

CONTRIBUTED PAPERS

Identifying inconsistencies in exotic pet regulations that perpetuate trade in risky species

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Abstract

Regulatory inconsistencies at different jurisdictional levels have contributed to the global expansion of the exotic pet trade, with resultant increases in the spread of invasive species and pathogens. Researchers have enumerated multiple limitations and environmental risks posed by international and national rules that govern the exotic pet trade, yet little attention has focused on the regulation of the exotic pet trade within national borders. We reviewed state-level regulations that apply to the trade of vertebrate animal taxa in the United States. Definitions and classifications for regulating different vertebrate taxa varied greatly across states, and the terms *pet* and *companion animal* were poorly defined and inconsistent across states. States implemented regulations that permit trade in exotic vertebrate pets that are banned from import into the United States owing to public health and conservation concerns. Once species have been imported into the United States, inconsistent internal regulations facilitate the movement of animals that pose substantial invasion and disease risks. Violations of state laws were typically listed as misdemeanors, and the median fine for violating state wildlife trade laws was \$1000. Inconsistent and incomplete regulation of exotic vertebrate pets across state borders, in conjunction with limited penalties for violating regulations, has facilitated continued possession of exotic pets in states where these animals are banned. Based on our review of regulatory weaknesses, we conclude that a transition to a federally enforced list of vertebrate species that may be traded as pets is needed, with all other vertebrate species banned from the exotic pet trade unless their potential invasion and disease risks have been assessed and demonstrated to be low or nonexistent.

KEYWORDS

disease risks, information asymmetries, invasion risks, laws, moral hazard, violations

Identificación de las inconsistencias en las regulaciones de las mascotas exóticas que perpetúan el mercado de especies riesgosas

Resumen: Las inconsistencias regulatorias en diferentes niveles regulatorios han contribuido a la expansión mundial del mercado de mascotas exóticas, con un incremento resultante en la dispersión de especies invasoras y patógenos. Los investigadores han enumerado varias limitaciones y riesgos ambientales que representan las normas nacionales e internacionales que dictan el mercado de mascotas exóticas, pero se ha puesto poca atención en la regulación de este mercado dentro de las fronteras nacionales. Revisamos las regulaciones a nivel estatal que aplican al mercado de taxones de vertebrados en los Estados Unidos (EU). Entre los estados, las definiciones y clasificaciones para regular el mercado de los diferentes taxones de vertebrados variaron mucho y los términos *mascota* y

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animal de compañía contaban con definiciones deficientes e incoherentes. Los estados implementaron regulaciones que permiten el mercado de vertebrados como mascotas exóticas cuya importación está prohibida para los EU debido a cuestiones de salud pública y conservación. Una vez que las especies han sido importadas a los EU, las regulaciones internas incoherentes facilitan el traslado de animales que representan un riesgo importante de invasión y de enfermedad. Con frecuencia, las violaciones a las leyes estatales se denominaban delitos menores y la multa promedio por violar las leyes estatales de comercio de fauna era de \$1,000. La regulación incompleta e incoherente del mercado de mascotas exóticas entre los límites estatales, en conjunto con las penalizaciones limitadas por violar las regulaciones, ha facilitado la posesión continua de mascotas exóticas en estados en donde estos animales están prohibidos. Con base en nuestra revisión de las debilidades regulatorias, concluimos que se necesita transitar a una lista con aplicación federal de especies de vertebrados que pueden ser comercializadas como mascotas, con todas las demás especies de vertebrados vetadas del mercado a menos de que se haya evaluado su riesgo potencial de invasión y de enfermedad y se haya demostrado que es bajo o inexistente.

PALABRAS CLAVE

asimetría informativa, leyes, peligro moral, riesgo de enfermedad, riesgo de invasión, violaciones

确定助长风险物种长期贸易的外来宠物管理条例矛盾

【摘要】 司法管辖中不同层级的监管不一致导致了全球范围内外来宠物贸易的扩张,进而加剧了物种入侵和病原体传播。已有研究列举了外来宠物贸易管理的国际和国家法规所带来的多种限制和环境风险,但却很少关注国内的外来宠物贸易监管。我们回顾了适用于美国脊椎动物类群贸易的州级法规,发现各州对不同脊椎动物监管的定义和分类存在很大差异,且“宠物”和“伴侣动物”这两个词在各州的定义不清晰也不一致。各州实施了允许外来脊椎动物宠物交易的法规,但出于公共卫生和保护方面的考虑,许多宠物已被禁止进口到美国。一旦这些物种被进口到美国,国内法规的矛盾会为动物的移动提供便利,由此带来巨大的入侵和疾病风险。违反州级法律的行为通常被判为轻罪,违反州级野生动物贸易法的罚款金额中位数为1000美元。对于跨越州界的外来脊椎动物宠物的监管不一致、不全面,再加上对违反法规的处罚力度不大,为在各个州继续饲养被禁止的外来宠物提供了便利。根据我们对监管缺陷的审查,我们提出,应转变为由联邦政府统一确定可作为宠物交易的脊椎动物物种名录,并禁止所有其他脊椎动物物种作为外来宠物进行交易,除非已评估并证明其潜在的入侵和疾病风险很低或不存在风险。**【翻译:胡怡思;审校:聂永刚】**

关键词: 疾病风险,信息不对等,入侵风险,法律,道德风险,违法行为

INTRODUCTION

The exotic pet trade, defined as the trade in non-domesticated animals for the purposes of exhibition or companionship, has contributed to the overexploitation of wildlife, species extinction, wildlife population declines, and the spread of invasive species and pathogens globally (Lockwood et al., 2019; Marra, 2019; Máximo et al., 2021; Toland et al., 2020). Recent analyses suggest that invasive species are strongly overrepresented in the global pet trade in mammals, birds, reptiles, amphibians, fish, and ants (Gippet & Bertelsmeier, 2021). The global exotic pet trade has also spread emerging infectious diseases (e.g., amphibian chytrid pathogen *Batrachochytrium dendrobatidis* [Fu & Waldman, 2022]). Both native and non-native animals are traded as exotic pets (Toomes et al., 2022, 2023). Although exotic pets may be native within geographic borders, the release of pets

outside their native ranges may still result in the establishment of so-called “domestic” invasive species, the introduction of pet-borne pathogens and parasites, and hybridization between non-native and native subspecies (Robinson et al., 2020). Effective mitigation of the invasion and disease risks associated with the exotic pet trade has been undermined by incomplete information on the size, composition, and trade flows associated with the exotic pet trade (Olden et al., 2021; Sinclair et al., 2021; Stringham et al., 2021a); lack of formal documentation to track the pet trade (Marshall et al., 2020); expanding internet-based trade in exotic pets that is generating invasion and disease pathways that are difficult to regulate (Lenda et al., 2014; Olden et al., 2021); lack of comprehensive regional, national, and international policies governing the pet trade (Brown, 2006; Essl et al., 2015; Toomes et al., 2023; Voyles et al., 2015); and poor enforcement of existing policies and regulations (Fonseca et al., 2021).

Accordingly, scientists and lawyers have called for improved, proactive regulation of the exotic pet trade (Auliya et al., 2016; Brown, 2006; Hulme et al., 2018; Marshall et al., 2020; Patoka et al., 2018).

