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Regulating pets using an objective positive list approach

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ABSTRACT

Pet trading and keeping globally involves at least 13,000 species, and at least 350 million individual nondomesticated or "wild pet" animals annually. In addition, over 445 million domesticated dogs and cats are thought to occupy homes worldwide. Several major problematic concerns are associated with pet keeping, in particular linked to nondomesticated or wild pet forms, including: animal welfare; species conservation; public health and safety; antimicrobial resistance; agricultural animal health; invasive alien organism introductions; and poor information uptake by the public. Regulation of both domesticated and wild pets characteristically involves negative list systems, under which all trading and keeping problems continue to burgeon. Negative lists involve the itemization of animal types that are monitored, restricted or banned in the context of trading and keeping, with all nonlisted animals essentially being unregulated. In contrast, positive lists involve the itemization of animal types that are permitted for trading and keeping, with all nonlisted animals essentially being barred. Compelling rationales, as well as an important scientific evidence-base, strongly indicate replacement of historically common negative list approaches with objective positive list systems to better regulate the sale and keeping of both wild pet and domesticated pet animals. This report aims to produce a novel method for developing positive lists that meets several criteria that we considered to be fundamental to a robust decision-making protocol: operational objectivity; quantitative algorithm design; no or negligible consensus-based decision-making; binary results; independent repeatability; user-friendliness; resource efficiency; optional use alongside other methods.

Introduction

Pet trading and keeping globally involves at least 13,000 species (Warwick et al., 2018), and at least 350 million individual nondomesticated or "wild pet" animals annually (Karesh et al., 2005). Although annual trade volumes for domesticated species are unclear, over 220 million dogs and over 225 million cats are thought to occupy homes worldwide (Anon, 2020). According to country, pet keeping habits and populations vary, but for example, in United States households there are over 200 million pet fishes, reptiles, birds, and small mammals, and over 94 million dogs and 90 million cats (Anon, 2020), and in UK households there are over 33 million pet fishes, reptiles, birds, and small mammals, and over 9 million dogs and 7 million cats (PFMA, 2020). Thus, trading and keeping animals occurs on a large scale, making regulation an important area. Animals such as dogs and cats are commonly recognized for their domesticated status. However, other species are variously referred to as "non-domesticated," "exotic," "non-traditional," "non-native," "wild," or "wild pet" animals, whether of wild-caught or captive-bred origin (Décory, 2018). For this article, we will adopt the term 'wild pet' (ENDCAP, 2012) as a broad term for nondomesticated species.

Wild pets include all invertebrates, fishes, amphibians, and reptiles, as well as most birds and most mammals (Warwick et al., 2014; Décory, 2019). Domesticated pets include dogs and cats, as well as (arguably semi-domesticated) fowl, rabbits, guinea pigs, and small rodents (Warwick et al., 2014; McBride, 2017; Décory, 2019). Several areas of major concern are recurrently described in the scientific literature regarding consequences of pet trading and keeping, in particular involving: animal welfare; species conservation; public health and safety; antimicrobial resistance; agricultural animal health; invasive alien organism introductions; and poor information uptake by the public. Positive lists for pet regulation are recognized by numerous governmental and nongovernmental agencies to offer important proactive approaches that preventatively alleviate common problems and im-

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prove management efficiency (e.g., in Europe, Di Silvestre & van der Voeven, 2016; Croatian Ministry of Environment Ordinance, 2017; Government of Flanders, 2018; Government of Malta, 2017; Grand-Duché de Luxembourg, 2018; Norway, Toland et al., 2020, and in North America, New Brunswick Government, 1992; New Jersey Government, 1995; Delaware Government 2010; Utah Government, 2018; Rhode Island Government, 2020). In contrast, negative lists are reactive measures instituted following the widespread occurrence of significant harms that require reparatory or ongoing managemental efforts, and all recognized problematic issues have persisted under this system (Toland et al., 2020). We will briefly introduce each of these concerns (which are not ordered to indicate priority) before turning to regulatory issues.

Aims

This report aims to: (a) present and discuss key available methodologies relevant to the development of positive lists; (b) discuss potentially important principles and scenarios for positive list design; and (c) outline a novel methodological option for developing positive lists.

