal Tier 2 (n = 14) and similar Tier 2a (n = 21) guidance.

Table 6 Summary example use of animal welfare models or principles by region, country, or state

Region, country, or state	Primary model/principle (Tier 1)	Secondary guidance (Tier 2 or 2A)	Applicable animal	Sources
Northern America				
United States	Approximately equivalent to Five Welfare Needs 1,2,3,5 (wholesale pet dealers only) (national)	Tier 2A	Mammals, birds	[89]
Arizona, Arkansas, California, Colorado, Connecticut, Delaware, District of Columbia, Florida, Georgia, Guam, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Missouri, Montana, Nebraska, Nevada, New Hampshire, New York, North Dakota, Northern Mariana Islands, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virgin Islands, Washington, West Virginia, Wyoming	Approximately equivalent to Five Freedoms 1,2,3	Tier 2 (Oregon, Rhode Island) Tier 2A (California, Colorado, Florida, Indiana, Louisiana, Nevada, Ohio, Pennsylvania, Vermont)	The definition of 'animal' varies from State to State and is often not defined at all. Invertebrates and fishes are often excluded, and two States (Kentucky and New Mexico) also exclude reptiles and amphibians from the legislation	[90]
Alaska, Hawaii, Illinois, New Jersey, Virginia	Approximately equivalent to Five Welfare Needs 1,2,5			[90]
Maine, Puerto Rico, Wisconsin State	Approximately equivalent to Five Welfare Needs 1,2,3,5			[90]
Alabama	Approximately equivalent to Five Freedom 3			[90]
Minnesota	Approximately equivalent to Five Freedoms 1,2	Tier 2A		[90]
Mississippi, New Mexico, North Carolina	Approximately equivalent to Five Freedoms 1,3	Tier 2A (Mississippi, New Mexico)		[90]
Canada	Offence to cause unnecessary suffering to an animal (national)		'Animal or bird'	[91]
British Columbia, Newfoundland and Labrador, Nova Scotia, Yukon	Approximately equivalent to Five Freedoms 1,2,3	Tier 2A (British Columbia, Newfoundland and Labrador)	The definition of 'animal' varies between regions including undefined (British Columbia, Ontario), mammals, birds and fish (Yukon), all vertebrate classes (Newfoundland and Labrador, New Brunswick, Nova Scotia), 'domestic or wild animal living with a human as a companion and for enjoyment purposes' (Quebec), 'non-human living being with a developed nervous system' (Manitoba, Prince Edward Island), and all animals except human beings (Alberta, Saskatchewan)	[92–95]
Alberta, Manitoba, New Brunswick, Ontario, Prince Edward Island, Quebec, Saskatchewan	Approximately equivalent to Five Welfare Needs 1,2,5	Tier 2A (Manitoba, New Brunswick, Ontario, Prince Edward Island)		[96–102]

Table 6 (continued)

Region, country, or state	Primary model/principle (Tier 1)	Secondary guidance (Tier 2 or 2A)	Applicable animal	Sources
Europe				
European Union	Animals are sentient beings and welfare requirements should be provided for		Undefined	[103]
	Approximately equivalent to Five Welfare Needs 1,2,3,4,5; Five Freedoms 1,2,3,4,5		Any animal kept or intended to be kept by man in particular in his household for private enjoyment and companionship	[104]
Austria	Approximately equivalent to Five Welfare Needs 1,2,3,4,5	Tier 2	Undefined	[105]
Belgium	Approximately equivalent to Five Welfare Needs 1,2,3,5	Tier 2 (Wallanie and Flanders)	Vertebrates and certain determined invertebrates	[106]
Finland	Approximately equivalent to Five Welfare Needs 1,2,3,5	Tier 2	All animals	[107]
France	Approximately equivalent to Five Freedoms 1,2,3		Domestic animals or wild animals tamed or held in captivity	[108]
Germany	Approximately equivalent to Five Welfare Needs 1,2,3,4,5	Tier 2	Undefined	[109]
Italy	Approximately equivalent to Five Freedoms 1,2,3,4,5		Any companion animal	[110]
Spain	Approximately equivalent to Five Freedoms 1,2,3,4,5		Undefined	[111]
Sweden	Approximately equivalent to Five Welfare Needs 1,2,3,4,5	Tier 2	Animals kept by people	[112]
Switzerland	Approximately equivalent to Five Welfare Needs 1,2,3,4,5	Tier 2	Vertebrates	[113]
The Netherlands	Five Freedoms 1,2,3,4,5		Undefined	[114]
United Kingdom	Five Welfare Needs 1,2,3,4,5	Tier 2	Vertebrates	[115]
Australasia				
Australia	Five Domains 1,2,3,4,5		Undefined	[116]
Queensland	Five Freedoms 1,2,3,4,5	Tier 2	Vertebrates and invertebrates from classes Cephalopoda Malacostraca	[117]
Northern Territory	Approximately equivalent to Five Welfare Needs 1,2,5	Tier 2	Vertebrates	[118]
New South Wales, South Australia, Tasmania, Victoria, Western Australia	Approximately equivalent to Five Freedoms 1,2,3	Tier 2 (New South Wales, Victoria) Tier 2A (South and Western Australia)	Vertebrates (New South Wales and Tasmania), vertebrates excluding fish (South and Western Australia), vertebrates and decapod crustaceans (Victoria)	[119–123]
New Zealand	Approximately equivalent to Five Welfare Needs 1,2,3,5		All animal classes except certain invertebrate species (octopus, squid, crab, lobster and crayfish are included)	[124]

Table 6 (continued)

Region, country, or state	Primary model/principle (Tier 1)	Secondary guidance (Tier 2 or 2A)	Applicable animal	Sources
Global				
All regions	Five Freedoms 1,2,3,4,5		Mammal, bird, reptile, bee	[125]

See Discussion for more extensive information

3.2 Pet trading and keeping: animal welfare concerns (Tier 3)

From the literature we identified the following numbers of welfare concerns for animals kept in trade and private home situations: invertebrates $n = 21$, fishes $n = 27$, amphibians $n = 26$, reptiles $n = 43$, birds $n = 22$, mammals $n = 43$. Tables 7, 8, 9, 10, 11, 12 provide summary information regarding negative issues or concerns identified in literature.

Table 13 provides comparisons of selected basic criteria relevant to welfare *versus* formal trade husbandry guidance provided by two governments (England, United Kingdom and Queensland, Australia) that utilise the Five Freedoms and Five Welfare Needs, and that are relevant to commonly kept exotic pet animals.

Table 7 Summary example pet welfare issues or concerns identified in literature and from observation of images of captive conditions: invertebrates

Wholesale / retail conditions	Sources	Home conditions	Sources
Difficulty to keep/unanticipated or overly demanding husbandry	[13, 52]	Difficulty to keep/unanticipated or overly demanding husbandry	[13, 52]
Overly restrictive spatial conditions	[49, 66]		
Long periods in poor conditions	[49]		
Insanitary environments/poor hygiene	[49, 66]		
Inappropriate thermal and humidity provisions	[49, 66]		
Incompatible conspecifics	[49, 66]		
Co-occupant aggression	[49]		
Cannibalism	[49]		
Absent or minimal environmental enrichment	[49, 66]		
Overcrowding	[49, 66]		
Overcrowding/injuries, crushing	[49, 66]		
Injuries consistent with inhumane handling techniques	[49, 66]		
Hypothermia	[49, 66]		
Stress	[49, 66]		
Abnormal behaviours	[57]	Abnormal behaviours	[57]
Dehydration	[49]		
Starvation/emaciation	[49]		
Infection, parasitism	[49, 126, 127]		
Mortality rate 18% in 10 days (arachnids, chilopods, diplopods, crustaceans)	[49]		

Table 8 Summary example pet welfare issues or concerns identified in literature and from observation of images of captive conditions: fishes

