Pet Retail Business Case

Amphibians and Reptilians in the North American Pet Industry

WORLD ANIMAL PROTECTION

Contents

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Summary

Trade in wild animals for their use as pets is a known driver of biodiversity loss. Very large quantities of wild animals are taken from the wild, bred in captivity or ranched to be imported into dynamic urban markets. Among the most popular of animal classes commercially sold as pets are hundreds of species of amphibians and reptiles (A&R), highly vulnerable animal classes whose wild populations are particularly affected by extractions from the wild.

The economic underpinnings of pet markets of A&R are not well understood, neither are those of its consequences. This study focuses on the trade in A&R species traded as pets in North America (Canada and the United States) and assesses the costs and benefits (CB) of the pet trade from a broad perspective that includes both monetized and non-monetized categories of benefits and costs.

Economic benefits are directly measurable as the revenue paid by consumers all across the trade supply chain of live A&R and associated products. But the A&R pet trade also has a high impact on biodiversity, human-, animal- and ecosystem-health. These impacts generate very important costs to society as a whole: commercial pressure upon vulnerable populations of A&R, risks to human health, costs derived from invasive alien species, and emissions of greenhouse gases. After estimating these costs, we weigh them to the economic gains of this segment of the pet trade.

Economic benefits are highly concentrated at the retail end, and on A&R pet's consumer products. We estimate that the North American pet industry imports every year live A&R for a cost between $7.9 to $11.3 million USD. This is but a fraction of the total revenue from consumer products for maintaining A&R as pets, which is in the range of $300 million and $3 billion USD.

Agents at the point of extraction of wild A&R (the first nodes of the trade network at the regions of origin) obtain less than 2% of the export value of live animals.

Between 2000 and 2020 the U.S. imported 108 million live individual amphibians and reptiles covering 1,693 species and 732 genera, from 176 different countries. We estimate that between 1.3 and 1.4 million animals of these classes are imported on average every year into North America for the pet trade. In the five years previous to 2020 there has been a general increase in the prices paid for imported amphibians (44%) and reptiles (175%).

Most species of imported A&R (over 1,000) are sourced from the wild. For 25% of the species of imported A&R there is no assessment of conservation status, and for those species with assessment 29% of the traded species are considered threatened. Of the 35 species of A&R currently on sale at superstores, 10.5 million animals have been imported into North America in the last 20 years. Almost half of imported amphibians and more than half of imported reptiles of these 35 species come from wild populations, 19% are considered near threatened, and 17% are vulnerable.

We estimate expected health costs to be in the range of $7 million to $103 million USD per year (average $43 million). In the lower bound estimate, hospitalizations account for 76.7% of the total cost of salmonella infections, while in the upper bound case, 72% of the costs are associated with premature deaths.

Regarding the impact of A&R as invasive alien species, we estimate a lower bound of $1.2 billion (observed damages) per year and an upper bound of $9.9 billion USD (both observed and potential damages).
The costs derived from emissions of greenhouse gases (GHG) associated with the trade and ownership of A&R kept as pets are estimated to be in the range of $35.4 million to $134 million USD per year. 99% of the estimated carbon costs come from the annual energy consumption required for the maintenance of captive A&R.

The overall CB assessment yields the following results:

- The trade and ownership of A&R for pet keeping relies on the imports of millions of animals every year, exerting pressure upon more than 1,000 wild species, a third of which is threatened. Half of the species sold at superstores come from the wild and 36% are threatened or vulnerable.

- There are very important monetized costs, most of which derived from impacts of invasive alien species, but also important health costs.

- There are very important hidden costs associated with the trade and ownership of A&R kept as pets. These costs are not internalized by the industry. Not only the owners of these animals are exposed to risks, but society as a whole.

- A&R for pets will continue to be sourced in the wild, with a corresponding sustained pressure on local wild populations.

- Sustaining the 'business-as-usual' level of demand for A&R to be kept as pets will continue to impose very large costs to North American people, ecosystems, and endemic species.