The failure of international trade regulations (e.g., CITES) to mitigate the risks associated with the pet trade is well recognized (Marshall et al., 2020). However, there is growing evidence that inconsistent regulations within national borders substantially contribute to the invasion risks associated with the pet trade (Fonseca et al., 2021; Toomes et al., 2022, 2023). In Australia, state-level regulations for species in the pet trade have influenced the quantity of pets traded and pet escapes, even after accounting for species-level attributes (Toomes et al., 2022). In Brazil, the devolution of pet trade regulations to individual states and municipalities has facilitated increased commercial breeding and trade of exotic pets and undermined monitoring of the exotic pet trade (Fonseca et al., 2021). We focused on limitations and inconsistencies in state-level regulations pertaining to the exotic pet trade in the United States (US), specifically how varying regulations for different taxa and differing penalties for violating state regulations exacerbate invasion and disease risks associated with the exotic pet trade. Ours is the first effort to identify state-level regulations pertaining to all vertebrate taxa in the exotic pet trade in the United States.

The United States is one of the world's largest consumers of wildlife for commercial and pet trade purposes (Collard & Dempsey, 2013), thereby significantly driving the global pet trade. Approximately 50% of the US pet population is considered exotic (Lockwood et al., 2019). There are multiple federal regulations in the United States that pertain to the exotic pet trade, but regulatory oversights and inconsistencies remain (Brown, 2006; Graening, 2022; Prestridge, 2009; Toland et al., 2020). The federal Lacey Act places prohibitions on the trade of endangered species and their parts, and the Migratory Bird Act regulates the possession of migratory bird species that are native to the United States and its territories (Maas, 2005; Toland et al., 2020; Wyler & Sheikh, 2008). The Wild Bird Conservation Act requires trade in wild birds to be biologically sustainable, and limits or prohibits imports of non-native birds if trade is not beneficial to these species. The Captive Wildlife Safety Act regulates "potentially dangerous" exotic animals, defined as "any exotic mammals, birds, reptiles, amphibians, or non-game species which...[are] capable of inflicting serious or fatal injuries or which [have] the potential to become...a menace to the public health or indigenous wildlife populations" (Lucca, 2013: 137). The Big Cat Public Safety Act restricts possession and exhibition of big cats (i.e., species of lion, tiger, leopard, cheetah, jaguar, or cougar or any hybrid of such species) and direct contact between the public and big cats (e.g., cub petting). Although designed to address risks associated with the exotic pet trade, internet-based interstate trade in regulated species still occurs, even if these species are protected by federal law (Shirey et al., 2013). Moreover, federal laws do not apply to all species that are traded as exotic pets, and much of the trade continues to be regulated at the state and local levels (Brown, 2006; Graening, 2022; Toland et al., 2020).

In the United States, state governments are the sovereign governments, and the federal government is the limited, dele-

gated government (Brown, 2006; Favre, 2003). As such, state governments have primary control over the exotic pet trade, unless the federal government exercises its authority based on treaty power (e.g., migratory bird treaties with other countries) or the commerce clause (which applies to issues that are multi-state or cross-state borders [Drouet & Siev, 2022; Favre, 2003]). Inconsistent state and local pet trade regulations may thus contribute to invasion and disease pathways because participants in the exotic pet trade can transport pets across state borders or county lines in violation of regulations enacted by that state or county and without appropriate inspection of the animals they are transporting (Brown, 2006; Graening, 2022; Johnson et al., 2018). Moreover, if individuals who purchase exotic pets are unaware of all relevant regulations or have incomplete information about regulations that apply to the pet trade, then this may lead to strategic behavior by pet sellers. Information asymmetries arise when buyers (i.e., pet owners) lack information about the pets they are purchasing (including restrictions on pet ownership) and this information is difficult, costly, or time-consuming to obtain (Hadfield et al., 1998). Pet sellers who are better informed about regulations may exploit information asymmetries by failing to inform pet buyers that they may not own certain pets in their state of residence in order to generate profits from the sale of prohibited exotic pets. Because pet owners bear the legal responsibility for violating pet regulations, pet sellers are disincentivized to comply with exotic pet regulations or to inform pet owners about the legality of exotic pets in their state—an outcome that is referred to as moral hazard (Galenianos et al., 2012).

Unfortunately, there is no single publicly available resource listing all state laws and regulations pertaining to exotic pets (Maas, 2005), which exacerbates information asymmetries and the potential for moral hazard. If regulations are included in a state's administrative code (state regulations and rules written and enforced by a state agency), then a clearly designated regulatory agency exists, to which queries about pet regulations can be directed. However, if regulations are included in the state's general statutes (laws written and enacted by the state legislature), then no single agency is assigned to enforce the regulations and to respond to queries about regulations. Counties and municipalities may also implement pet regulations that are more restrictive than state regulations (Maas, 2005; Toland et al., 2020), thereby exacerbating potential information asymmetries and moral hazard. For example, it is legal to own a venomous snake in the state of North Carolina; however, legislation passed in June of 2022 made it illegal to own "dangerous animals" (including venomous snakes) within the city limits of Raleigh, North Carolina. Veterinarians may be in violation of state laws if they treat exotic pets that may not be owned within the state or if they return exotic pets to owners who do not have the appropriate permits for that pet (Maas, 2005). This may lead pet owners with sick or illegally owned animals to release their pets if they cannot surrender them to a rescue, shelter, or another owner (Maceda-Veiga et al., 2019).

Pet regulations are further complicated because states use a mix of prohibited lists of species that may not be legally imported or owned (commonly referred to in the wildlife trade literature as blacklists) and lists of approved species for import

and ownership (commonly referred to as whitelists) (Bowen, 2021; Hulme, 2015) to regulate the pet trade. Lists of prohibited species can be effective in mitigating invasion and disease risks; however, they are typically a reactive measure to ecological, disease, or human safety threats rather than a proactive approach to addressing threats (Simberloff, 2006; Toland et al., 2020). Government agencies are required to demonstrate that species pose substantial risks before they ban or restrict trade, which invites legal action and delays the process of implementing restrictions on the trade in or possession of species (Brown, 2006). By contrast, if only approved species may be traded as pets, the burden of proof that species do not pose invasion or disease risks must be met by the pet industry before a species is included on the list of approved exotic pets (Brown, 2006).

To elucidate inconsistencies in regulations and the potential for information asymmetries and moral hazard in the exotic pet trade, we searched state laws that govern the possession, sale, importation, and release of vertebrate exotic pets in the United States. We determined whether and how US states define exotic pets; which vertebrate species they regulate; types of state restrictions on ownership of vertebrate pets (i.e., whether states prohibit or approve species that may be traded as pets); whether regulations are consistent across states; and penalties for violating regulations in each state. We present examples of how regulations pertaining to exotic pets differ across states to demonstrate how regulatory inconsistencies may contribute to invasion and disease risks. Our research fills important research gaps on how the pet trade is regulated in the United States (Maas, 2005) and the socioecological factors that underlie invasion and disease risks associated with the exotic pet trade (Lockwood et al., 2019).

METHODS

We searched for relevant state laws in the WestLaw database, a Thomson Reuters research service for US legal and law-related materials (<https://legal.thomsonreuters.com/en/westlaw>). We used the following search terms: *amphibian, bird, captive, carnivore, dangerous animals, endangered, exotics, fish, hybrid, invasive, mammal, penalty, pet, reptile, turtle, venomous, and wildlife*. Based on our initial keyword searches, we identified the sections of state codes and statutes that contained regulations, rules, or laws governing the exotic vertebrate pet trade, including codes or statutes related to agriculture, fish and wildlife, natural resources, marine resources, criminal procedures, environmental protection, conservation, animals, environmental quality, and recreation. All state laws in our analysis of regulations at the class level of taxonomy were up to date through May 2022.