Wholesale / retail conditions	Sources	Home conditions	Sources
Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 52, 54, 128]	Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 52, 54, 128]
Overly restrictive spatial conditions	[49, 66]		
Poor water quality	[129]	Poor water quality	[129]
Mechanical disturbance	[129]		
Noise & disturbance	[129]		
Inappropriate photoperiods	[129]	Inappropriate photoperiods	[129]
Inappropriate water temperatures	[66, 129]		
Capture stress	[130]		
Handling stress	[12, 131]	Handling stress	[12]
Transportation stress	[12, 129, 131, 132]		
Poor feed management	[129]	Poor feed management	[129]
Overcrowding	[12]	Overcrowding	[12]
Co-occupant aggression	[12, 49, 66, 129]	Co-occupant aggression	[12, 129]
Stress	[66]	Stress	[13, 133]
		Lack of or failure to gain veterinary examinations	(Pizzi et al., 2022; BVA, 2023)
Abnormal behaviours	[57]	Abnormal behaviours	[57]
Morbidity and mortality rate 10 – 40% post capture/pre-export	[134]	Mortality rate 90 + % in home in 1 year	[140]
Morbidity and mortality rate 75% during transport after cyanide immobilization	[135] [136]	Mortality rate implicitly very high due to high turnover and relatively static residential population in home	[60, 138]
Morbidity and mortality rate 98% during wild capture	[137]		
Mortality rate 73% during handling transport	[60, 138, 139]		
Morbidity and mortality rate high	[8]		
Morbidity and mortality rate implicitly very high due to high turnover	[132]		
Morbidity and mortality rate implicitly very high; law allows 5% of fish to die daily (= 100% within 3 weeks) without need to record deaths			
Bronchial lesions / infections in 70% at pet shops			

Table 9 Summary example pet welfare issues or concerns identified in literature and from observation of images of captive conditions: amphibians

Wholesale / retail conditions	Sources	Home conditions	Sources
Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 52, 54, 128]	Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 52, 54, 128]
Overly restrictive spatial conditions	[49, 66, 77]		
Capture stress	[141]		
Long periods in poor conditions	[49, 77]		
Insanitary environments/poor hygiene	[49, 66]		
Inappropriate thermal and humidity provisions	[49, 66, 77]		
Inadequate, unreliable food and water	[49, 77]		
Incompatible conspecifics	[49, 66]		
Co-occupant aggression	[49]		
Cannibalism	[49]		
		Social deprivation	[28]
Absent or minimal environmental enrichment	[49, 66, 77]		
Overcrowding	[49, 66, 77]		
Overcrowding/injuries, crushing	[49, 66]		
Injuries consistent with inhumane handling techniques	[49, 66, 77]		
Dehydration	[49]		
Hypothermia	[49]		
Stress	[49, 66, 77, 142, 143]	Stress	[143]
Abnormal behaviours	[57, 77]	Abnormal behaviours	[57]
Starvation/emaciation	[49]		
		Lack of or failure to gain veterinary examination	[13, 133]
Infection, parasitism, disease	[49, 126, 127, 142]		
Mortality rate 44.5% in 10 days (anurans, caudatans)	[49]		

Table 10 Summary example pet welfare issues or concerns identified in literature and from observation of images of captive conditions: reptiles

Wholesale / retail conditions	Sources	Home conditions	Sources
Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 52, 54, 128, 144]	Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 52, 54, 128, 144]
Overly restrictive spatial conditions	[49, 61, 66, 77]	Overly restrictive spatial conditions	[33, 145]
Capture stress	[61]		
Long periods in poor conditions	[49, 61, 77, 79]	Long periods in poor conditions	[33, 145]
Insanitary environments/poor hygiene	[49, 66]	Insanitary environments/poor hygiene	[145, 146]
Inappropriate thermal and humidity provisions	[49, 61, 66, 77]	Inappropriate thermal and humidity provisions	[33, 145]
Inadequate, unreliable food and water	[49, 61, 77]	Inadequate, unreliable food and water	[145]
Incompatible conspecifics	[49, 66]		
Co-occupant aggression	[49, 66]	Co-occupant aggression	[145, 146]
Cannibalism	[49, 66]	Cannibalism	[145, 146]
		Social deprivation	[28, 147]
Absent or minimal environmental enrichment	[49, 61, 66, 77]	Absent or minimal environmental enrichment	[145, 146]
Overcrowding	[49, 66, 77]	Overcrowding/injuries, crushing	[145, 146]
Injuries	[49, 66, 77, 148]	Injuries	[145, 146, 149]
Hypothermia	[49, 66]	Hypothermia	[145, 146]
Capture-stress	[126, 127]		
Stress	[49, 61, 66, 77, 126, 127, 142]	Stress	[145, 146]
Abnormal behaviours	[57, 61, 77, 146, 150, 151]	Abnormal behaviours	[57, 146, 149–151]
Dehydration	[49, 66]	Dehydration	[145, 146]
Starvation/emaciation	[49, 66]	Starvation/emaciation	[145, 146]
		Lack of or failure to gain veterinary examinations	[13, 133]
Infection, parasitism, disease	[49, 142, 148]	Infection, parasitism	[145, 146]
Mortality rate 42% in 10 days (testudines, lacertilians, serpents)	[49]	Mortality rate 75% in 1 year in home Mortality rate 52% in 2 years	[48] [149]

Table 11 Summary example pet welfare issues or concerns identified in literature and from observation of images of captive conditions: birds

Wholesale / retail conditions	Sources	Home conditions	Sources
Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 52, 54, 82, 128]	Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 44, 52, 54, 82, 128]
Overly restrictive spatial conditions	[49, 66]	Overly restrictive spatial conditions	[44]
Long periods in poor conditions	[49]		
Absent or minimal environmental enrichment	[66]		
Overcrowding	[66]		
Injuries	[44, 66]	Injuries	[44]
		Social deprivation	[44, 82]
Capture-stress	[44, 126, 127]	Anxiety	[83]
Stress	[44, 66, 126, 127, 142]	Stress	[44]
		Lack of or failure to gain veterinary examinations	[13, 133]
Abnormal behaviours	[44, 57, 82]	Abnormal behaviours	[44, 57, 82]
Lack of social opportunity	[44, 82]	Lack of social opportunity	[44, 82]
Infection, parasitism, infection	[44, 126, 127, 142]	Infection, parasitism, infection	[44]
Mortality rate during capture, commercial sector 75–90%	[44]		

Table 12 Summary example pet welfare issues or concerns identified in literature and from observation of images of captive conditions: mammals

Wholesale / retail conditions	Sources	Home conditions	Sources
Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 44, 52, 54, 128]	Difficulty to keep/unanticipated or overly demanding husbandry	[13, 15, 52, 54, 128]
Overly restrictive spatial conditions	[44, 49, 66, 152]	Overly restrictive spatial conditions	[152, 153]
Long periods in poor conditions	[49, 79]		
Insanitary environments/poor hygiene	[49, 66]		
Inappropriate thermal and humidity provisions	[49, 152]		[152]
Sound disturbance	[152]	Sound disturbance	[152]
Handling stress	[152]	Handling stress	[152]
Visual disturbance	[152]	Visual disturbance	[152]
Stressful odours	[152]	Stressful odours	[152]
Inadequate, unreliable food and water	[49, 66, 152]	Inadequate, unreliable food and water	[152, 153]
Incompatible conspecifics	[49, 66]		
		Lack of social opportunity	[152, 153]
Co-occupant aggression	[49, 66, 152]	Co-occupant aggression	[152, 153]
Cannibalism	[49, 66]		
		Social deprivation	[152]
Anxiety	[152]	Anxiety	[83, 152]
Absent or minimal environmental enrichment	[49, 66, 152]	Absent or minimal environmental enrichment	[152, 153]
Overcrowding	[49, 66, 152, 153]	Overcrowding	[152, 153]
Overcrowding/injuries, crushing	[49, 66]		
Injuries	[49, 142]	Injuries	[152, 153]
Hypothermia	[49]		
Capture-stress	[126, 127]		
Stress	[49, 66, 126, 127, 142]		
Abnormal behaviours	[49, 57, 152]	Abnormal behaviours	[57, 152, 153]
Dehydration	[49, 66]		
Starvation/emaciation	[49, 66]		
		Lack of or failure to gain veterinary examinations	[13, 133]
Infection, parasitism, disease	[49, 126, 127, 142, 153]	Infection, parasitism, disease	[152, 153]
Mortality rate 5.5% in 10 days (rodents, carnivorans, eulipotyphlans, didelphimorphs, diprotodonts, pilosans, primates)	[49]		