Literature review

Animal welfare

Numerous reports summarize a raft of problematic animal welfare factors associated with pet keeping (Laidlaw, 2005; Toland et al., 2012; Bennett and Howell, 2013; Koch et al., 2013; Warwick et al., 2014; Auliya et al., 2016; Grant et al., 2017; Howell and Bennett, 2017; Moorhouse et al., 2017; Warwick et al., 2018; Alves et al., 2019; Benn et al., 2019; Howell et al., 2020). Both wild pet and domesticated pet animals are now widely considered to warrant recognition for their capabilities to experience sentience (Mendl et al., 2017; Lambert et al., 2019; Learmonth, 2020), pain, (Broom, 1991; Mason et al., 2013; Mendl et al., 2017), emotions (Mellor, 2012; Burghardt, 2013), and stress (Broom & Johnson, 1993; Mendl, 2001; Morgan & Tromborg, 2007), as well as having needs to express normal behavior (Dawkins, 1990; Mendl et al., 2017), experience spatio-environmental enrichment (Burghardt, 2013; Mendl et al., 2017; Warwick et al., 2019), psychological stimulation (Clubb and Mason, 2007; Mendl et al., 2017), sociality (Kleinhappel et al., 2016; Mendl et al., 2017; Brakes, 2019), control over their environments, and other requirements that are central to positive states and good welfare (Mellor, 2015; Mellor & Beausoleil, 2015; Mellor, 2017; Mendl et al., 2017). Without care-based recognition of all the above elements and fulfilment of welfare needs, suffering can be presumed (Dawkins, 1990; Broom, 1991; Broom & Johnson, 1993; Mellor, 2015; Mellor & Beausoleil, 2015; Mellor, 2017; Mendl et al., 2017). Accordingly, it is important that all these requirements are reasonably met for any species if it is to be considered suitable for keeping as a pet.

Among wild pets, there are prevalent problematic welfare issues, including, captivity-stress, abnormal behaviors, and stress-related morbidities (Cowan, 1980; Frye, 1991; Warwick, 1995; Warwick et al., 2013; Martínez-Silvestre, 2014; Whitehead, 2018; Warwick et al., 2019), and premature mortalities are also widely reported during marine ornamental fish capture and handling (Millar, 2013; Pouil et al., 2020), and while in private homes (Millar, 2013; Biondo & Burki, 2020). Reptiles in the home also experience high mortalities of approximately 75% per year (Toland et al., 2012). Global transportation can involve significant losses of 5%-100% across a range of species (Steinmetz et al., 1998; Laidlaw, 2005; McLennan, 2012; Collard, 2020). Stress and malhusbandry in wholesale environments have been found to cause 70% mortality within 6 weeks (Ashley et al., 2014; Warwick, 2014). Stress, behavioral problems and disease are recognized in domesticated dogs and cats, which can be specific to certain breeds (Howell et al., 2016a,b). However, despite significant breed-associated problems, longevity across dogs in general is typically consistent with natural potential lifespan (Michell, 1999). Semi-domesticated species (e.g., rats and mice) are also known to manifest captivity-associated stress, behavioral problems and disease (McBride, 2017). Accordingly, to varying degrees, all pets may suffer frequent negative welfare, although evidence-based information and understanding for species biologies, husbandry, and veterinary science are most deficient where wild pet animals are concerned (Whitehead & Forbes, 2013; Whitehead, 2018).

Species conservation

Many reports highlight the wild pet industry as an important species conservation threat (e.g., Auliya, 2003; Nekaris et al., 2010; Rosen & Smith, 2010; McLennan, 2012; Rhyne et al., 2012; TRAFFIC, 2012; Baker et al., 2013; Böhm et al., 2013; Bush et al., 2014; Rowley et al., 2016; Berkunsky et al., 2017; Biondo, 2017; Mendiratta et al., 2017; Biondo, 2018; Martin et al., 2018; Morgan & Chng, 2018; Frank & Wilcove, 2019; Scheffers et al., 2019). The majority of wild pet species and individuals are wild-caught (Yan, 2016; Smith et al., 2017). Some exotic animal species are captive-bred in ranches via open-cycle systems where wild animals supplement breeding stock, and others are farmed via closed-cycle systems involving no wild animal collection. However, welfare concerns regarding intensified production methods remain, for example, severe spatial limitations, lack of enrichment, and behavioral deprivations (Warwick, 2015; Tensen, 2016; Greggor et al., 2018) and captive-breeding occurs alongside or even exacerbates wild-caught trade. In addition, some animals claimed as captive-bred may also be wild-caught individuals (TRAFFIC, 2012). Many species in trade are not subject to any legislative protection or monitoring, although implied risks of unsustainability continue to be relevant because, for example, animal collectors may report declines in harvest or having to harvest over wider areas to maintain collection levels (Warwick, 2014; Warwick, 2015; Biondo, 2017; Hierink et al., 2020).

Public health and safety

Zoonotic and other animal-to-human infections are strongly implicated in global disease (Krauss et al., 2003; Brown, 2004; Kruse et al., 2004; Karesh et al., 2005; Chomel et al., 2007; Brugere-Picoux & Chomel, 2009; Aiken et al., 2010; Hale et al., 2012; Karesh et al., 2012; Nenoff et al., 2012; Smith et al., 2012; Zarecki et al., 2013; Broens & van Geijlswijk, 2018), including the most significant pandemics, for example, Spanish flu (1918), Asian flu (1957-1958), HIV-AIDS (1981-present), swine flu (2009), and SARS-Cov-2 (2019-present), with each of these pandemics causing approximately 50 m, 1.1 m, 30 m, 150,000-575,000, and >2.4 m deaths, respectively (Bean et al., 2013; CDC, 2020a,b; Lau et al., 2020; Sharp & Hahn, 2011; Gibbs et al., 2009; WHO, 2020a,b; Xiao et al., 2020), and both established and emergent human infections can be linked to wild animal species (Brown, 2004; Chomel et al., 2007). In addition, injuries to humans are associated with both wild pet species (Warwick & Steedman, 2012; Ng et al., 2018) and domesticated dogs and cats (De Keuster & Overall, 2011; Babovic et al., 2014). Antimicrobial resistance is an additional concern arising from overuse of chemical therapeutic and prophylactic measures, including treatment of widespread diseases across the privately kept pet spectrum and among commercial producers and