We identified which vertebrate animals are regulated by which US states and the taxonomic level of scientific classification within the laws (order, family, genus, and species). We identified the location for each law as being in the state penal code, state administrative code, or state general statutes. We further identified whether states implemented whitelists of approved species, blacklists of prohibited species, or a combination of list types to regulate the exotic vertebrate pet trade in each US state, including exceptions to these laws, such as the need for permits

and requirements that animals are captive bred. We identified state-imposed penalties for violating exotic pet or wildlife laws, specifically monetary fines and maximum duration of imprisonment. If laws pertaining to trade in wildlife or exotic vertebrate pets did not contain a penalties section, then we searched the penalty sections of state laws, such as the criminal procedures, penalties, fines, or misdemeanors.

Finally, to highlight how US state laws may, or may not, contribute to ongoing trade in vertebrate species that are documented as imposing a high risk of invasion, disease, or both invasion and disease in the United States, we focused on laws pertaining to trade in the Burmese python (*Python molurus bivittatus*), African clawed frog (*Xenopus laevis*), and domesticated ferret (*Mustela putorius furo*). We selected these cases to demonstrate how inconsistent state regulations pertaining to the possession of exotic vertebrate pets may facilitate the transport of exotic pets that pose invasion, disease, or human safety risks into states where they are banned. We examined two cases to demonstrate how the legal import of vertebrate species (e.g., the Burmese python and African clawed frog) into the United States may result in the release of exotic vertebrate pets that threaten biodiversity by affecting parasite-host dynamics of native species, altering the ecology of zoonotic pathogens, and spreading pathogens that cause emerging infectious diseases. We examined three cases (Burmese python, African clawed frog, and domesticated ferret) to demonstrate how the release of vertebrate pets may result in large declines of native and imperiled species through predation pressure and competition for resources. We conducted an additional search of US state laws to ensure that we captured all relevant state-level laws that were in force in February 2023 for each of these species. We examined two additional species that are prohibited under federal regulations from importation into the United States but are bred and sold as pets in the United States, namely, the rhesus macaque (*Macaca mulatta*) and the monk parakeet (*Myiopsitta monachus*) (Appendix S1).

Although we used multiple search terms to identify state laws that pertain to trade in exotic vertebrate pets, we may not have identified all relevant state laws, and the laws we identified may have subsequently changed. Thus, the state regulations pertaining to different vertebrate species may be incomplete. Several states used outdated scientific names for vertebrate species and higher taxa or different common names to denote the same species. This complicated our process of identifying relevant state laws and may have resulted in an incomplete listing of state regulations that pertain to exotic vertebrate pets. Finally, we did not include county or municipal laws in our analyses, owing to the time and effort needed to locate and analyze these laws. As such, we have not identified additional laws that may contravene state regulations.

RESULTS

We analyzed state laws for all 50 US states and the District of Columbia (hereafter collectively referred to as *state*, $n = 51$). Appendix S2 contains a list of the regulations that we identified for each state. Regulatory definitions and classifications and where laws were recorded varied greatly. States used an array of

TABLE 1 Classes of wildlife species that are regulated at the state level in the United States and the type of listing used for these classes, 2022 ($n = 51$).

	Blacklist only ^a	Whitelist only ^b	Both blacklist and whitelist	No regulation found ^c
Mammals	18	0	33	0
large carnivores	37	4	8	2
non-human primates	24	10	0	17
ferrets	2	30	18	1
Reptiles	16	1	35	0
turtles, tortoises	20	4	24	3
venomous snakes	35	5	9	2
non-venomous snakes	20	9	18	4
constrictor snakes	11	7	7	26
Amphibians	20	1	28	2
Birds	22	1	27	1
Fish	27	1	22	1
freshwater fish	29	1	19	2
marine fish	14	8	7	6
Hybrid animals	22	19	8	2

^aProhibited list of species that cannot be legally imported or owned.

^bApproved list of species that can be imported or owned.

^cAlthough our search did not identify state-level laws pertaining to different wildlife classes, it is possible that laws existed but were not identified by our search terms.

different terms to refer to non-domesticated wildlife species: 19 states used the term *exotic*, 10 used *non-native*, 11 used *invasive*, 7 used *injurious*, and 5 used *captive*. State laws that pertained to the exotic pet trade also focused on trade in native ($n = 18$) and endangered wildlife ($n = 34$). Laws included the terms *pet* and *companion animal*, without clear or consistent definitions of these terms. For example, Michigan defined a companion animal as “an animal that is commonly considered to be, or is considered by its owner to be, a pet.” Massachusetts defined a companion animal as “a domesticated animal including, but not limited to, fowl, birds, fish or reptiles; provided, however, that ‘companion animal’ shall not include animals intended for consumption or whose products are intended for consumption by humans or other animals.” By contrast, Utah defined a companion animal as “an animal that is a domestic dog or domestic cat.”

States implemented laws that listed vertebrate wildlife at the family, genus, or species level, although this did not mean that all species in a family or genus were included in state laws. All states had regulations for mammals and reptiles, although this did not necessarily mean that they regulated all animals included in the classes Mammalia and Reptilia (Table 1 & Appendix S2). States commonly regulated trade in large carnivores ($n = 49$, 96.1%), non-human primates ($n = 34$, 66.7%), and ferrets ($n = 50$, 98.0%). States also commonly regulated trade in turtles or tortoises ($n = 48$, 94.1%) and in venomous ($n = 49$, 96.1%) and non-venomous snakes ($n = 47$, 92.2%), although only 25

states (49.0%) regulated trade in constrictor snakes specifically. A few states did not regulate trade in amphibians, fish, birds, and hybrid animals. Hybrid animals are the offspring of matings between domesticated animals (e.g., domestic dogs [*Canis lupus familiaris*]) and their wild counterpart (e.g., gray wolves [*Canis lupus*]) or matings between two wild species (e.g., ligers, which are the offspring of a male lion [*Panthera leo*] and a female tiger [*Panthera tigris*]).

We focused on regulations pertaining to hybrids between domesticated dogs and cats and their wild counterparts. Three states (5.9%) regulated only wolf and dog hybrids (one state blacklisted these hybrids, whereas two states whitelisted these hybrids), whereas 46 states (90.2%) regulated both wolf and cat hybrids (i.e., cross-breeding of domesticated and non-domesticated cats) in their laws. In total, 22 states (43.1%) blacklisted both wolf and cat hybrids, 18 states (35.3%) whitelisted both wolf and cat hybrids, 1 state (2.0%) blacklisted wolf hybrids but whitelisted cat hybrids, and 5 states (9.8%) whitelisted wolf hybrids but blacklisted cat hybrids. Finally, 22 states (43%) implemented laws that regulated trade in so-called dangerous wildlife, namely, animals that the state deemed to be inherently dangerous to human health and safety, the environment, livestock, agriculture, or the wildlife in the state.