Table 13 Comparison of selected key criteria for animal biology *versus* formal trade husbandry guidance consistent with the Five Freedoms or Five Welfare Needs

Animal class/Species	Natural lifestyle criteria	Sources	Captive guidance	Sources
Invertebrates African land snail (*Lissachatina spp.*)	Home range: 3.58 m^2 Diet: Generalist feeding on more than 500 plant species, including both leaves and roots Habitat: Montane and lowland forest habitats, plantations, and scrublands Behaviour: solitary	[154–156]	Spatial provision: None Diet: None Habitat: None Behaviour: None	
Millipede (*Diplopoda/ Archispirostreptus* spp.)	Home range: 3.6 m^2 Diet: Decaying or fresh fruits, vegetables, leaves, occasionally carrion Habitat: Forests, coastal regions Behaviour: Arboreal, terrestrial	[157–159]	Spatial provision: None Diet: None Habitat: None Behaviour: None	
Fishes Goldfish (*Carassius auratus*)	Home range: 300–1400 m per day; 5 km per day have been observed Diet: Opportunistic omnivores consuming a wide variety of plant matter (45%) supplemented with, crustaceans (e.g., *Daphnia, Artemis*), eggs and insects, larvae, even detritus Habitat: Wide range of shallow temperate freshwater habitats, generally with little movement, including rivers, streams, lakes, swamps Behaviour: Highly social, forming shoals and having communication within the shoal. Non-territorial, non-hierarchical	[160–164]	General fish guidelines: Spatial provision: Able to move freely and turn around in aquariums or ponds Diet: A suitable diet should be provided Habitat: A suitable environment, enrichment accessories to stimulate natural behaviour appropriate to the species, substrate, temperatures, humidity, light, water quality Behaviour: Effectively included in Habitat above	[8, 165]
Cardinalfish (*Pterapogon* spp.)	Home range: 143 m + Diet: Copepods and planktonic organisms Habitat: Shallow, calm waters between coral reefs and seagrass beds Behaviour: Strong homing abilities, nocturnal	[166]	General fish guidelines: Spatial provision: Able to move freely and turn around in aquariums or ponds Diet: Suitable Habitat: Suitable environment, enrichment accessories to stimulate natural behaviour appropriate to the species, substrate, temperatures, humidity, light, water quality Behaviour: Effectively included in Habitat above	[8, 165]
Amphibians Wood frog (*Lithobates sylvaticus*)	Home range: 70 m^2 Diet: algae, eggs, invertebrates including shrimp, amphibian larvae, frogs Habitat: Woodland, forest, marsh, swamp, pond Behaviour: Highly terrestrial, mostly solitary, seasonally migratory	[167–171]	General frog guidelines: Spatial provision: 30 cm or 3 × snout-to-vent length* × 30 cm or 3 × snout-to-vent length × 30 cm or 3 × snout-to-vent (*whichever is larger) Spatial provision: small and moderate sized species (e.g. Uperoleia and Notaden): 40 × 40 cm floor area, larger species (e.g. Cyclorana): 60 × 60 cm floor area Diet: Suitable Habitat: Suitable environment, enrichment accessories to stimulate natural behaviour appropriate to the species, substrate, temperatures, humidity, light, water quality, ability to hide, ability to bathe Behaviour: Effectively included in Habitat above	[8] [172] [8, 165]

Table 13 (continued)

Animal class/Species	Natural lifestyle criteria	Sources	Captive guidance	Sources
Fire salamander (*Salamandra Salamandra*)	Home range: 1295 m^2 Diet: Highly diverse invertebrates (11 families and 12 genera) Habitat: Woodlands, forests, mountains, underground springs, rivers Behaviour: Complex movement patterns	[173–176]	Spatial provision: 30 cm or 3 × snout-to-vent length* × 30 cm or 2 × snout-to-vent length × 30 cm or 3 × snout-to-vent length (*whichever is larger) Diet: Suitable Habitat: Suitable environment, Suitable, enrichment accessories to stimulate natural behaviour appropriate to the species, substrate, temperatures, humidity, light, water quality, ability to hide, ability to bathe Behaviour: Effectively included in Habitat above	[8] [8, 165]
Reptiles Bearded dragon (*Pogona vitticeps*)	Home range: Up to 45,000 m^2 Diet: Opportunistic omnivores consuming a wide variety of invertebrates and vegetable matter, and occasional small mammals or reptiles Habitat: Eastern and central Australia. Large range of habitat types from semi arboreal to desert, scrublands and dry forest Behaviour: Not highly social. Highly hierarchical and territorial	[177–179]	Spatial provision: 4 × snout-to-vent length by 2.5 × snout-to-vent length Spatial provision: 2–3 adults: 100 cm × 150 cm × 80 cm Diet: Suitable Habitat: Suitable environment, enrichment accessories to stimulate natural behaviour appropriate to the species, substrate, temperatures, humidity, light, water quality, ability to hide, ability to bathe Behaviour: Effectively included in Habitat above	[8] [172] [8, 165]
Corn snake (*Pantherophis guttatus*)	Home range: 7.9 hectares Diet: carnivorous, ovivorous, feeding on a variety of herpetofauna, mammals and birds as well as birds' eggs Habitat: Fields, trees, open habitat, range of altitudes to 1800 m Behaviour: Solitary, crepuscular/nocturnal	[167, 180, 181]	General snake guidelines: Spatial provision: 2/3 length of snake by 1/3 length of snake Spatial provision: one adult snake (200 cm total length) will require a cage with floor area at least 100 cm × 100 cm Diet: Suitable Habitat: Suitable, enrichment accessories to stimulate natural behaviour appropriate to the species. Suitable environment, substrate, temperatures, humidity, light, water quality, ability to bathe Behaviour: Effectively included in Habitat above	[8] [172] [8, 165]
Birds African grey and timneh parrot (*Psittacus ssp.*)	Home range: 283 km^2 Diet: Found to have a varied diet comprising 38 plant species, from 14 families. Nuts, grains, seeds, fruit, flowers, leaves, grubs, berries, occasional insects are consumed Habitat: Rainforest and Savannah of West Africa Behaviour: Highly social. Live in flocks, which assist in predator avoidance. Strong social bonds. High cognitive ability	[54, 182, 183]	Spatial provision: 140 × 105 × 105 cm (minimum length: 2 × wingspan) Spatial provision: 10,000 cm^2 floor space × 90 cm height (bird length 40 cm) Diet: Suitable, constant Habitat: Suitable, enrichment accessories to stimulate natural behaviour appropriate to the species, sufficient perches Behaviour: Effectively included in Habitat above. Social species to be kept in social groups	[8] [184] [8, 165]

Table 13 (continued)

Animal class/Species	Natural lifestyle criteria	Sources	Captive guidance	Sources
Budgerigar (*Melopsittacus undulatus*)	Home range: Flocks are nomadic, travelling distances between sites of 200–300 km Diet: Major part component seeds (*Astrebla* spp.), not available outside Australia, as well as a wide variety of grains, grasses, seeds, spinifex, fruit, flowers, leaves, grubs, berries Habitat: Australian open scrublands, open woodlands, grasslands Behaviour: Highly social. Large flocks which assist in predator avoidance. Strong social bonds. Intelligent	[54, 185–187]	Spatial provision: 60 × 45 × 45 cm (minimum length: 2 × wingspan) Spatial provision: 1600 cm^2 cm floor space × 34 cm height (bird length 20 cm) Diet: Suitable, constant Habitat: Suitable, enrichment accessories to stimulate natural behaviour appropriate to the species, sufficient perches Behaviour: Effectively included in Habitat above. Social species to be kept in social groups	[8] [184] [8, 165]
Mammals Degu (*Octodon degus*)	Home range: Up to 2.5 hectares, varies with gender and season Diet: Grasses, green vegetation, bark, seeds and fruit, bulbs, tubers, twigs Habitat: Chilean Andes, sometimes at very high altitude, they prefer low temperature (< 20 degrees) Behaviour: Highly social	[54, 188, 189]	Spatial provision: 30 × 30 cm Diet: Suitable, ad libitum, clean hay Habitat: Suitable, enrichment accessories to stimulate natural behaviour appropriate to the species., sand bath, paper tunnels, other furnishings Behaviour: Effectively included in Habitat above	[8]
African pygmy hedgehog (*Atelerix albiventris*)	Home range: 300 m^2 radius from the burrow Diet: Insectivore, ovivore. Consumes a wide diversity of species. Invertebrate prey includes millipedes, ants, grasshoppers, termites, beetles, earthworms, slugs, snails and crabs. Small vertebrate prey includes lizards, snakes, frogs. Eggs and chicks of ground-nesting birds. Smaller percentage of vegetable matter including fungi, fallen fruits, roots, and groundnuts Habitat: grassy plains, steppes, savannas, and agricultural fields in west and central Africa Behaviour: Solitary, nocturnal	[190]	General small mammal guidance: Spatial provision: 0.52 × 0.52 × 0.3 m** (**Not specifically covered. Where species-specific guidance does not exist, standards for similar or related species must be considered as to their appropriateness and standards extrapolated; e.g., guinea pig (*Cavia porcellus*) provisions used as alternative) Diet: Suitable, ad libitum, clean hay Habitat: Suitable, enrichment accessories to stimulate natural behaviour appropriate to the species Behaviour: Effectively included in Habitat above	[8, 191] [8, 165]