handlers, notably by the ornamental fish trade (Rose et al., 2013; Broens & van Geijlswijk, 2018).

Agricultural animal health

Several pet-related epidemic and pandemic infections have resulted in major negative consequences for agriculture, with imported wildlife being a significant contributor, for example the near introduction of heartwater disease (*Ehrlichia ruminantium*) to cattle in the United States by imported African tortoises (Clarke, 2001; Spickler, 2015a), avian influenza (H5N1) circulated among farmed poultry globally via free-living and pet birds (Dudley, 2006; CDC, 2018; OIE World Organization for Animal Health, 2020a,b,c), and Newcastle disease (*Paramyxovirus*), circulated among farmed poultry globally via free-living and pet birds (WHO, 2020c).

The combinations of atypical or novel pathogens invading agricultural facilities, as well as the use of intensive animal production systems are relevant to major and catastrophic outcomes in which entire farm stocks may be routinely culled (Chomel et al., 2007; Jones et al., 2013; Tarazona et al., 2020).

Invasive alien organism introductions

Pet animals that escape or are released can adopt invasive potential as either novel predators or resource competitors - or both (Rebelo et al., 2010; Vilà et al., 2010; Henderson & Bomford, 2011; Keller et al., 2011; Langton et al., 2011; Simon et al., 2011; Kubiak & Pellett, 2018; Hierink et al., 2020). Introduced species may also act as carriers of invertebrate pests and microbial infections to indigenous animals, as now notoriously evidenced in the case of the amphibian fungal pandemic, chytridiomycosis (*Batrachochytrium* sp.) (Fisher & Garner, 2007; Spickler, 2015a,b; Fisher & Garner, 2020). Free-roaming dogs (Home et al., 2018) and cats (Loss et al., 2013) can also become invasive organisms, because they may affect wild populations and threaten species conservation. In Europe alone invasive species management is estimated to cost approximately 13.5 billion Euros annually (European Commission, 2008, 2011), and globally invasives may cost hundreds of billions of dollars per year to manage (Strayer et al., 2006; Shine et al., 2010).

Poor information uptake by the public: educational challenges

Increasingly, attention is being drawn to challenges in educating sellers and keepers of animals as pets, with poor information uptake being a regular problem (Whitehead & Vaughan-Jones, 2015; Grant et al., 2017; Howell & Bennett, 2017; McBride, 2017; Moorhouse et al., 2017; Warwick et al., 2018; D'Cruze et al., 2020a). Educational challenges are compounded by several factors. For wild pet animals, there is a particular dearth of evidence-based information pertaining to biological and husbandry specifics (Whitehead & Vaughan-Jones, 2015; Mendyk, 2018; Warwick et al., 2018). Misinformation is circulated by traders and hobbyists that grossly understates known physiological, psychological and behavioral complexities of animals, and thus their care requirements (Warwick et al., 2018). Ingrained, handed-down, simplistic, non-evidence-based trial and error care practices permeate pet trading and keeping communities (Mendyk, 2018; Warwick et al., 2018). Information that is scientifically based, and perhaps more importantly, conflicts with incorrect commonly poor husbandry may be poorly adopted among prospective and actual keepers and presents a barrier (Abbott et al., 2012; Warwick et al., 2018; Warwick et al., 2019), where bad practice becomes normalized (Grandin, 2015). In whatever proportions, these factors variously contribute to poor biological understanding and husbandry, which is common among both trade and keeping sectors, and compliance with basic evidence-based guidance is lacking (Whitehead & Vaughan-Jones, 2015; Grant et al., 2017; Howell & Bennett, 2017; McBride, 2017; Moorhouse et al., 2017; Warwick et al., 2018; D'Cruze et al., 2020a).

Regulatory issues

Regulatory agencies aim to manage the aforementioned issues with technically viable and procedurally defensible systems. Many regulatory mechanisms exist at local, national, and international levels that are relevant to all aspects of wild pet and domesticated pet trading and keeping (Jeffery et al., 2008; OECD, 2019; Toland et al., 2020). The majority of these mechanisms involve negative lists, in which certain species, or activities relating to certain species, are intentionally controlled via the itemization - listing - of particular animals as restricted or banned in a given context (Jeffery et al., 2008; OECD, 2019; CITES, 2020; Toland et al., 2020). An additional approach is to promote market reduction, by education and enforcement in order to shrink the functional landscape of trade and facilitate easier identification of illegalities and other problems (Schneider, 2008; Ayling, 2015). Below, we briefly discuss negative lists and their prominent role in regulating both wild pet and domesticated animal trading and keeping, before focusing on positive lists as an alternative management policy.