Photo: Animals on display at the Canadian Reptile and Exotic Pets Breeders' Expo near Toronto, September 2018.

Introduction

Halting biodiversity loss is critical for sustainability and wellbeing. This includes reducing the impact of the multiple direct and indirect drivers of biodiversity loss, preserving and remediating key natural habitats, and assessing the multiple levels at which human-animal interactions occur and develop. One such a level is the large number of wild animals traded as pets every year.

The Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) defines drivers of biodiversity loss as the human forces that exert pressure on biodiversity in direct and indirect ways.[1] Direct drivers affect biodiversity and ecosystem services in an immediate form, in a specific region or system. Indirect drivers refer to deeper causes that act upon direct drivers, like economic and population growth, through distinct channels like institutional systems, trade, finance, and technological development.[2] Maxwell et al. found that over-exploitation is the main direct driver of biodiversity impacts, followed by habitat loss (from agriculture and urban development), the introduction and spread of invasive alien species, pollution, ecosystem modification, and climate change.[3] IPBES ranks direct exploitation of animals as the second most important driver of biodiversity loss.[1] More than 80% of threatened species are impacted by more than one driver, e.g., they face the pressure from overexploitation and habitat loss simultaneously.[4]

Trade in wild animals for their use as pets is a use of biodiversity of particular concern. Pets, whether domesticated or wild animals, have been traded since ancient times, driven by an elementary human fascination for the diversity and companionship of animal life. In its modern form the pet trade is part of a global industry, in the sense that the activities that make this trade possible are the result of an international network of agents, each one specialized in particular goods and services including, but not restricting to, the trade of live animals. This network connects biodiversity-rich ecosystems with highly dynamic commercial and manufacturing agents that have emerged as a result of the mainstreaming of non-domesticated pet-owning.

The rate and scale of this type of use can paradoxically destroy the very biological diversity upon which it is based, as the unsustainable extraction of wild animals has led to population decline and collapse for many species.[5]

Despite being a non-essential use of biodiversity, the pet trade represents an important share of total demand for wildlife use. In the U.S. and Canada millions of amphibians and reptiles are kept as pets and millions more are imported commercially every year. Of all live wild animals that are imported into Canada, almost half go to the pet industry, but in the case of amphibians and reptiles this share is almost 70%.[6] While this trade produces an important flow of economic revenue, the international movement and expanding ownership of these animals as pets poses serious ecological and health risks that affect animals, people and ecosystems, both in the regions of origin as well as in the importing regions. The magnitude of these risks and hidden costs has not been assessed, and this study aims at making a first step in that direction.

This study focuses on the trade in amphibian and reptilian (A&R) species traded as pets in Canada and the United States (hereto after, North America) and assesses the benefits and costs of the pet trade from a broad perspective. Cost-benefit analysis (CBA) is an assessment technique based on the construction of monetized economic estimates of benefits and cost of specific activities or alternative policy actions. It is a dominant standard for decision-making and policy design (e.g., it is a key policy criterium in the U.S. Species Conservation Act). In this study we undertake a holistic CBA that includes both monetized and non-monetized categories of benefits and costs, considering the international trade of live A&R imported into North America, estimates of the value of complementary products, as well as hidden costs like direct ecological impact on A&R populations, health risks, costs derived from invasive alien species, and emissions of greenhouse gases.

Industry overview

The A&R pet industry can be represented as a multilevel chain consisting of two major types of commodity flows: a flow consists of the supply (sub)network of live animals, linking a wild source with final consumption, and a flow of complementary products for pets' maintenance.