4 Discussion

The key welfare models may be open to some interpretation as to their scope. In particular, the Five Freedoms and the Five Welfare Needs are superficially similar in design and wording, although subtle and important differences are implied. For example, in the Five Freedoms, provision 1 states: 'Freedom from hunger and thirst', and in the Five Welfare Needs, provision 2 states: 'Need for a suitable diet'. Five Freedom provision 1 does not indicate appropriateness or quality of diet, whereas Five Welfare Need provision 2 does indicate appropriateness or quality of diet. Broadly, these examples convey how the Five Freedoms are more directed at avoiding negative experiences for animals, whereas the Five Welfare Needs are more directed at both avoiding negative outcomes or experiences and promoting positive outcomes or experiences for animals. In this regard, the Five Domains also reflect the Five Welfare Needs. In terms of construction of wording, the Five Freedoms are essentially written in a negative (e.g., not deprive) context, whereas the Five Welfare Needs and the Five Domains are essentially written in a positive (e.g., must provide) context. However, the wording used in some legislation is arguably ambiguous, because provisions may be expressed in negatively worded contexts whilst also implying some degree of positive outcome-led instructions. For this report, we have interpreted ambiguous contexts cautiously by ascribing predominantly negatively worded legislation to be more closely aligned with the Five Freedoms, and predominantly positively worded legislation to be more closely aligned with the Five Welfare Needs or the Five Domains.

4.1 Key animal welfare models and principles: global use

In Table 6 we presented summary examples of use of animal welfare models or principles by region, country, or state, which we will discuss further. The US Federal Animal Welfare Act [89] does not apply to pet animals (with the exception of dealers where minimum care is promulgated), and individual states and territories regulate the treatment of pet animals. Most US states and territories have animal welfare acts that make it an offence to neglect an animal or subject it to cruelty or physical torture with minimum care requirements of food, water, and adequate shelter. Generally, US legislations incorporate minimal care requirements only and none of them wholly incorporate any of the models in this paper.

The Federal Canadian Criminal Code [91] makes it an offence to cause unnecessary suffering to an animal, but more comprehensive legislation regarding pet animals is governed by individual provinces and territories. Of the 10 provinces and three territories in Canada, all but two (Nanavut and the Northwest Territories, which have no relevant animal welfare regulations), include the basic standards of care for animals similar to the Five Freedoms (1,2,3) and the Five Welfare Needs (1,2,5) in their respective legislation.

The European Union and its member states, under the Treaty of Lisbon, 'shall, since animals are sentient beings, pay full regard to the welfare requirements of animals, while respecting the legislative or administrative provisions and customs of the Member States' [103]. The recognition of animals as sentient beings, and therefore having the capacity to experience pleasure, pain and subjective emotions, should be a head-starter for EU animal welfare legislators, but in fact animal welfare protections and enforcement in many countries are seriously lacking [192]. Also, The European Convention for the Protection of Pet Animals [104], which has been ratified by 26 EU countries, states that 'any person who is keeping a pet animal or who is looking after it shall provide accommodation, care and attention which take account of the ethological needs of the animal in accordance with its species and breed', which is in spirit similar to the Five Welfare Needs. The provision further stipulates that an animal shall not be kept as a pet animal if in spite of these conditions being met, the animal cannot adapt itself to captivity. Member states that have ratified this Treaty do not necessarily specify meeting the behavioural needs of pet animals or their potential inability to adapt to a captive environment.

The Austrian Animal Welfare Act [105] and Belgian legislation [106] use similar provisions within the Five Welfare Needs, including meeting both physiological and ethological needs of animals. The Finnish Animal Welfare Act [107] has general principles that include meeting the physiological and behavioural needs of all animals and prohibition of undue distress, and is therefore similar to provisions within the Five Welfare Needs model. In France, the Code Rural et de la Pêche Maritime [108] makes it an offence not to provide for basic needs of animals(equivalent to provisions within the Five Freedoms), but does not cover ethological needs or mental state. The German Animal Welfare Act [109] encompasses most of the Five Welfare Needs principles, including behavioural requirements although the mental state of the animal is not specifically mentioned. Italy's Animal Welfare Act [110] makes it unlawful to mistreat or abandon an animal, which is in greater accord with the Five Freedoms. However, regional laws legislate more specifically. The Netherlands Animals Act [114] uses the Five Freedoms to define animal welfare. Spanish animal welfare legislation [111] includes minimal animal protection rules that apply to pet animals, and indicate World Organisation for Animal Health care principles,

which promote the Five Freedoms. However, each region of Spain can legislate more specifically. The Swedish Animal Welfare Act [112] states that animals kept by people must be in an environment that promotes their well-being, enables behaviours for which they are strongly motivated (natural behaviour), and prevents behavioural disorders, which broadly equate to the Five Welfare Needs. In Swiss legislation [113], the well-being of animals encompasses clinical health, appropriate husbandry and feeding, and allowance for species-specific behaviour within the limits of the animal's biological capacity to adapt, and therefore is also similar to the Five Welfare Needs model. In the United Kingdom the Five Welfare Needs form the basis of animal welfare legislation [115], and are widely referenced in various laws and codes of practice.

In Australia, as in the UK, the RSPCA has a range of powers to enforce animal welfare legislation (across the whole of Australia except the Northern Territories). The Australian RSPCA [116] uses the Five Domains as a basis for its animal welfare protocols, and stipulates the need to address mental well-being as well as physical health. Individual state legislation varies in Australia, and currently Queensland [117] encompasses the Five Freedoms. In New South Wales, South Australia, Tasmania, Victoria, and Western Australia [119–123] legislation includes individual provisions for basic minimum standards of care similar to specific elements within the Five Freedoms, whereas in the Northern Territory [118], provisions are similar to those within the Five Welfare Needs (1,2,5). Four States are currently reviewing their animal welfare legislation, and recent official reviews of the New South Wales Prevention of Cruelty to Animals Act 1979 and the Western Australia Animal Welfare Act 2002 emphasise the need to update legislation in line with current scientific opinion by including the Five Domains model to focus on the subjective experiences of the animal. Relevant New Zealand legislation [124] incorporates the provisions similar to those within the Five Welfare Needs.

The World Organisation for Animal Health (WOAH, formerly OIE) incorporates the Five Freedoms as guiding principles for animal welfare, defining good welfare as an animal that is 'healthy, comfortable, well nourished, safe, is not suffering from unpleasant states such as pain, fear and distress, and is able to express behaviours that are important for its physical and mental state'. The scientific basis for WOAH recommendations also includes measuring the strength of animals' preferences, motivations and aversions to assess the animals' needs and affective states such as hunger, pain, and fear [125].

4.2 Frequency of citation

To acquire information concerning frequency of citation and / or use of each key welfare model in relation to others, we also conducted a simple search (Table 14) using Google (non-scientific and governmental items) and Google Scholar (scientific items) for the number of registered results for "Five Freedoms", "Five Domains", "Five Welfare Needs", "three ethical concerns", respectfully, and in conjunction with the term "animal welfare".