Negative lists

Regulatory methodologies relevant to animal welfare, species conservation, and ecological protection associated with pet trading and keeping characteristically embody a “negative list” principle. Negative lists involve the itemization of animal types that are monitored, restricted or banned in the context of trading and keeping, with all nonlisted animals essentially being unregulated. In principle, this approach allows trading and keeping animals until substantive contradictory evidence is agreed adequate (often pivotally requiring acceptance by animal use sectors) to counter existing practices, at which point bans may be imposed (Warwick et al., 2018; Toland et al., 2020). Negative lists of banned species have been successfully used to control, for example, wildlife trade (D'Cruze et al., 2020b; Toland et al., 2020). The primary negative list-based regulatory system for monitoring and controlling wildlife trade is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES historically emerged from agreements between regulatory authorities and vested interest traders of wildlife (Hoyt, 1994), and given the operational trade-biases inherent in the approach, it is understandably favored by trade sectors.

Although it has been shown that while the negative list approach can work in selected cases, its historical record (as notably implemented via CITES) is frequently problematic, including administrative inefficiencies (Mair et al., 2019), and incomplete reporting compliance (Moorhouse et al., 2017). In any event, wildlife trade, and all of its attendant problems, for example, ecologically destructive collection practices such as use of dynamite blasting and cyanide stunning for fish capture, threats to conservation due to over-collection of animals from nature, inhumane capture and transportation methods across all species, and captivity-stress-associated morbidity and mortality in wholesale, retail and home environments, continue to burgeon under current negative list systems (Nekaris et al., 2010; Rosen & Smith, 2010; Toland et al., 2012; TRAFFIC, 2012; Baker et al., 2013; Böhm et al., 2013; Ashley et al., 2014; Bush et al., 2014; Daut et al., 2015; Moreto & Lemieux, 2015; Saxena, 2015; CBD, 2016; Petrossian et al., 2016; Rowley et al., 2016; Berkunsky et al., 2017; Biondo, 2017; Frey & Berkes, 2017; Kurland & Pires, 2017; Mendiratta et al., 2017; Vaz et al., 2012; Biondo, 2018; Martin et al., 2018; Morgan & Chng,

2018; Frank & Wilcove, 2019; Kolby, 2019; Scheffers et al., 2019; Eskew et al., 2020; Lieberman, 2020; Pouil et al., 2020).

Commercial practices are systematically and persistently driven by free-trade approaches and financial incentives, whereas research and reporting of trade-contradictory evidence is relatively limited to sporadic investigatory projects that arise on an ad hoc basis (Warwick, 2014). Accordingly, investigations and evidence-gathering regarding species sustainability in trade is both reactive and occasional compared with continuous trade activities. Relatedly, there is no dedicated system that provides consistent and proportionate funding to consider the assignment of species to negative lists, thus local or global trade in animals is essentially documented on an arbitrary basis, and with little or no mandatory monitoring or control. Therefore, trade practices significantly outpace research and regulation. Relatedly, where research is adequately funded and documented, barriers including political inertia and frequent disproportionate governmental leniency toward traders, along with industrial sector counter efforts, commonly obfuscate, delay, or obstruct evidence-based recommendations for protection (Warwick, 2014). These barriers allow traders to maintain harmful practices either indefinitely or until alternative similar resources are identified, thus renewing the problematic cycle of being "locked-in" to poor regulatory practices.

Positive lists in industry and society

In contrast to negative lists, which name animal species that are not permitted to be kept as pets, thus enabling all others to be legally kept as pets, positive lists take the opposite approach. Accordingly, positive lists involve the itemization of animal types that are permitted for trading and keeping, with all nonlisted animals essentially being barred. Essentially, positive lists are permissive regulatory systems requiring strict criteria assuring compliance with essential safeguards pertaining to, for example, animal welfare, human health and safety and environmental protection (Warwick et al., 2018; Toland et al., 2020). At their roots, positive lists are precautionary approaches enabling endorsement of people, products or procedures that satisfy relevant criteria. Thus, people in certain positions of responsibility (e.g., doctors, veterinarians, pharmacists, pilots, as well as commercial and ordinary vehicle operators who must first hold verified permits) and others, are obliged to meet relevant training, qualifications and other standards prior to acquiring permission to operate. Similarly, products (e.g., aircraft, marine vessels, cars, buildings, drugs, electrical goods, and diverse protocols) are also required to meet acceptable operational conditions (Warwick et al., 2018; Toland et al., 2020). Accordingly, the precautionary principles of positive lists are embodied in most aspects of societal and industrial sectors, and the burden of proof is normally placed on the proponent of products or practices to objectively demonstrate their integrity. Given the extensive problematic issues associated with pet trading and keeping, and the failure of negative lists to reactively control these problems, the application of the precautionary positive list principle in this context is particularly relevant and timely.