The value chain approach is being increasingly applied to wildlife trade networks.[8] Sinclair et al. provide a useful summary of this general structure (see figure 1 below).[9]

- At the entry point of the sequence (the source) there is always a wild population [a].
- The first group of agents in the network are collectors, who either capture animals in their natural habitats, or ranch or breed animals in captivity. Ranching and breeding also rely on wild populations for accessing eggs or juveniles (ranching) or for maintaining their breeding stocks and are usually subject to quotas, however not always in compliance to them.[10]
- A second tier of traders aggregate and obtain captured, ranched, or bred animals from different origins and species for their transport to points of sale or export.
- The third and fourth stages of the trade are operated by exporters and importers, who are located near international ports and further accumulate stocks from different traders; these agents specialize in international operations, involving large-scale, long-distance transportation, and intermediate points of re-exports, using increasingly electronic and social media platforms.[11]
- Wholesalers acquire imported or locally bred animals for their regional distribution and from there into final sale points, which tend to be geographically dispersed and concentrated in urban centers.
- Finally, retailers control the selling outlets that make animals available to consumers, either directly in specialized stores, specialty markets and trade fairs[12], and also increasingly through internet platforms.[13] Retailers are usually distinct from the rest of the agents in that they are diversified into multiple animal and product markets.

Photo: Tortoise being kept as a pet. iStock.

[a] A study on sales prices of live A&R in Madagascar found that local collectors obtained around 1.4% of the final export price, while exporters captured 92%.[14]

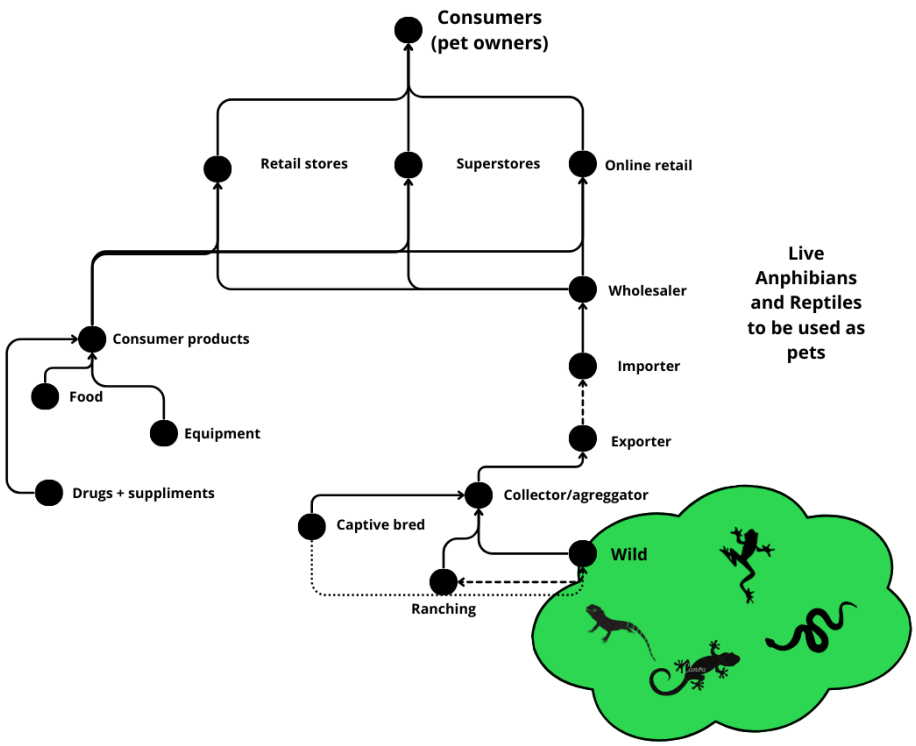


Figure 1. **Trade networks of live animals (right) and consumer products (left). Each point corresponds to a different type of agent. Source: own elaboration based on Sinclair et al.[11]**

Rationale

The trade of A&R for pets produces economic gains to the agents that supply the live animals and the products required for their maintenance. From an economic perspective, every agent in the supply chain pays a price that includes, in principle, all the monetary costs incurred by the previous agents. But the trade produces many other costs that are silent or invisible.[15] Ecological impacts in the regions of origin, damages derived from health hazards, ecological impact of invasive alien species, and emissions of pollutants and greenhouse-gases are the most visible of those costs that are not accounted for in the prices that guide business-as-usual economic transactions. An assessment of these costs is necessary to evaluate the social and ecological sustainability of the trade in A&R destined for the pet industry.