States commonly listed their laws pertaining to the exotic vertebrate pet trade in their administrative codes (state regulations and rules that are written and enforced by a state agency, $n = 14$), in their general statutes (laws written and enacted by the state legislature, $n = 5$), or in both their administrative codes and general statutes ($n = 31$). Although courts may interpret statutes, they may not interpret administrative codes. Two states (California and Michigan) listed some of their laws in their penal code (laws pertaining to crimes and offenses and their punishment).

Most regulations were listed under a fish, game, or wildlife section of the administrative code ($n = 33$) or the natural resources or conservation ($n = 15$) section, which gives regulatory authority to the state wildlife or natural resources agency. However, regulations were also listed under public safety ($n = 9$), agriculture or livestock ($n = 13$), or animals ($n = 11$). Several states listed regulations under multiple sections of their administrative code ($n = 18$), thereby assigning responsibility for regulating the trade in vertebrate wildlife and exotic vertebrate pets to personnel in multiple state agencies. We also found species-specific regulations listed under the captive wildlife, non-domestic animal control, crimes and punishment, law enforcement, plant industry, amusements, parks, and recreation sections of state laws.

Most states ($n = 49$, 96.1%) used monetary fines, imprisonment, or both fines and imprisonment to penalize individuals who violated laws pertaining to the wildlife trade, including trade in exotic pets (Table 2). Indiana and Massachusetts did not list specific fines or terms of imprisonment, but rather stated that offenders’ licenses to own animals could be revoked and animals could be seized for violation of wildlife trade laws. Rhode Island also stipulated that the state could revoke licenses and seize animals if a person was found in violation of any exotic or native wild animal regulation, in addition to a \$100 fine (250 R.I. Code R. § 250-RICR-40-05-3.14). Fines ranged from \$100

TABLE 2 Maximum penalties associated with violations of US state laws pertaining to the trade in wildlife, including exotic pets, 2022 (*n* = 49).

State	Maximum monetary fine (US\$)							Maximum imprisonment							Increasing penalty per offense	Classification
	100	500	1000	5000	≤500,000	5 days	30 days	60 days	90 days	6 months	1 year	≤5 years				
Alabama				X			X						no	class c misdemeanor		
Alaska	X												no	civil penalty		
Arizona				X									no	class a misdemeanor		
Arkansas				X						X			no	standard misdemeanor		
California			X										no			
Colorado													no			
Connecticut				X							X		no	class a misdemeanor		
D.C.	X							X					yes			
Delaware	X					X							no			
Florida		X								X			yes	level 3 violation		
Georgia				X						X			yes			
Hawaii					X							X	yes			
Idaho				X									no			
Illinois				X									no	class c misdemeanor		
Iowa				X									yes	civil penalty		
Kansas			X								X		no	class a misdemeanor		
Kentucky		X								X			no	class a misdemeanor		
Louisiana			X						X				yes	class 3 violation		
Maine			X						X				no	class c criminal offense		
Maryland		X								X			no			
Michigan			X										yes			
Minnesota				X					X				yes	gross misdemeanor		
Mississippi				X									no	class 1 violation		
Missouri			X									X	no	class c misdemeanor		
Montana					X								no	wildlife violation		
Nebraska	X												no	class 3 misdemeanor		
Nevada			X								X		no			

(Continues)

TABLE 2 (Continued)

State	Maximum monetary fine (US\$)							Maximum imprisonment							Increasing penalty per offense	Classification
	100	500	1000	5000	≤500,000	5 days	30 days	60 days	90 days	6 months	1 year	≤5 years				
New Hampshire				X							X		no	class a misdemeanor		
New Jersey					X							X	no	crime of the third degree		
New Mexico			X								X		no			
New York			X										yes	civil penalty		
North Carolina		X							X				no	class 2 misdemeanor		
North Dakota				X			X						no	class b misdemeanor		
Ohio			X					X					yes	misdemeanor of the first degree		
Oklahoma				X			X						no			
Oregon				X					X				yes	class b misdemeanor		
Pennsylvania			X					X					no	summary offense of the first degree		
Rhode Island	X												no			
South Carolina				X				X					yes	class c misdemeanor		
South Dakota		X				X							no	class 2 misdemeanor		
Tennessee	X					X							no	class c misdemeanor		
Texas		X											no	class c misdemeanor		
Utah			X					X					no	class b misdemeanor		
Vermont				X					X				yes	violation of order		
Virginia				X						X			yes	class 1 misdemeanor		
Washington					X						X		no	class c felony		
West Virginia				X							X		no	felony		
Wisconsin				X					X				yes	violation of order		
Wyoming					X					X			no	high misdemeanor		

to ≤\$500,000 for violating state wildlife trade laws (median fine \$1000, $n = 49$, 96.1%). Terms of imprisonment for wildlife trade violations ranged from 5 days to 5 years (median imprisonment 180 days, $n = 41$, 80.4%). Fifteen states (29.4%) stipulated that penalties for violating wildlife laws would increase with each offense. States typically classified violations of their laws pertaining to the trade in exotic pets as misdemeanors, which are criminal offenses that carry potential imprisonment times of 1 year or less (depending on the level of misdemeanor). Typically, jail time is served in the local county jail rather than a high security prison when an individual is charged with a misdemeanor, and prosecutors have considerable flexibility in deciding what crimes to charge, what punishment to impose, and which bargains they may negotiate. However, some states allowed for substantial penalties for violating exotic pet laws. For example, Hawaii has stipulated that any person convicted of owning, transporting, or possessing any snake or prohibited animal may be fined up to \$200,000, imprisoned for up to 3 years, and required to pay for all costs relating to the capture or eradication of the animal.

Case studies of non-native species traded as exotic pets that are known invasion or disease risks

Risk-assessment models indicate that non-native boa constrictors (*Boa constrictor*), ball pythons (*Python regius*), and reticulated pythons (*P. reticulatus*) pose high invasion risks in the United States (Reed, 2005). The pet trade in non-native snakes also poses disease risks (Engeman et al., 2011). For example, the Burmese python, which was legally imported into the United States via federal import permits and subsequently released by pet owners into the Everglades in Florida (Brown, 2006), has affected the parasite-host dynamics of native snakes (Miller et al., 2018) and altered the ecology of zoonotic pathogens (Burkett-Cadena et al., 2021) in southern Florida. This species has also resulted in severe declines in native mammal populations, including threatened and endangered species, owing to predation pressures (Dorcas et al., 2012; Van Wilgen et al., 2010). Although it is unclear whether the Burmese python may extend its invasive range outside southern Florida, owing to cold-induced mortality (Dorcas et al., 2011), only nine states (17.6%) blacklisted the Burmese python (also referred to as the Indian python) at the species level, and North Carolina whitelisted trade in this species, provided the appropriate enclosure is used (Figure 1 & Table 3). Regulations related to non-native boas and pythons were inconsistent across the states, with multiple states only listing a subset of boa and python species in their regulations. Hawaii blacklisted all snakes, except for two male non-venomous snakes in the zoo and four sterile brown tree snakes for the training of detection dogs. However, apart from Hawaii, only 10 states (19.6%) blacklisted reticulated pythons, and the three states (5.9%) that specifically listed boa constrictors or ball pythons whitelisted these species (Table 3).