Thus, the remainder of this report aims to produce a novel method for developing positive lists for pet trading and keeping that meets several criteria that we considered to be fundamental to a robust decision-making protocol: operational objectivity; quantitative algorithm design; no or negligible consensus-based decision-making; binary results; independent repeatability; user-friendliness; resource efficiency; optional use alongside other methods.

Methods

A literature search was conducted via standard engines Google and Google Scholar (since 2000), using the following key words and combinations: "positive list" + "pet" + "regulation" + "suitability," and involving the first 10 result pages for each search. We aimed to identify peer-reviewed scientific methodologies for assessing the suitability of animal species as pets. Following deselection of items not containing a scientific method for assessing suitability of species, 4 peer reviewed reports remained. We further examined the 4 published scientific methodologies and offered a determination for each in terms of relevance, objectivity, consensus involvement, and user-friendliness, and we summarize findings in Table 1 and further in the Results and Discussion section.

Results and Discussion

The literature search identified a total 49 items of the following origins: 5 scientific (e.g., peer-reviewed journal or book), including the 4 identified reports cited in Table 1; 7 semi-scientific (e.g., veterinary documents, letters in veterinary journals, or reports by nongovernmental stakeholders); 9 governmental (e.g., administrative proposals and reports); and 28 nonscientific (e.g., media reports and website articles). Although the literature search found that positive lists are liberally referred to in publications, their mention typically discusses principles of operation and examples of use, rather than introducing or reviewing methodologies for applying the concept as workable regulatory tools. However, the 4 reports listed in Table 1 differ significantly from other materials relevant to positive lists in that they include specific methodologies for assessing the suitability of species as pets.

Current positive list methodologies: relevance, objectivity, consensus involvement, and user-friendly abilities

The 4 identified methodologies with references to the suitability of animals for keeping as pets, and with stated or implied relevance to the development of positive lists, were authored by: Schuppli and Fraser (2000); Schuppli et al. (2014) Warwick et al. (2014); and Koene et al. (2016). Schuppli and Fraser (2000) provides a framework for assessing the suitability of different species as "companion" animals, based on a self-assessment checklist containing 12 awareness- raising questions concerning animal welfare, human health and safety, species conservation threats, and invasive species potential. The framework has broad application across its range of subjects, but is aimed mainly at scientific professionals thus requiring qualified analyses, and strongly uses open questions that invite variable, nonbinary, responses.

Schuppli et al. (2014) provides a discussion that prioritizes 4 key welfare factors that constitute a checklist promoting that pet animals: "function well biologically," are "free from negative psychological states," are "able to experience normal pleasures," and are able to "lead reasonably natural lives." The method also considers risks from zoonotic infection as well as invasive species potential. Thus, the method provides a broad guide to pet suitability and again strongly uses open questions that invite variable, nonbinary, responses. Warwick et al. (2014) provides a pet suitability algorithm called "EMODE," that categorizes animals as "easy," "moderate," "difficult," or "extreme" according to degree of challenge in relation to securing animal welfare and human health and safety factors. The method provides 6 questions that accrue points generating an overall score relating to the degree of ease or difficulty to keep a species. The method is intended to be user-friendly and scientific. Thus, the method provides species- and breed-specific determinations regarding pet suitability, and uses

Table 1
Summary of four methodologies (by author names) relevant to the development of positive lists (based in part on reviews in Warwick et al., 2018).