Table 14 Approximate number of results per simple search for each key animal welfare model

Model	Results per search Google	Results per search Google Scholar
"Five Freedoms"	226,000	10,900
"Five Domains"	1,540,000	117,000
"Five Welfare Needs"	7930	130
"Three ethical concerns"	Term insufficiently specific to provide relevant results	

Search conducted 10.3.24

Table 14 provides the results of the simple Google and Google Scholar searches regarding frequency of citation and / or use of each key welfare model in relation to others.

The results of the simple Google and Google Scholar searches regarding frequency of citation of each key welfare model (Table 14) indicated that the Five Domains were the most frequently cited model in both engines, followed by the Five Freedoms, and Five Welfare Needs. The search regarding the three ethical concerns provided non-specific and largely irrelevant results. However, the frequency of citation during the searches did not corroborate the actual representation of a model, or selected similar provisions, in practical use. In this study, the Five Freedoms, or selected similar provisions, were most commonly used, followed by the Five Welfare Needs, or selected similar provisions.

4.3 Information relevance and study limitations

The three tiers of relevance in our study should have an operational continuum where Tier 1 establishes primary principles necessary for good welfare, Tier 2 provides operational care instructions based on Tier 1, and Tier 3 constitutes the outcomes or consequences related to the application of Tiers 1 and 2. Below, we briefly discuss each of these tiers, their relevance, and limitations within this study.

4.3.1 Tier 1. Key welfare models & principles

The key welfare models (Tables 1, 2, 3, 4, 5) can be considered the primary or foundational components of relevant government regulation for a functional control system. Tier 1 should adopt modern evidence-based concepts and principles that provide fundamental welfare guarantees. As detailed in Table 6, numerous regional, national or local governments have adopted Tier 1 concepts and principles; thus, this component of the operational continuum is reasonably well documented, at least for many authorities.

4.3.2 Tier 2. Formal guidance & Tier 2a minimalistic examples of formal guidance

Tier 2 information should rationally adopt modern evidence-based and detailed husbandry guidance that provides enhanced welfare guarantees. During our study and limited search of government databases, 35 (out of 91) formal agencies were found to have published Tier 2 guidance. Accordingly, the majority of governments appeared to rely primarily on relatively minimal guidance published by individual authorities that interpret and directly apply certain Tier 1 key models to welfare protection. The species covered and the amount of documented information detail for the Tier 2 and Tier 2a guidance varied widely. Also, numerous examples of Tier 2 guidance were significantly lacking both in terms of history of introduction and detail. For example, the UK only introduced Tier 2 guidance for pet sellers in 2018 [8, 193], and there remains no formal guidance for animals in the private home environment. Australian regional governments have provided Tier 2 guidance for keepers since at least 2013 (e.g., New South Wales [194]; Queensland [172]; Victoria [195]).

It is beyond the scope of this study to critically evaluate Tier 2 or Tier 2a guidance generally; thus, we have focused on its availability rather than quality. However, it is worth noting that some of the detailed Tier 2 guidance has been strongly criticised by the scientific community [67, 69] for its lack of scientific credibility. Certain governments, for example, Manitoba, New Brunswick, Newfoundland and Labrador, and Prince Edward Island, in Canada, utilise guidance developed by the pet industry, which holds a vested interest in certain types of messaging. This reported lack scientific credibility is exemplified by the English Government guidance [8], which has raised concerns regarding its interpretation of Tier 1 concepts and principles, as well as for its lack of evidence-based and objective content [67, 69]. In particular, rather than utilise independent objective scientific input to develop policy and educational tools, DEFRA operates selective consultation practices with exotic pet selling and keeping vested-interest stakeholders, which can be managed in secret without broad input from independent scientists and animal welfare organisations [67, 69] [FOI response DEFRA to E Toland 20th March 2024]. Similarly, although to a far lesser extent, Australian State governments (Victoria [195]; Queensland [172]; New South Wales [194]) have also been criticised for publishing guidance lacking in scientific substance and its development in association with vested interest groups [62, 81, 196].

In addition, application of Tier 2 or Tier 2a guidance is further problematically compounded due to poor uptake by animal keepers, for example, in the UK [46], USA [197], and in Australia [62]. Moreover, instead of voluntarily using objective evidence-based guidance from scientific sources, many exotic pet sellers and keepers instead frequently rely on handed-down arbitrary husbandry practices that lack validity or are known to be harmful [144, 198]. Therefore, even where established Tier 1 concepts and principles, as well as obligatory formal Tier 2 guidance, are published, end point practices do not necessarily follow such instructions or may even be harmful to animals if followed. Nevertheless, the apparent incompleteness of published Tier 2 guidance means that this component of the educational continuum is probably lacking, at least for many species. The lack of examples prevents more comprehensive analysis of such prospective provisions. In any event, a lack of Tier 2 guidance does not hinder assessment of key welfare models and related welfare outcomes, as discussed below.

4.3.3 Tier 3. Welfare outcomes

Established welfare criteria, which are extensively documented for both behavioural and physiological considerations (discussed elsewhere herein, see Tables 7, 8, 9, 10, 11, 12), constitute the primary indicators for the effectiveness or otherwise of husbandry practices, whether or not resulting from any specific guidance. For example, a person or business can be held to account for welfare infringements based entirely on the existing condition of animals and their current care without reference to them knowing relevant laws or recommendations for husbandry. Accordingly, whether or not a government has adopted key welfare models or has introduced any obligatory husbandry guidance, the outcomes or consequences for animals constitute standalone measures regardless of welfare of any Tier 2 guidance. As detailed in Tables 7, 8, 9, 10, 11, 12, while incomplete, there is a strong body of evidence indicating that welfare outcomes for exotic pet animals are persistently and widely poor; thus, this component of the operational continuum is also reasonably well documented, at least for many species. Accordingly, while the incompleteness of Tier 2 information must be acknowledged, such information does not anyway necessarily translate to good welfare outcomes, and conclusions can be formulated regarding the effectiveness Tier 1 information based entirely on Tier 3 outcomes, and without Tier 2 information.

4.4 Evaluating the key animal welfare models

4.4.1 Five Freedoms

Of the Five Freedoms (Table 1), Freedoms 1, 2, 3 & 5 are directed at providing for essential husbandry conditions and for avoiding or preventing negative impacts and states; thus, they do not specifically instruct good welfare. Only Freedom 4 (Freedom to express normal behaviour), directly implies positive physical and affective states, in that animals must be allowed carry out strongly motivated behaviours. If applied in an animal-welfare centric way, Freedom 4 would dramatically alter how captive animals are housed and managed. However, in practice, the stipulation has strong limitations, because there is an inherent yet silent presumption that in this context normal behaviours are confined to those permitted within the restrictions of frequently minimalistic captive environments in terms of space and habitat diversity. Thus, as typically used, the Five Freedoms continue to limit the model to mean, for example, that animals are simply allowed the abilities of stretching their bodies, moving around, and having shelters in which to hide, without proper assessment of a wide range of naturalistic behaviours.

Normal behaviours such as long-distance flight, terrestrial transient or migratory behaviour, and deep burrowing are, by default, not typically accommodated. Reproductive and young-rearing behaviours are frequently thwarted, as are many natural social interactions. Accordingly, whilst Freedoms 1, 2, 3 & 5 remain inherently minimalistic, Freedom 4 holds considerably greater relevance if interpreted within the context of modern animal welfare science, and if applied more robustly to include factors such as relevant space and habitat diversity. At development, the Five Freedoms model reflected aspirations aimed at cruelty prevention that resulted largely from specific deprivations [2, 7]. The Five Freedoms also have their roots in farm animal welfare, which is often held to a lower standard than for pets. However, today the Five Freedoms are criticised for essentially lagging behind modern animal welfare science, as presented and discussed in detail [7, 14].

From the simple Google search regarding frequency of citation (Table 14), the Five Freedoms model manifests strong representation, despite recent criticisms of the model being out of date. Although uncertain, this greater representation may relate to two factors. First, the early publication and, thus, the head-starting of the model. Second, the preparedness and / or ability of regulators and others to minimally interpret its provisions due to the basicness of the criteria and their aspirational rather than outcome-led nature. In addition, publications concerning, in particular, The Five Domains, but also other models, frequently discuss the Five Freedoms in a historical context, thus potentially also raising that model's profile in the literature.