The African clawed frog, which has established invasive populations in Asia, Europe, South America, and North America,

has been implicated in the spread of the fungal pathogen, *Batrachochytrium dendrobatidis* (Lobos et al., 2013; Measey et al., 2012). However, only nine states (17.6%) blacklisted trade in this species; a further six states blacklisted trade in the genus *Xenopus* (Figure 2). Notably, Colorado blacklisted trade in the African clawed frog but whitelisted trade in its family *Pipidae*. This meant that only 15 states (29.4%) had implemented laws that prohibited trade in the African clawed frog, despite the fact that Measey (2017) estimated that 1.83 million African clawed frogs were imported over 15 years into the United States to supply the pet trade.

The domesticated ferret can easily escape captivity, preys on native birds and rabbits, presents a threat to poultry, and is a human safety concern owing to its propensity to bite humans (Graening, 2022). Although the number of pet ferrets in the United States is disputed, estimates suggest that ~1,000,000 domesticated ferrets were traded as pets over the past 30 years (Graening, 2022). California has the largest number (~100,000) of pet ferrets, even though in 1933, California banned the importation and ownership of all species in the family *Mustelidae*, which includes domesticated ferrets, in the state (Graening, 2022) (Figure 3). Domesticated ferrets may be deliberately released by pet owners who do not have the necessary resources to care for them because ferrets are highly agile, lively animals, whose behavioral needs are difficult to meet, and are subject to a number of diseases and disorders (Vinke & Schoemaker, 2012). If domesticated ferrets have been neutered, then they cannot breed, but breeding populations of feral ferrets have been reported by Alaska, New Mexico, and Washington (Graening, 2022). The domesticated ferret is either not regulated ($n = 1$, 2.0%) or is whitelisted ($n = 30$, 58.8%) by most states, which facilitates the continued trade of pet ferrets across the United States. A search of regulations that pertain to the family *Mustelidae* showed that various states used blacklists or whitelists to also regulate native species, namely, the ermine (or stoat) (*Mustela erminea*), least weasel (*Mustela nivalis*, *Mustela rixosa*), long-tailed weasel (*Mustela frenata*), American mink (*Mustela vison*), and endangered black-footed ferret (*Mustela nigripes*). Ermines are traded as pets, but exotic pet owners may also seek to acquire other mustelids as pets. Multiple states within the historic ranges of these native species have not implemented regulations that would govern pet trade in native mustelids that are not protected by federal regulations.

DISCUSSION

Our results show the inconsistencies in US state laws pertaining to trade in exotic vertebrate pets, thereby highlighting information asymmetries regarding which exotic vertebrate pets people may own in different states and the potential for moral hazard in the exotic vertebrate pet trade. States did not provide consistent definitions of an exotic pet, often failing to define exotic pets at all. Laws were listed in different sections of the legal code across states and carried different penalties if pet owners violated these laws. The agencies responsible for enforcing laws varied across states and were not clearly defined if laws were included in the

TABLE 3 Species-specific US laws pertaining to trade in pythons and boa constrictors, February 2023.^a

Common name ^b	Scientific name ^b	Native species	Blacklist ^c	Blacklist (except with permit)	Whitelist ^d	Whitelist (permit required)	Whitelist (enclosure requirement)
Reticulated python	<i>Malayopython reticulatus</i>	no	Arkansas, Connecticut, Montana, New York	Florida, Louisiana, Massachusetts, Maine, Ohio, Texas		Rhode Island	North Carolina
Burmese python	<i>Python bivitatus</i>	no	Arkansas, New York	Georgia, Ohio, Texas			
Indian rock python	<i>Python molurus</i>	no	Arkansas, Montana, New York	Florida, Georgia, Louisiana, Maine, Ohio, Texas			North Carolina
Amethystine python	<i>Simalia amethystina</i>	no	Connecticut, Montana, New York	Florida, Louisiana, Maine, Ohio			
Lesser African python	<i>Python natalensis</i>	no	Arkansas, Connecticut, New York	Florida, Louisiana, Maine, Ohio, Texas			
Beni anaconda	<i>Eumeces beniensis</i>	no	Connecticut, New York	Florida			
Dark-spotted anaconda	<i>Eumectes deschauensei</i>	no	New York	Florida			
Green anaconda	<i>Eumectes murinus</i>	no	Connecticut, Montana, New York	Florida, Ohio, Texas			North Carolina
Yellow anaconda	<i>Eumectes notaeus</i>	no	Connecticut, New York	Florida, Ohio			
Northern three-lined boa	<i>Liabanura orcutti</i>	yes	Nevada		California		
Northern rubber boa	<i>Charina bottae</i>	yes	Oregon	Maine		California, Wyoming	
Southern rubber boa	<i>Charina umbratica</i>	yes		Maine		California	
Puerto Rican boa	<i>Chilabothrus inornatus</i>	no		Maine			
Jamaican yellow boa	<i>Chilabothrus subflavus</i>	no		Maine			
Papuan olive python	<i>Apodora papuana</i>	no		Louisiana			
Olive python	<i>Liasis olivaceus</i>	no		Louisiana, Maine			
African rock python	<i>Python sebae</i>	no		Florida, Louisiana, Massachusetts, Maine, Ohio, Texas		Rhode Island	North Carolina
Carpet python	<i>Morelia spilota</i>	no		Louisiana			
Scrub python	<i>Simalia kinghorni</i>	no		Florida, Louisiana, Maine			
Ball python	<i>Python regius</i>	no			Arkansas, Maine		
Argentine boa constrictor	<i>Boa constrictor</i>	no			New Jersey		

(Continues)

TABLE 3 (Continued)

Common name ^b	Scientific name ^b	Native species	Blacklist ^c	Blacklist (except with permit)	Whitelist ^d	Whitelist (permit required)	Whitelist (enclosure requirement)
Cuban boa	<i>Chilabothrus angulifer</i>	no			Maine		
Dumeril's boa	<i>Acrantophis dumerili</i>	no			Maine		
Madagascar ground boa	<i>Acrantophis madagascariensis</i>	no			Maine		
Hispaniola boa	<i>Chilabothrus striatus</i>	no			Maine		
Emerald tree boa	<i>Corallus caninus</i>	no			Maine	Rhode Island	
Amazon tree boa	<i>Corallus hortulanus</i>	no			Maine		
Mexican rosy boa	<i>Lichanura trivirgata</i>	yes			Maine		
Children's python	<i>Antaresia childreni</i>	no			Maine		
Cape York Spotted python	<i>Antaresia maculosa</i>	no			Maine		
Pygmy python	<i>Antaresia perthensis</i>	no			Maine		
Black-headed python	<i>Aspidites melanocephalus</i>	no			Maine		
Ramsays python	<i>Aspidites ramsayi</i>	no			Maine		
Bismarck ringed python	<i>Bolbrochilus boa</i>	no			Maine		
African burrowing python	<i>Calabaria reinhardtii</i>	no			Maine		
D'Albertis' python	<i>Leiopython albertisi</i>	no			Maine		
Freckled python	<i>Liasis mackloti</i>	no			Maine		
Green tree python	<i>Morelia viridis</i>	no				Rhode Island	
Anchieta's dwarf python	<i>Python anchietae</i>	no			Arkansas, Maine		
Borneo python	<i>Python breitensteini</i>	no			Arkansas, Maine		
Blood python	<i>Python brongersmai</i>	no			Arkansas, Maine		
Sumatran python	<i>Python curtus</i>	no			Arkansas, Maine		
Lesser Sunda python	<i>Malayopython timoriensis</i>	no			Maine		

^aHawaii blacklists all snakes and thus is not included in this table, which pertains to species-level laws. Iowa whitelists *Hemiphysalis*, a former superfamily of the suborder *Serpentes* that contains boas and pythons provided pet owners pay a yearly registration fee.