Methodology			
Schuppli and Fraser, 2000	Schuppli et al., 2014	Warwick et al., 2014	Koene et al., 2016
Target users			
Primarily scientific/experienced users	Primarily scientific/experienced users	Layperson- scientific/experienced users	Scientific/experienced users
Animal scope			
All classes	All classes	All classes	Mammals (possibly all vertebrate classes)
Issues relevant			
Animal welfare Public health & safety Invasive species	Animal welfare Public health & safety Invasive species	Animal welfare Public health & safety	Animal welfare Public health & safety Invasive species
Evidential threshold required			
Moderate-high	Moderate-high	Moderate	Very high
Information input determination			
('low', 'moderate', 'high' indicates degree of input required to allow determination of species suitability)			
Qualitative-based (high) Primarily factual (high) Experiential/knowledge-based judgement (moderate-high)	Qualitative-based (high) Primarily factual (high) Experiential/knowledge-based judgement (moderate-high)	Quantitative-based (high) Primarily factual (high) Experiential/knowledge-based judgement (low)	Quantitative-based (high) Primarily factual (high) Experiential/knowledge-based judgement (high-very high)
Potential to meet robust criteria			
(operational objectivity, quantitative algorithm design, no or negligible consensus-based decision-making, binary results, independent repeatability, user-friendliness, resource efficiency, and optional use alongside other methods).			
Operational objectivity			
Potentially yes (but may involve vulnerability to degree of objectivity or subjectivity of assessor)	Potentially yes (but may involve vulnerability to degree of objectivity or subjectivity of assessor)	Yes/no (but may involve some vulnerability to degree of objectivity or subjectivity of assessor)	Yes (but may involve some vulnerability to degree of objectivity or subjectivity of assessor)
Quantitative algorithm design			
No (uses both open, qualitative and closed quantitative questions)	No (does not include an algorithm)	Yes (uses closed quantitative questions)	Yes (but uses both open qualitative and closed quantitative questions)
No or negligible consensus-based decision-making			
No (includes experiential decision-making, thus results may be highly variable)	No (includes experiential decision-making, thus results may be highly variable)	Yes (excludes experiential decision-making, thus results minimally variable)	No (includes experiential and consensus decision-making, thus results minimally variable)
Binary results			
Yes/no (uses both open, qualitative and closed quantitative questions)	No (uses open, qualitative questions)	Yes (uses closed, quantitative questions)	No (uses both open qualitative and closed quantitative questions)
Independent repeatability			
No (inclusion of experiential decision-making and lack of non-binary responses potentially confounds repeatability)	No (inclusion of experiential decision-making and lack of non-binary responses potentially confounds repeatability)	Yes (due to closed quantitative questions)	Potentially yes, potentially no (due to use of both open qualitative and closed quantitative questions and consensus decision-making)
User-friendliness			
Yes (for biological professionals)/ = no (for ordinary users)	Yes (for biological professionals)/ = no (for ordinary users)	Yes (for both biological professionals for ordinary users)	No (intended for biological professionals
Resource efficiency			
Yes (requires only competent persons and moderate access to scientific literature)	Yes (requires only competent persons and moderate access to scientific literature)	Yes (requires only competent persons and moderate access to scientific literature)	No (requires competent persons and extensive access to and processing of scientific literature)
Optional use alongside other methods			
Yes (inherent points of principle may complement other methods)	Yes (inherent points of principle may complement other methods)	Yes (inherent points of principle may complement other methods)	No (self-contained system)

closed questions that invite minimally variable or binary responses. Koene et al. (2016) provided an algorithm-based decision tree to evaluate species suitability for pets. The method requires collation and evaluation of species-specific scientific literature regarding animal biology, behavior, husbandry, welfare, health, zoonoses, and human-animal relationship as input for into the algorithm. The framework has specific application across its range of subjects, but is aimed mainly at scientific professionals rather than nonbiologists, thus requiring qualified analyses, and strongly uses open questions that invite variable, nonbinary, responses.

The 4 methods were determined to be capable of variously assisting in the regulation of animal welfare, species and ecological protection, and public health and safety issues, which we summarize in Table 1 and discuss further.

Accordingly, in our assessment, all 4 reviewed systems hold merit and relevance to the development of positive lists. However, we considered that no single method met all of our Aims criteria. Differences across governments in terms of perspectives, policy approaches, and legal frameworks, and susceptibility to challenge, imply correspondingly necessary variations in administrative need. Therefore, no single positive list system may be viable for all government frameworks. Accordingly, options in terms of methodological design and application of positive lists are important considerations. Administrative acceptability of a framework might depend on numerous factors, including a particular required level of implied scientific rigor to attain governmental and public confidence, operational transparency to assure understandability of a process, use and resource efficiency to proportionalize costs, localized species-specific competencies to ensure relevant oversight securities, and legal defensibility to avoid or rebut challenges. Arguably, therefore, the most robust methods of principle for developing positive lists for animals as pets are those that involve

Table 2
Suitability of animal/species for inclusion on positive lists (itemization of animal types that are permitted for trading and keeping as pets, with all non-listed animals essentially being barred). Animal must pass all criteria for inclusion on a positive list.