4.4.2 Five Domains

The Five Domains (Table 2) constitute an advancement of the Five Freedoms aimed at incorporating modern animal welfare science [2, 5, 7, 25, 26], and arguably provides the most evolved framework of its kind that potentially allows for improved estimation of what an animal may experience. The model, especially if applied scientifically and animal-centrically, provides for systematic assessment and promotion of welfare, including environmental, physiological, behavioural,

and—in some depth—mental, factors, as well as determining negative and positive outcomes and states [7, 199]. Along with the target of securing animals 'a life worth living' [5, 7, 200–202], inherent messages convey that animals should experience positive emotions and pleasures, which elevate the value of the Five Domains above many existing protocols. Relatedly, feelings and emotions may be separable from other welfare measures in their importance [35].

The summary principle of a 'life worth living', inherent to The Five Domains, is an intelligent proposal that, if robustly interpretated, ought to convey that a captive animal is holistically thriving and content with its conditions. As for the Five Freedoms, a minimalist interpretation may still be pursued to infer that various compromises can be presumed whereby an animal simply chooses life over death (or has no such choice). In human terms, such a choice may also be made by a permanently incarcerated person occupying deprived conditions in which they may experience some positive states. Therefore, it is conceivable, on the isolated principle of 'life worth living', that an animal may or may not be provided with genuinely good conditions that fulfil that principle.

From the simple search regarding frequency of citation (Table 14), the Five Domains was the most represented model. Whilst the Five Domains model is significantly more evidence-based and detailed than the Five Freedoms, and includes a greater outcome-led element, it is also more intricate and complex in design, which perhaps deters some potential users. Relatedly, some legislators may be reluctant to fully adopt the Five Domains due to anticipated probable highly limiting impacts (although scientifically justified) on pet selling and keeping practices.

4.4.3 Five Welfare Needs

The Five Welfare Needs model (Table 3) promotes healthy condition through stipulating fundamental environmental and biological requirements with broad welfare implications. These implications cause the model to involve a strong outcome-led context beyond the more aspirational foundations used for the Five Freedoms [3]. The aims of the Five Welfare Needs arguably infer greater responsibility, above the Five Freedoms, to provide for animals, including for behaviours such as calm interaction, relaxation, and play [2, 203]. Of the Five Welfare Needs, Need 4 (Need to be housed with, or apart, from other animals) is infrequently inferred in legislation, although, arguably, it is also implied in Need 3 (Need to be able to exhibit normal behaviour patterns).

From the simple Google search regarding frequency of citation (Table 14), the Five Welfare Needs was the least represented model. Curiously, despite similarities in application and simplicity to the Five Freedoms, the Five Welfare Needs appear not yet to have achieved similar traction.

4.4.4 Three ethical concerns

The three ethical concerns (Freedom, Feelings & Function) (Table 4), provide concepts and principles that historically and currently underlie or are integral to various animal welfare models, due to inherent broad biological and philosophical elements [4, 7, 29, 204, 205]. Of the three ethical concerns, Freedom implies consideration of the animal's welfare by its ability to lead a life under its control, rather than measurements such as, physiological criteria, immune competence, fitness and morbidity. Feelings convey that if an animal feels comfortable or good, then its life quality may meet a satisfactory welfare standard, regardless of environmental or physiological factors. Function implies the importance of providing for an animal's biological (including environmental, nutritional, and clinical) requirements, so that certain essential 'life-support' elements are not overlooked. All elements of the three ethical concerns should be regarded as a unified concept. Accordingly, the three ethical concerns are both enduring and strongly animal-centric in their nature, and loosely included in the background of other models.

From the simple Google search regarding frequency of citation (Table 14), the three ethical concerns provided an extremely high number of results, and irrelevant results with no identifiable reference to animal welfare. Accordingly, its proportionate relevance to all other models was not possible to assess. However, given the wide influence and endurance of the three ethical concerns in animal welfare science, it is in our view unfortunate that the model appears, at least superficially, to be considerably under-represented as an outcome-led system compared with the other approaches.

4.4.5 Other animal welfare principles

Whilst the Five Freedoms, Five Domains, Five Welfare Needs, and three ethical concerns constitute structured models, a raft of other scientific principles have been conceived that offer standalone criteria, or potentially, models in themselves (Table 5). The other animal welfare principles or models are diversely utilised across, for example, governmental, private managemental, research, and publication situations. However, these principles or models are often not distinctly presented as such, and instead probably become introduced as philosophical ideas and guides during discussion of particular problems.

Although Table 5 presents summary definitions for these principles or models, there are arguably two clear categories, human-centric (focused on humans or their preferences), and animal-centric (focused on animals or their preferences). Human-centric considerations include Quality of life [27, 206], Controlled deprivation [28], Positive and negative states [7], Our control, Our responsibility [29], One Welfare, One Biology [30–32], and Crypto-overcrowding [33]. These considerations constitute powerful instructors of human liability towards both managing and understanding animals in their care. Rationally, these considerations ought to underpin and govern all efforts, responsibilities, and obligations, whether formal or informal, by caretakers towards animals. Animal-centric considerations include Motivation and preference [34], Control over environment (e.g., [34, 35]), Sentience (e.g., [20, 29]), and If it leaves, does it come back? (e.g., [33, 44]). These considerations incorporate expressions by animals of self will and the ability to choose the best available options based on individual physiological, behavioural, and psychological drivers. The ability of animals to constantly express self-will should constitute a fundamental concept for captive individuals. However, expression of self-will does not infer that, for example, predator and prey species interactions are to be encouraged, because doing so would not reflect the will of the prey and, thus, could contradict managemental responsibilities.

4.5 Pet trading and keeping

Objective data regarding welfare outcomes associated with pet trading and home keeping are generally lacking, which may be due to inherent difficulties in conducting investigations into commercial enterprises, lack of openness among those entities, and challenges in surveys and obtaining accurate data based on self-declared information across both situations. Also, there appears to be relatively little information concerning some animals, in particular for invertebrates, which may be due to broadly lower levels of concern and lack of relevant research regarding the well-being of these animals compared with others, and to minimal or no legal or other regulation regarding their care.

Whilst Tables 7, 8, 9, 10, 11, 12 summarise numerous documented exotic pet welfare issues or concerns, certain common background reasons may be inherently related to these problems. In particular, these background reasons include stresses associated with: 1. wild-capture, handling, storage, and transportation (e.g., [146, 207]); 2. captive-breeding and associated intensive housing (e.g., [146, 207]); 3. development of genetically-related morbidities among captive-bred species (e.g., [146]); 4. poor adaptability of many species to captive environments (e.g., [54, 146]); 5. fundamental limitations of captivity as a holistic provider for animals (e.g., abnormal stressors pertaining to artificial environments) (e.g., [146, 150]); 6. inherent unsuitability of wild animals (whether wild-caught or captive-bred) for trading and keeping as pets, or unanticipated and overly demanding husbandry (e.g., [13, 15, 52, 54, 82, 128, 144]); 7. difficulties due to widespread lack of knowledge regarding species-specific biologies, husbandry needs, and veterinary treatment (e.g., [53, 54, 65]); 8. poor quality trade-generated information (e.g., [46, 52, 74, 144, 208, 209]); 9. and poor uptake of quality information even when provided (e.g., [52, 53, 62, 81–83, 144, 150, 196]). These considerations are plainly relevant to all welfare criteria within all models because they include matters of nutrition, environment, health, behaviour, sociality, mental state, adaptability, function, feelings, and, overarchingly, positive and negatives states.

4.5.1 Animal welfare models versus welfare outcomes

Based on the reports identified for this study, the frequent presence of significant welfare problems among pet animals in both commercial and home environments constitutes a persistent and major cause for concern. Such persistent welfare problems can be regarded as strong indicators that any or all approaches to their resolution (including key welfare models and guidance) are, at least partially and probably grossly, failing. As indicated previously, all welfare models probably harbour highly relevant limitations, both inherently and as a result of under-implementation. Whether a model is used and to what extent may depend on policy makers balancing scientific information with common trade husbandry practices.