^bCommon and scientific names are consistent with the Global Biodiversity Information Facility (GBIF) taxonomic database. However, scientific and common names of species are not updated in Appendix S2, which shows how different states regulated vertebrate species in order to highlight that state regulations may refer to species by outdated or inaccurate common and scientific names.

^cProhibited list of species that cannot be legally imported or owned.

^dApproved list of species that can be imported or owned.

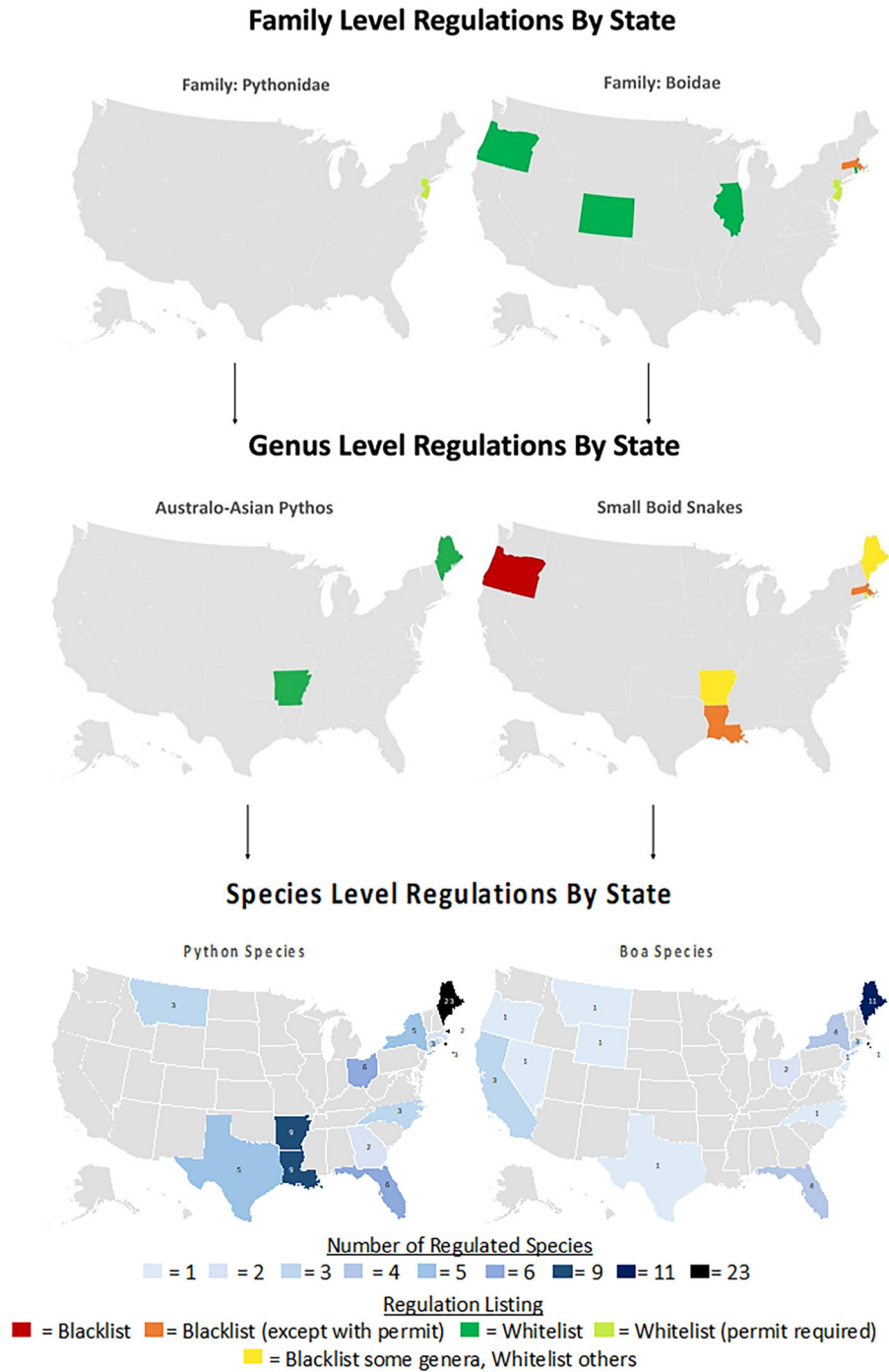


FIGURE 1 States in the United States that implemented laws that apply to trade in pythons and boas, February 2023. Hawaii blacklisted all *Serpentes*, and Iowa whitelisted *Henophidia* provided pet owners pay a yearly registration fee.

general statutes. As such, exotic pets may fall in a regulatory and legal gray area, where it is unclear whether jurisdiction lies with the state agricultural agency (which may regulate domestic animals as well as livestock), state natural resources or wildlife agency, or other state agencies, such as public health agencies (Shapiro et al., 2022). This ambiguity reduces the likelihood that exotic pet trade laws are enforced, thereby reducing the risk of prosecution for individuals who violate regulations (Pickering & Fox, 2022) and exacerbating adverse incentives to continue trad-

ing exotic pets that pose significant invasion and disease risks across the United States.

States also regulated species at different taxonomic levels (order, family, genus, species), if at all, and used an array of common and scientific names to refer to the same species across states and regulations. States used a combination of approved and prohibited lists, with various permits or exceptions, to regulate the same species (or taxa), thereby exacerbating inconsistencies in state laws. For example, Oregon allowed trade in