Animal/species	Criteria relevant to the animal and species considerations (animal welfare, species conservation, and sustainability) Common name Scientific name	
Criteria	Rationale	*Satisfies criterion?*
1. Animal/species must be suitable to keep in the context of social needs.	To protect animal welfare, certain animals require pairings or large groups for their wellbeing: animal must not have high social dependence/large group needs that cannot be accommodated in the domestic environment. Species scientifically described as naturally pairing or occupying social groups meet this criterion.	√ / ✗
2. Animal/species must be suitable to keep in the context of normal behavioral activity patterns and observability.	To protect animal welfare, animal must not be naturally nocturnal or crepuscular: humans are habitually diurnal (normally active in daytime) and cannot normally observe the behavior and welfare state of animals habitually nocturnal or crepuscular (normally active at night or at twilight); also these different activity periods may cause disturbance to nocturnal or crepuscular animals and thus affect their welfare.	√ / ✗
3. Animal/species must be suitable to keep in the context of space.	To protect animal welfare, some animals have innate regular needs to wander great distances that cannot be met in captivity; animal must not naturally occupy a large home range or manifest innate environmental transientism beyond spatial scope of typical domestic dwelling unless there is regular access to additional activity or exercise areas.	√ / ✗
4. Animal/species must be suitable to keep in the context of origin.	To protect animals and their populations in the sourcing and supply, chain including capture welfare and species conservation: animals must not be listed as vulnerable, threatened or endangered; animal must originate only from governmentally- or independent scientifically-approved captive-bred sources.	√ / ✗
5. Animal/species must be suitable to keep in the context of government or agency expert oversight.	To protect animal welfare, governmental/relevant agencies must possess staff with wholly objective high-level relevant scientific qualifications and experience to reliably investigate and oversee all aspects of biological and husbandry factors on a species-/animal type-relevant basis; governmental/relevant agencies must only approve animals where relevant oversight can be assured.	√ / ✗
	Criteria relevant to public and environmental considerations (public health and safety, agricultural animal health, and environmental considerations)	
6. Animal/species must be safe to keep in the context of size, weight, aggression, defensive attributes, and toxicity.	To protect human safety from kept animals, animal must not present relevant risk: animal must not be formally recorded as a dangerous wild animal or similar description (relevant if animal is identifiably recorded in any country).	√ / ✗
7. Animal/species must be safely handled in an emergency	To protect human handlers in an emergency where animals must be moved quickly and humanely: animal must be of a type not normally as adults exceeding 10kgs (for wild predatory species), 25kgs (wild non-predatory species), or 50 kgs (domesticated species), it should be presumed that an animal will attain full maturity and size, and that wild animals are likely to be physically less manageable, for example in an emergency when rapid evacuation from a building is necessary. Large pet animals such as horses exceed the 50kg criterion, but because these animals do not occupy a normal domestic dwelling, the limit is not applicable.	√ / ✗
8. Animal/species must be safe to keep in the context of zoonotic and other animal-human infections.	To protect human health: animal must not present relevant risk of harbouring zoonotic or other animal-human infections that cannot be prevented through vaccines and other veterinary measures; and animal must not be referenced in any regional register as a notable infection risk; and animal must not score above low risk in any available peer-reviewed scientific public health or safety risk assessment.	√ / ✗
9. Animal/species must be safe to keep in the context of agricultural animal pathogens.	To protect agricultural animal health and regional ecologies: animal must not present relevant risk for zoonotic and other agricultural animal infections that cannot be prevented through vaccines and other veterinary measures. Animal must not present risk of infection to agriculture via direct contact, or via indirect contact due to intermediate human or other animal hosts, such as pet keepers who work at centers of domesticated animal production.	√ / ✗
10. Animal/species must be safe to keep in the context of introduction and becoming environmentally invasive organisms.	To protect environment health: animal must not be referenced in any regional register as a regionally invasive species. Species present risk of invasion where there are sufficient environmental elements for adaptation. Thus, regional, rather than global, lists of invasive species are relevant, and which may or may not include established rather than novel introductions (e.g. domesticated cats may be introduced but not considered novel invasives).	√ / ✗
Pass/fail		

scientific evidence-based criteria, clear user-friendly operation, and no consensus or opinion-guided basis in determinations. Below are 2 scenarios out-lining problematically subjective methodological elements that could confound determinations for including species suitable for positive lists.

Problematic scenario 1. Independent expert committee using qualitative methods that require opinion or consensus-based determinations.

A regulatory agency assigns an independent expert committee (presumably composed of relevantly qualified and experienced scientists with no competing interests) to apply experiential- and knowledge-based judgements to qualitative criteria in order to assess species suitable for inclusion on positive lists.

Problematic scenario 2. Multistakeholder committee using qualitative or quantitative methods that require consensus-based determinations

A regulatory agency assigns an approved multisector committee (presumably composed of both relevantly qualified and experienced scientists with no competing interests as well as stakeholders with competing interests) to apply consensus agreement in order to assess species suitable for inclusion on positive lists.

In Scenario 1, the qualitative opinion- or experiential-based approach involves inherent variabilities regarding interpretation or

evaluation of information pertinent to species. Therefore, determinations regarding inclusion of species on positive lists may differ between such expert committees, and thus lack defensive scientific consistency. In Scenario 2, the same variability of determinations may occur, with the additional problematic element that arrival at agreed interpretations and determinations may follow various degrees of debate, sector perspectives, and compromises rather than from an impartial and objective evidence-base.

Accordingly, both Scenarios 1 and 2 involve several problematic scientific or administrative issues, including: user variability; results repeatability; unreliable or discriminatory determinations (especially where stakeholders with competing interests are involved), and exposure to validity challenges. Such issues would not meet the aforementioned standards for required level of implied scientific rigor to attain governmental and public confidence, operational transparency to assure understandability of a process, use and resource efficiency to proportionalize costs, localized species-specific competencies to ensure relevant oversight securities, and legal defensibility to avoid or rebut challenges.