4.5.2 Evolved animal biologies versus welfare models

In this section, we present case examples that examine potentially important considerations pertinent to some common exotic pet species under natural and captive conditions. Probably all animals have some form of avoidance mechanism for adverse stimuli, indicating that negative situations or stress or pain can affect any species. In any event, such presumption should be made. Whilst birds and mammals are commonly regarded as highly social, many other studied species, for example, amphibians and reptiles, manifest sociality often rivaling that of the popular contenders (e.g., [28, 147]); thus, these features should be assumed relevant to all animals. However, certain relatively solitary species, as well as individuals of some highly social species may display agonistic behaviours resulting in conspecific co-occupant aggression, injuries, and stress [57]. In nature, space is almost unlimited, and thus animals are typically able to preferentially select their home ranges, which frequently also involve extended ranges where animals migrate or manifest other transient behaviours. Obviously, home ranges are greatly variable. For example, some species that are frequently referred to as sedentary, such as certain spiders (e.g. tarantulas), may generally occupy areas of metres above and below ground, but detailed studies have shown that home ranges can be extensive, although include periods of sedentarism [210, 211]. Therefore, even for apparently highly sedentary species, actual home ranges may be far more extensive than is often anticipated. Accordingly, the natural home ranges of animals are manifestly at great odds with the characteristically diminutive enclosures measured in centimetres or metres that are associated with almost all captive conditions.

Relatedly, all animals should be presumed to possess strong internal motivations to pursue the behaviours and the lifestyles that they were evolved to live, as well as the sentience to acknowledge the environments that they occupy (e.g., [20, 29, 36–42]). All animal classes have been studied to varying degrees regarding sentience. Sentience implies the capacity to perceive and feel subjectively, including positive, neutral, and negative experiences, such as pleasure, enjoyment, emotion, rest, pain, and suffering, as well as to experience consciousness and self-awareness. Growing evidence as well as scientific and legal acceptance of sentience, observation of behavioural indicators of stress, and the precautionary principle, imply that all animals should benefit from the best husbandry and general welfare protections that are applied to the most well-safeguarded animal classes [12, 18, 20, 37, 40, 57, 212–227]. In addition to the above commonalities, there are also certain specific attributes to ectothermic or endothermic organisms.

4.5.3 Ectothermic animals

Ectothermic animals (invertebrates, fishes, amphibians, and reptiles) have certain features in common that influence their welfare needs. In particular, these features include: very strong dependence on environmental temperatures, temperature-linked thermoregulatory behaviours, physiological states, and related immunological condition; strong innateness; and common nocturnalism [150, 228, 229]. Anticipating or providing for these features can be extremely difficult to manage. Thermoregulation involves often highly precise control of body temperatures that can only be realistically determined by the activities of each individual animal according to its present physiological state. Achieving thermal homeostasis, normal movement, digestion, metabolism, and immunity are all examples directly linked to thermoregulation, which is also directly linked to spatial and other habitat conditions [150, 228]. For many, if not most, species thermoregulatory needs typically far exceed the limitations of captive environments [144, 230]. Innateness infers naturally programmed ancestral drives pertaining to behavioural and mental habits and needs, which includes such factors as hard-wired requirements towards long-distance roaming, complex exploratory activity, environmental interactions, acquisition of food, and others; which for certain ectotherms (e.g., reptiles) is a recognised behavioural-spatial issue (e.g., [33, 146]). There is also great diversity in lifestyles amongst the very many (at least 860 [46]) species of invertebrate pet, which implies extensive requirement for specific biological data and husbandry requirements.

Failure to account for these needs frequently results in captive animals failing to adapt to artificial conditions, and developing a range of stress-related behavioural and mental problems. Relatedly, presumptions such as the provision of food in captivity negates biological drives directed at searching out food over extensive spaces are erroneous [144, 231]. Nocturnalism means that relevant species are characteristically active at low light or during darkness, which conflicts with the usual activity patterns of humans. Whilst nocturnalism is not a unique feature of ectotherms, it is inherently common. Nocturnal lifestyle activities conflict between these animals and humans, which implies not only potential disturbances to animals' normal resting periods (e.g., caused by noise, vibration, light, and extraneous movement), but also human caretakers likely are unable to observe nocturnal creatures sufficiently to be able to assess potential welfare issues [33, 57, 152, 232].

Many ectotherms (such as most invertebrates, fishes, and amphibians) kept as pets are commonly of small size (whether as species, larvae, or juveniles) and possess delicate structures (e.g., insect extremities and fish or amphibian skin), which expose these animals to particular risks from injury, dehydration, and other problems; and, where aquatic forms are involved, there is significant susceptibility to water quality [40, 52, 57, 233]. However, for larger individuals, the lower general metabolic rate means development of malnutrition, injuries, and diseases and associated onset of signs can involve a significant lag-phase, during which time animals may appear normal but be experiencing decline and poor welfare [228]. Thus, superficial appearance of healthy animals can be highly misleading, and relatedly, good health does not infer good welfare [231]. All of these considerations hold relevance to several criteria within different models; for example, nutritional, social, and behavioural needs that are imbedded within The Five Freedoms (e.g., criteria 1,2,3,4,5), The Five Domains criteria (e.g., 1,2,3,4,5), and the Welfare Needs (e.g., criteria 1,2,3,4,5). Further, all of these considerations are also itemised as problematic outcomes; for example, see Tables 7, 8, 9, 10, 11, 12.

4.5.4 Endothermic animals

Endothermic animals (birds and mammals) frequently have certain features in common. In particular, these features include: high energy demands due to strong physiological heat production; large social groupings; and parental care. Again, anticipating or providing for these features can be extremely difficult to manage. Endothermy is a high-cost biological system that infers corresponding high intake of food as fuel. In turn, this need for fuel places strong demands on food gathering and eating, which when mixed with strong social and other needs, require energetic-loop lifestyles [152]. Even short period deficits in food can result in hunger, aggression, and cannibalism, loss of physiological condition, and poor health. Large social groupings imply a strong need for animals to be with multiples of their own species, especially within a complex spatial environment in order to preserve natural interactive dynamics. Failure to provide for such dynamics holds strong prospects for psychological stress, and many if not most captive conditions are unlikely to offer the adequate environments to support all important social behaviours. Parental care is a strong characteristic of endotherms, implying a need to directly raise offspring, and can be regarded as an important expression of normal behaviour necessary for holistic welfare [234]. Relatedly, receiving parental care may be highly important to offspring [54]. Also, many birds and small mammals are crepuscular or nocturnal and, as indicated for many ectotherms, welfare implications are implied for captive animals [152]. All of these considerations hold relevance to several criteria different models; for example, nutritional, social, and behavioural needs that are imbedded within The Five Freedoms (e.g., criteria 1,3,4,5), The Five Domains criteria (e.g., 1,3,4,5), and the Welfare Needs (e.g., criteria 2,3,4,5). Further, all of these considerations are also itemised as problematic outcomes; for example, see Tables 7, 8, 9, 10, 11, 12.

4.5.5 Comparing selected biological criteria with formal husbandry guidance

The comparative examples presented in Table 13 regarding formal regulatory husbandry guidance for some species commonly kept as exotic pets (although highly incomplete and notably lacking for invertebrates) frequently present strongly contrasting information between lifestyles experienced in nature and those in captivity under the provisions of animal welfare models. When other general biological information that is essential to good welfare (as presented above regarding: 1. All animal classes, 2. Ectothermic animals, and 3. Endothermic animals) is factored-in to the selected criteria and examples in Table 13, the contrast between natural lifestyles and those in captivity is magnified.

Government stipulations using, for example the key welfare models, as indicated in Table 14, did not include guidance pertaining to invertebrates; thus, the care of these animals is essentially abandoned by legislators, despite the evidence for their sentience and welfare needs (e.g., [40, 215, 220, 224, 227, 233]). Government stipulations also frequently cited guidance in terms of provisions being 'suitable', which does not offer, require, or even promote scientific evidence-based information standards regarding biological needs or husbandry. When referencing to Zoo Standards, which are better than other standards, these are not readily used by the pet trade, regulators or general public. Governmental guidance refers to expectations that private home environments for animals should be of a higher standard than commercial conditions (e.g., [8]). However, guidance on animal care in the home is typically based on compliance with primary legislation. Primary legislation establishes broad rules and principles rather than specific husbandry guidance, thus it is frequently even more minimalistic than formal guidance for commercial sellers. Accordingly, in the absence of better formal guidance, prospective and actual keepers are likely voluntarily or otherwise directed towards widely available information provided by vested interest sectors, such as sellers and hobbyists, that frequently produce non-scientific, non-evidence-based, and inaccurate materials [46, 144, 197].