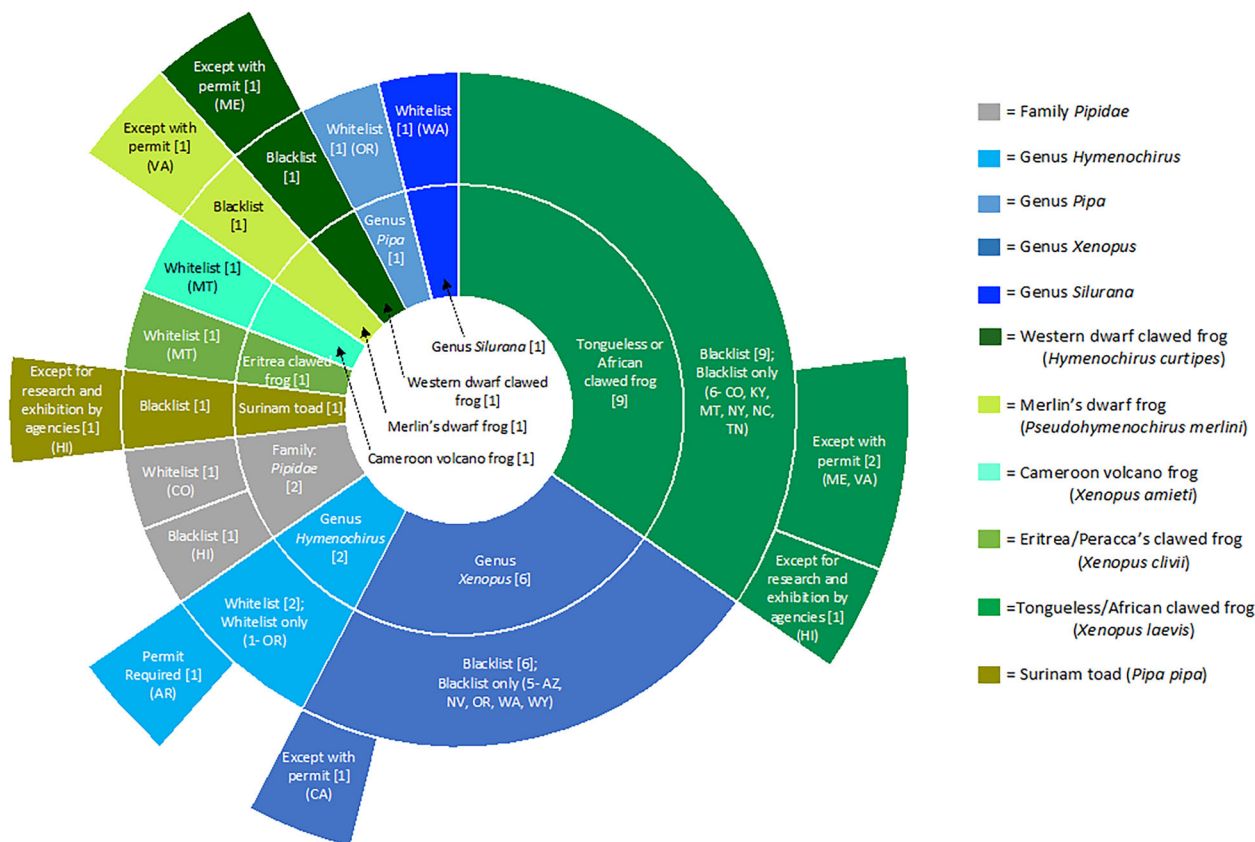


FIGURE 2 States in the United States that implemented laws that apply to trade in the African clawed frog (*Xenopus laevis*), February 2023. Blacklists and whitelists were implemented at the family and species levels.

the family *Pipidae*, but prohibited trade in the African clawed frog, a member of that family. Finally, states that shared a border did not implement consistent laws pertaining to trade in native and non-native vertebrate species, including which species were regulated and whether regulated species could be traded as pets or were prohibited. This spatial inconsistency in regulations can lead to the transport of exotic vertebrate pets across state borders with the regulatory and legal status of that species changing at the state line. For example, California, which prohibits possession of the domesticated ferret, also has the largest population of domesticated ferrets in private possession across the United States (Graening, 2022)—a clear violation of state law.

Accordingly, scientists and lawyers have recommended implementing federally enforced lists of animals that may be traded as pets (with all other species being banned from the pet trade) to allow trade in less harmful species within and across state borders (Brown, 2006; Fonseca et al., 2021). This solution is consistent with proposed amendments to the federal Lacey Act (America COMPETES Act [HR4521]) to create a list of approved species that may be imported into the United States, with each species not listed being treated as injurious and banned from import; ban interstate movement of species listed as injurious; and establish new emergency powers that provide the US Fish and Wildlife Service (USFWS) with the ability to prohibit the importation of injurious species for up to 3 years.

Our results suggest amendments to the Lacey Act are needed to address inconsistencies in the regulation of the exotic pet

trade across states. These amendments to the Lacey Act would allow the US Federal government to exercise authority over state governments with respect to the exotic pet trade, thereby overcoming inconsistencies in state laws. A more coherent and consistent set of regulations that apply across states would address ambiguities in which species are regulated, how these species are regulated, and the penalties associated with violating regulations. The Lacey Act empowers government agencies to revoke any permit or license possessed by anyone who has been convicted of a felony or misdemeanor Lacey Act violation (Anderson, 1995). Importantly, restricting trade to approved species does not require the federal government to demonstrate that species are injurious before they can be banned (Brown, 2006). Under current federal regulations, injurious species can still be imported with the appropriate permits, and species (e.g., the Burmese python) have been imported into the United States and entered the interstate pet trade before a determination that the species is injurious was made (Brown, 2006). Rather, under a federal list of approved species, the burden of proof that a species does not present an invasion or disease risk falls on the pet trade (Brown, 2006). It is thus unsurprising that the pet industry has used its economic resources and lobbying power to oppose more stringent state-level pet regulations and federal regulation of the pet trade to prevent limits on the interstate trade of exotic pets (Brown, 2006).

Proposed amendments to the Lacey Act would prohibit trade in exotic pets that pose clear invasion and disease risks in the United States. For example, the suckermouth catfish

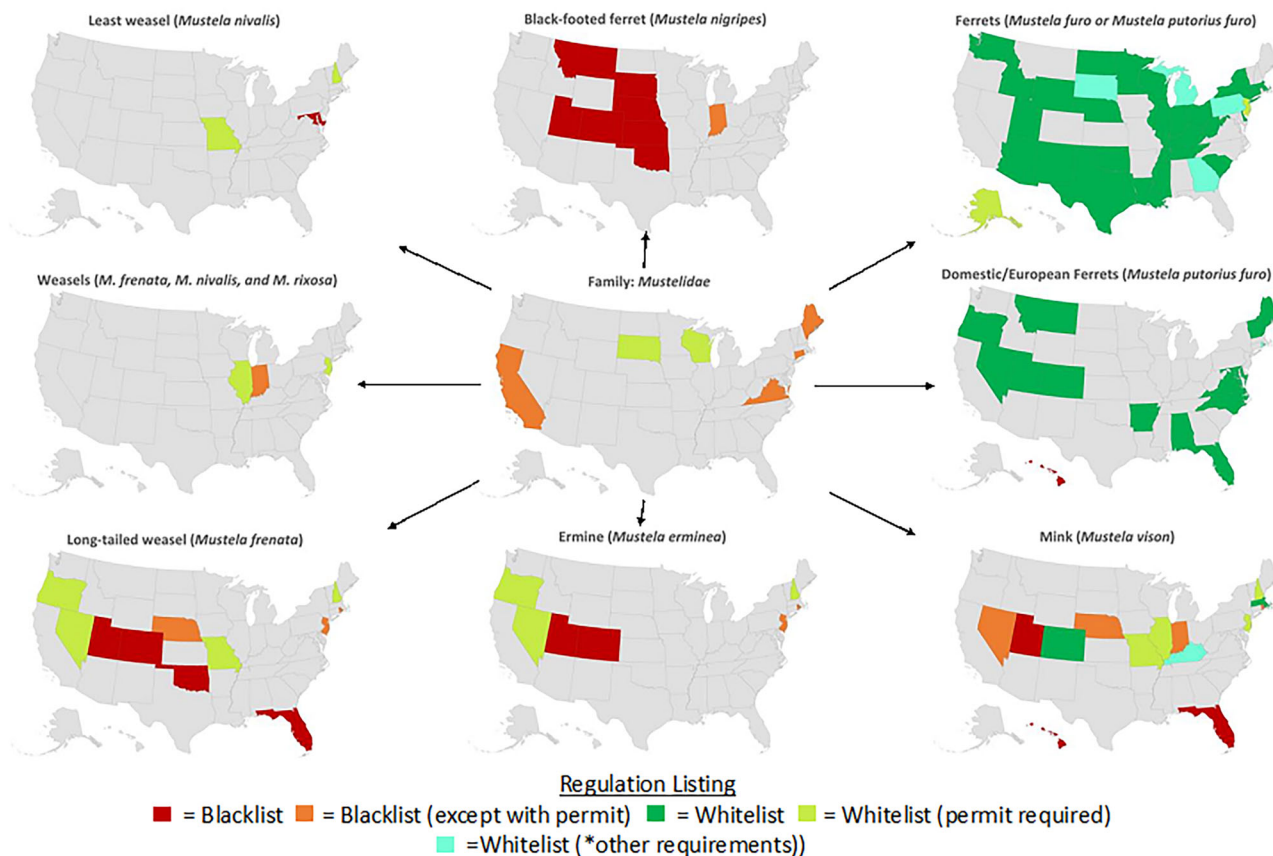


FIGURE 3 States in the United States that implemented laws that apply to trade in mustelids, 2022. Blacklists and whitelists were implemented at the family and species levels.