The estimation of many of these costs is not straightforward; some have been measured and monetized (e.g., incidences and costs of salmonella infections attributed to reptiles and amphibians), some are only partially assessed (e.g., damages and costs of managing invasive alien species), some cannot be measured (e.g., extinction of undocumented species), and others are priceless (e.g., human lives, healthy ecosystems). Moreover, estimating the scale of loss of diversity and integrity of ecosystems, or disruption of environmental functions or health risks involves different degrees of uncertainty. Similarly, the costs and benefits of product innovation and development of new markets are also difficult to determine in advance. **In addition to uncertainty, decision making in the context of biodiversity conservation must also consider the nature and scale of potential damage. When potential damage is very large or irreversible, even small probabilities of occurrence are of concern.** These considerations about the decision landscape (uncertainties and high costs) call for an approach based on the principles of prevention and precaution.

Ecosystem services of A&R and potential losses

Amphibians and reptilians constitute a large diverse group of vertebrates that share habitats and characteristics (e.g., ectothermy), which creates the necessity of artificial habitats when kept as pets. They are adapted to very different types of habitats: temperate, tropical to desertic environments in terrestrial, marine, and freshwater ecosystems. They are important mutualistic agents, and in their roles as predators, prey, grazers, and commensal species they provide key ecosystem services like pest population control, pollination and seed dispersion.[16] They also provide key information about ecosystem's health and are of cultural value.

A&R animal classes often have narrower habitat ranges relative to other vertebrates, which makes them more vulnerable to threats from environmental degradation and invasive alien species. About 41% of amphibian and 21% of reptilian species are threatened with extinction [17-19]. These estimates are conservative, as only 87.9% of amphibians and 87.1% of reptilians have been assessed.[19] **Together with habitat destruction and over-exploitation, A&R are also threatened from epidemics like the chytrid fungus (*Batrachochytrium dendrobatidis*), which has taken a very high toll on amphibian populations in Latin America, Australia, and Brazil, making amphibians the most threatened vertebrate class.**[20,21]

The loss of local populations, the extinction of species and the reduction of taxonomic diversity of specific populations in these animal classes represent multiple risks of ecological disruption. The decline of amphibian species, for example, has large scale effects on ecosystems by altering the structure of algal community, modifying the circulation of organic matter and essential nutrients, affecting insect and predator populations, and weakening biomass transfers in freshwater habitats.[22] Over-exploitation of wild amphibian populations can produce indirect negative effects, like augmenting the use of pesticides to combat the increase in insects, to the point that value of trade is lower than the cost of chemical pesticides.[23] Finally, the distribution of impacts is highly unequal, as the losses derived from the disruption of ecological services are mostly borne by rural populations in the countries of origin.[1]

This "ecological footprint" of the pet trade in A&R species is incredibly difficult to measure and even more in a monetized way, as the value of ecosystem services of A&R in their habitats of origin is a difficult task yet to be undertaken. At one extreme, the collapse of entire ecosystem services can have catastrophic effects. The contribution of animal pollinators to the U.S. economy has been estimated in $24 billion USD, including $9 billion from native insect species (The White House, 2014). This approach, the valuation of ecosystem services, thus always depends on the value of the local economy; the high value of some U.S. crops affected by losing pollinators. A broader assessment estimates the value of these ecological services provided by insects in the U.S. to be at least $57 billion per year when services like dung burial, pest control, pollination, and wildlife nutrition are included (a major component of value in Losey & Vaughan´s estimate comes from recreational services, i.e. money expended in hunting and fishing wildlife that feeds on insects).[24]

But costly losses are not restricted to high-value economic systems. Johnson et al. estimated that the costs of collapsing tropical forests, wild pollinators or marine fisheries would produce disproportionately large damages in low and lower-middle income countries, reaching losses equivalent to 7% to 10% of the national gross domestic product (compared to 0.8% to 3% in upper-middle and high income countries).[25] Inadequate pollination can lead to losses of 3%-5% in the production of fruits, vegetables and nuts in low income countries, and reduce the value of agricultural production between 12% and 31%, with dire consequences for health and nutrition.[26]

Even without specific measures it is reasonable to assume that the impact upon ecosystem services would be a function of the number of extracted animals, the number of species, the different risks associated to the sources of origin (wild, ranched, and captive breeding), and the relevance of ecosystem functions of each species. Even without a precise figure of costs and risks, the ecological impact of the A&R pet industry can be approximated by the level or volume of animals extracted from the wild and their conservation status.