Objective-based methodology for development of pet-related positive lists

As indicated above, assessments of animals regarding their suitability or otherwise for inclusion on positive lists requires determination by individual assessors, given that no automated system is available. Differences pertaining to knowledge-base, experience, gross or subtle conflicting interests, and cognitive bias, among other factors, imply that decision-making may be significantly affected by individual subjectivity regarding whether or not animals meet relevant criteria. Such subjectivity has been a matter of foundational and deterministic concern within both the scientific and jurisdictional sectors. Accordingly, the use of factually verifiable, rather than individual experiential or consensus-based, approaches are arguably fundamental to ensuring consistency in determinations and thus repeatable results and decision-making.

It is important to emphasize the value of selecting the 7 criterial principles as key to this proposed methodology for development of pet-related positive lists. *Operationally objective*, *quantitative algorithmic* methods that involve *no or negligible requirement for consensus-based decision-making* with *binary*, *independently repeatable, results*, provide for closed questions and closed responses, thus minimizing or eliminating variability and subjectivity, promoting systematic transparency, and simplifying administrative processes. These criterial principles are arguably essential in order to provide independently verifiable and defensible determinations, especially where challenges to systems are anticipated. *User-friendly*, *resource efficient* approaches that are *optional alongside other methods*, promote operational transparency, avoid administrative over-burden, and accommodate greater variation of policy need among regulatory agencies. Understandably, the public may expect that governing agencies ought not to include species on positive lists for which they do not possess full oversight competence. Accordingly, an additional reasonable factor may involve local agencies wishing to limit suitable species to those for which they possess wholly objective internal expert competence. Also, education and regulation efforts that reduce demand, both for species diversity (Whitehead & Forbes, 2013; Warwick et al., 2018), as well as general volume of animals (Schneider, 2008; Ayling, 2015), are important considerations for managing trade and keeping problems for which positive lists can play an important role, and the proposed methodology may assist in this regard.

To meet the aims of this report, it was particularly important to avoid criteria for positive lists that were nonrepeatable or that result in divergent determinations arising from knowledge, experience or consensus input variations or biases between assessors. Relatedly, because the proposed method requires that all criteria must be favorably met, even if some erroneous or poorly interpreted inputs are provided, overall determination for suitability of species is not confounded.

Table 2 constitutes the proposed objective-based methodology for development of pet-related positive lists. Table 2 provides for assessment of species suitability for inclusion on positive lists based on criteria concerning *animal and species* considerations (animal welfare, species conservation, and sustainability), and for assessment of species suitability for inclusion on positive lists based on criteria concerning *public and environmental* considerations (public health and safety, agricultural animal health, and environmental protection).

Users of the method are required to conduct basic background searches relevant to the animal and species under consideration. Although the terms “animal” and “species” have conjoined inference in this report, they are used separately because some species (e.g., domesticated dog [*Canis lupus familiari*]) involve great variation in genetic background or “breed,” and such variation may mean that certain breeds are determined as suitable and others unsuitable for inclusion on positive lists. Standard search engines and online encyclopedias can reasonably be expected to identify answers to each of the total 10 questions presented in Table 2. All questions were designed to allow binary responses, either a target animal and/or species satisfies the queried requirement or it does not, or if any element of uncertainly should exist it is likely to be negligible. Relatedly, it is recommended that in the event that doubt may exist in the mind of a user, animals are afforded the benefit of such doubt, and negative responses are given.

Conclusions

Positive list systems represent long-established applied approaches for the regulation, prevention and control of almost all aspects of societal, professional and industrial governance, and this precautionary principle is well-accepted and inarguably sound. Although public health and safety policies characteristically rely on the positive list approach to ensure a high degree of confidence prior to implementation, bizarrely the regulation of, in particular, wild pet trading and keeping, typically evades protective precautionary animal welfare, public health and safety, and other measures. Compelling rationales, as well as an important scientific evidence-base, strongly indicate replacement of historically common negative list approaches with positive list systems to better regulate the sale and keeping of both wild pet and domesticated pet animals. Regardless of the type of inclusion or exclusion criteria that may be involved in positive lists relating to pet trading and keeping, it seems clear that any approach that involves significant competing interest or consensus-based agreement is inherently problematic due to extensive implicit biases.

Our assessments found that the 4 reviewed current methodologies are relevant for the development of positive lists for exotic and domesticated pets, and can meet standards for assuring reasonable and defensible decision-making. However, we recognize that, for various reasons, some governing authorities may need to consider certain scientific-political opacities and public interest requirements that can arise when addressing complex issues. We believe that the presently proposed tool provides an objective methodology that eliminates or renders negligible problem-

atic consensus involvement in decision-making, thus allowing for a widely defensible protocol for the development of positive lists for pet trading and keeping.

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Conflict of Interest

The authors declare no conflict of interest.

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