The apparent failure of the key animal welfare models and principles to safeguard pet animal welfare across numerous regions and countries is concerning, but not entirely surprising. As concluded by Burghardt [28], even in the most advanced and well-resourced situations such as the best zoos, providing for animals' complex needs is unachievable, resulting in controlled deprivation. Thus, it may be said that evolved lifestyles in nature set a very high bar that few or no protocols and provisions in captivity can reach. As indicated previously, captive lifestyles and care can probably be regarded as inadequate or poor for most species. Importantly, many exotic pet species, such as red-kneed tarantulas (*Brachypelma smithii*), clownfishes (*Amphiprion ocellaris*), bearded dragons (*Pogona vitticeps*), ball pythons (*Python regius*), lovebirds (*Agapornis* spp), and hedgehogs (*Atelerix albiventris*), are commonly presented as 'easy' animals to care for, and it may be argued that these species are supported by the most developed and available information bases [52]. However, the presence of persistent welfare problems for these commonly kept animals implicitly signals major welfare concerns for the majority of the other 13,000 or more traded and privately kept species, for which there is less available information regarding their biology and needs. Despite the challenges of meeting the natural lifestyle bar, the duty of care remains among caretakers and legislators to pursue conditions as close as possible towards safeguarding welfare for wild animals on which artificial environments are imposed, and the key models occupy an important role in this regard.

4.6 Animal-centric preferred life quality

Measuring animal welfare can be complex, and may be significantly compromised by inherent difficulties involved in assessing an animal's subjective mental state [235]. Accordingly, most elements of welfare assessment are essentially assumptive and observational [29, 231]. Whilst some issues, including basic environmental, physiological, behavioural, and clinical factors, can be strongly guided by modern species-specific biological data, understanding what an animal truly needs or prefers is not amenable to the same types of evidence-based considerations.

Preference studies are increasingly used across all animal classes as high-standard investigative methodologies for determining criteria relevant to animal welfare (e.g., [145, 199, 236–245]). Essentially, preference studies provide strong indications for motivational states. Accordingly, in some important respects, there can be few, if any, better guides to animal welfare and to necessary life quality than what an animal itself prefers to do. In this context, animal-centric preferred life quality means not merely aiming for or achieving a life worth living, but also a life that the animal would itself choose, and where it can occupy conditions capable of satisfying such motivations; hence the principle: 'open the cage doors and test its desire for freedom!'.

Some interpretative caution is required concerning animal-centric preferred life quality in that, for example, an animal may express the preference to voluntarily leave an enclosure yet become exposed to a particular threat, such as: 1. unexpected and inappropriate climate; 2. leap from a window during escape and acquire injury; 3. fail to leave an enclosure due to some underlying problem, such as physical disability, clinical disease, or behavioural compromise; or 4. become fixated on excessively consuming unnatural and eventually unhealthy foods due to certain enticing contents. Also, an animal may be provided with overly limited choices, for example, between two or more unsuitable options. Relatedly, a predatory animal might prefer to attack and kill its own prey, but this may not be a desirable outcome from a preference—the prey would prefer not to be attacked and killed by the predator.

Domesticated species, namely dogs, typically have the ability to express preferences to, for example, occupy a house or a garden at will, explore habitat over additional and large areas, accept or reject social experiences, and even largely determine when their caretaker attends to their preferences. Such preferences are largely accepted as normal conditions for the welfare of these animals. Additionally, dogs are highly affiliative species involving a strong human-animal bond [45], and much is known and locally available (i.e., via veterinarians) regarding their biology, care, and welfare. In contrast, exotic species are typically restricted or entirely prevented from expressing preferences due to forced confinement in diminutive enclosures, with presumptively controlled climates, and caretaker-assumed biological needs. Were a comparative-sized dog to be housed in facilities that were similarly restrictive for a snake then the caretaker might face prosecution for cruelty. Relatedly, many species do not possess affiliative traits, and little—or incorrect—information is available regarding their welfare biology.

Life quality (positive or negative) is arguably imbued in all animal welfare assessments and objectives, and positive or good life quality is clearly a primary target. Duration of good life quality has in itself also been suggested as a positive marker of welfare [246]. A generalised attitudinal shift towards animal-centric preferred life quality may offer a reset for welfare enhancement, and arguably assist towards the proper interpretation of the key animal welfare models, as well as other animal welfare principles.

5 Conclusions

The Five Freedoms, Five Domains, Five Welfare Needs, and other key welfare models provide relevant criteria for both fundamental and, potentially, advanced positive animal welfare safeguards. Formal or informal stipulations frequently utilise these models, or variations of them, as foundations for the protection of animals. Accordingly, these key models have clearly been successful through raising the profile of scientific and other assessments of welfare, regular inclusion in governmental and non-governmental policy, frequent citation, setting guidance standards, and inspiring consideration of welfare issues within a wide variety of situations.

However, despite the adoption of and claimed commitment to these welfare models, wild animals across all classes frequently experience commercial practices and husbandry conditions that manifestly do not meet either the aspirational or outcome-led principles integral to any welfare model summarised herein. These failures raise serious concerns on at least two grounds. First, biological (including physical and mental) requirements that are essential to animal welfare are being poorly, or at least inconsistently, met. Relatedly, such deficiencies in the hard application of these models probably cause significant stress, morbidity, and mortality for animals. Second, by not strongly applying available welfare models, government authorities, commercial entities, and animal keepers, are probably not fulfilling, and in some cases are potentially directly breaching, both formal legal provisions and / or ethical criteria for protecting animal welfare. Moreover, when compared with other welfare principles, as presented earlier, some key welfare models manifestly and largely fail both hypothetical and applied tests. Regardless of actual performance in securing or improving animal welfare, it is probably also the case that reliance on these common welfare models may invite regulatory complacency through over assumption of compliance and effectiveness. In summary conclusion, with regard to how well the Five Freedoms, Five Domains, Five Welfare Needs and other models are serving exotic pet welfare, it may reasonably be said that in both the contexts of evolved biological needs and scientifically documented outcomes of concern, these models, as currently applied, may fail to serve animal welfare well, or even entirely.

Robust application of Five Freedoms, Five Domains, Five Welfare Needs, or other commonly cited approaches such as the three ethical concerns, holds the capacity to alleviate or rectify many of the current major concerns inherent to exotic pet trading and keeping, and indeed to wider animal welfare issues. However, our assessment of the application of these models suggests that formal authorities and others that are responsible for implementing these welfare-protection systems currently aim for an overly minimalist interpretation. This interpretation undervalues numerous provisions within the key welfare models, and probably stems from compromises that disfavour animals and welfare science in favour of the facilitation of pet trading and keeping. Such favouritism towards pet trading and keeping wrongly undermines the purposes and designs of the welfare models. Accordingly, attitudinal, applied, and outcome-led shifts are required, and scientifically warranted, to refocus priorities to animal welfare as the centralised and mandatory objective of any and all animal welfare models and principles. With respect to these shifts, we provide recommendations that redirect priorities to promote animal-centric preferred life quality as a unifying theme for legislation and practice.

6 Recommendations

1. Animal welfare and not the facilitation of any pet selling or keeping practices should constitute the centralised and mandatory objective in the use of relevant models and principles.
2. Modernised interpretation and robust enforceable application should be urgently and universally promoted in the use of existing and future animal welfare models and principles.
3. Animal welfare models, principles, and criteria should aim to promote animal-centric preferred life quality.
4. Governments should develop legally enforceable detailed husbandry guidance and welfare assessment protocols using primarily objective scientific evidence-based information from independent non-vested interest parties to instruct both commercial and private sectors to better ensure the conveyance of key animal welfare models, principles, and outcomes.
5. Updating models, principles, and criteria should be underpinned by evolving scientific knowledge.
6. Precautionary principles should be instituted where uncertainty exists on welfare issues, thus applying the benefit of doubt to any animal in any situation.

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