(*Hypostomus plecostomus*), also known as the common pleco or armored catfish, is native to South America and, through accidental or intentional release, has established populations in subtropical and spring-fed waterways in the United States (Scott et al., 2012). The suckermouth catfish is common in pet stores and is owned by hobbyist aquarists for its algivorous diet (Hoover et al., 2014). Pet stores often sell young, small individuals, and pet owners may be unaware that the species may outgrow its tank and subsequently release the fish into nearby waterways (Hoover et al., 2014; Page & Robins, 2006). The suckermouth catfish can grow up to 15 inches (30 cm) long if kept in a tank or can reach 24 inches (60 cm) outside of a tank and has been known to out-compete native species that eat algae (Hubbs et al., 1978). It also disturbs nest sites and ingests the eggs of native fishes, thus lowering native fish populations (Hoover et al., 2014). Their armored body, fin spines, and general camouflage in combination with their ability to breathe air in hypoxic conditions, provide this species with the ability to survive environmental extremes and predation (Hoover et al., 2014). These highly adaptative features have allowed the species to establish populations in Hawaii, Texas, and Florida (Hoover et al., 2014). Yet, the common pleco is not listed in any state regulations, except in Hawaii, where it can be found on the list of conditionally approved animals, and juveniles (approximately 2–4 inches long) can still be found for purchase at most pet stores at low prices (Chapman et al., 1997).

With the rapid increase in the volume of online trade in exotic pets (Stringham et al., 2021b; Valdez, 2021), current penalties for violating state-level laws that regulate the exotic pet trade are unlikely to disincentivize illegal trade in and possession of exotic pets. Online exotic pet websites provide a diverse array of species for purchase and ship pets across the United States by partnering with animal transport services (Gan et al., 2019; Sinclair et al., 2021). Although online pet providers state on their websites that they will ship pets to states in which these animals may be legally owned, it is the responsibility of pet owners to determine if possession of that pet is legal. The rapidly expanding online pet trade thus exploits information asymmetries by making pet owners responsible for knowing all the relevant regulations in their state and municipality, thereby profiting from the sale of pets that may not be legally owned in a state.

Furthermore, most states listed illegal trade in, and possession of, exotic pets as a misdemeanor, which means that prosecutors may exercise leniency or may choose not to prosecute offenders because violations of exotic pet laws are likely to be nonviolent misdemeanors (Agan et al., 2021). Prosecutors often overlook exotic pet trade crimes due to incomplete understanding of state or local laws, lack of personnel or resources to effectively prosecute pet trade violations, or prioritization of crimes that are considered more serious (e.g., illegal trade in weapons and drugs) (Runhovde, 2017). Limited agency funding and resources, combined with an incomplete understanding of

regulations by enforcement officers, also reduces the likelihood of prosecution for pet trade participants who violate state regulations (Runhovde, 2017). If pet trade violations are unlikely to be prosecuted or the fines are low, then there is a clear financial incentive to disregard state laws. For example, prior to the recent passage of the Big Cat Public Safety Act, we found a white tiger cub for sale online for \$3500 in Louisiana, a state in which the maximum penalty for violating exotic pet trade laws was \$1000, 180 days of imprisonment, or both. Considerable profits may be earned by selling exotic pets, in violation of state laws. We further note that the \$5000 fine for violating the law against owning domesticated ferrets in California has not precluded state residents from owning the largest number of domesticated ferrets in the United States (Graening, 2022).

Although our results provide support for the transition to a federal list of approved vertebrate species that may be sold and owned as exotic pets, potential adverse consequences of a regulatory shift must be considered. Breeders and sellers are likely to oppose a federal list that excludes income-generating species (Millington et al., 2022). Shifting species' status from unregulated to banned could exacerbate releases into the wild and lead to inabilities or unwillingness to access veterinary care for those animals. Changes in regulation could also increase confusion among pet owners, who already face difficulties understanding the complex and inconsistent legal landscape. Thus, a transition period between adoption and enforcement of a federal list of approved species will be necessary, during which provisions can be emplaced for animals currently possessed by breeders, sellers, and pet owners (Toland et al., 2020). For instance, breeders and sellers of exotic pets may be required to obtain permits for the exotic pets already in their possession, allowing them to sell existing stocks and giving them time to change their breeding operations. As part of the transition, permits should also be provided to owners of exotic pets that are legally owned at the state or provincial level, provided that they agree not to breed, sell, or release these animals (Hess et al., 2016). By allowing exotic pet owners to legally register their pets, the United States would secure better records of the number, species, and locations of exotic pets, while also reducing incentives to deliberately release pets and assuring access to veterinary care. Before and during the transition period, the new federal regulations and approved lists should be widely communicated to the public and the pet trade so that individuals know the status of their current and future pets, obtain necessary permits during the transition period, and buy or sell only approved or permit-bearing animals in the future. To increase industry trust in, and compliance with, the transition to a federal approved species list, representatives from the exotic pet trade, invasion and disease experts, veterinarians, ecologists, and lawyers should be included in decisions to appropriately define what an exotic pet is and to determine which species to approve at the federal level. Engaging diverse representatives can also help build strategies and awareness campaigns that valorize responsible exotic pet ownership as a way to motivate compliance by exotic pet breeders, sellers, and owners (Hausmann et al., 2023).

Consistent with the larger research literature, our results suggest that current state-level exotic pet laws in the United States

do not mitigate the invasion and disease risks associated with the exotic pet trade, owing to their inconsistencies (Essl et al., 2015; Fonseca et al., 2021; Toomes et al., 2022, 2023; Voyles et al., 2015). Inconsistent penalties and the designation of exotic pet trade violations as misdemeanors are likely to contribute to deliberate violations of laws and poor enforcement of existing policies and regulations (Fonseca et al., 2021; Runhovde, 2017). Improved, consistent, proactive regulation of the exotic pet trade at the federal level is needed to mitigate invasion and disease risks by precluding trade in, and possession of, high-risk species across the United States (Auliya et al., 2016; Hulme et al., 2018; Patoka et al., 2018; Toland et al., 2020). In the absence of such interventions, the financial returns from the exotic pet trade and the high demand for exotic pets are likely to reinforce trade and movement in species across states, in clear violation of state laws. Further studies on exotic pet trade regulations should be conducted in other countries where jurisdiction over, and regulatory enforcement of, the exotic pet trade is inconsistent across states or provinces to better address the adverse impacts of the exotic pet trade, while still allowing people to own, breed, and sell exotic pets that do not pose invasion, disease, or other biosecurity risks.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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