As a caveat to this estimate, it must be stressed that actual wild A&R extraction rates are much higher than shown in import data due to mortality during transport, storage and distribution, under-reporting, and illegal trade. Estimates of mortality in A&R pets are however scarce.

Robinson, et al.[27] found mortality rates of A&R pets at homes to be 3.6% on average, arguing that mortality rarely exceeds 4.5% at each stage of the trade chain.[b] Toland et al. found mortality rates of 72% of reptiles after six weeks at a wholesale facility in the U.S. and 75% mortality rate of reptiles within the first year at home in the United Kingdom.[28] Robinson et al. report that exporters of live reptiles in Madagascar "were permitted by authorities to collect 10% above quotas to allow for mortality" .[14]

Even when considering low mortality rates at each stage, overall mortality will depend on the length of the trade chain. **Assuming a typical trade chain is composed of seven stages (harvest, collection, storage, export, import, wholesale, retail, final consumer, cfr. Sinclair, et al.[11]) with an average mortality rate of 4%-8% at each point of exchange the overall mortality rate would reach between 24.9% and 44.2%.** Mortality along the trade chain is a cost to the industry, as animal losses add up to costs. However, the low prices of imported A&R may well justify this level of waste.

Photo: Veiled chameleon. Shutterstock.

[b] This study is based on a questionnaire conducted at breeders' events; only 9% of respondents have kept reptiles for one year or less, while more than 60% of respondents have had reptiles for 6 years or more. Thus, mortality estimate is most likely biased down, as experienced pet owners, are overrepresented in the survey.

Health

Amphibian and reptilian species used as pets have been identified as vectors of bacterial and viral diseases that affect both humans and other animals, like encephalitis, herpes, West Nile viruses, multiple bacteria[29,30], leptospirosis[31], and salmonella. Given restrictions of data availability we restrict the cost analysis to potential salmonella infections, noting that these cost estimates are thus lower than the total health costs associated with the trade and pet keeping of these species.

Salmonella is widespread among animal species, and is ranked second among the ten most frequently reported infectious diseases for mammals, amphibians, birds and reptiles.[30] Reptiles are natural reservoirs of salmonella, which can hold a wide variety of serovars (distinct variation of species of salmonella) simultaneously without exhibiting disease symptoms.[32,33] Marin et al. found that 48% of pet reptiles examined from both households and pet shops were salmonella carriers.[34] Salmonella can spread through the sharing of terrariums and boxes, since salmonella is highly durable outside the host.[35] Incidence tends to be higher in shops than households, 67% vs 33% according to Marin et al..[34] Nakadai et al. reported an incidence rate of 74.1% in pet shops, as these spaces tend to be always occupied, cleaning is costly and there is exposure to multiple vectors and hosts.[36] Salmonella is more frequently detected in snakes and lizards compared to chelonians, which may be related to the fact that snakes and lizards are mainly fed with rodents and other small animals (which are kept frozen then thawed) that can in turn be a source for salmonella and cross-contaminate spaces.[34]

Salmonella infections have "a significant economic impact, which has been estimated at 3.6 billion dollars annually."[c] During the 1960s and 1970s there were 280,000 cases of Reptile Related Salmonellosis (RRS) diagnosed in the U.S., a 14% incidence.[37] Warwick, et al. argued that 8 million reptiles kept as pets in the U.S. were behind an increasing incidence of reptile-related salmonellosis which reached 76,000 cases per year.[35] In 2003 the Center for Food Security and Public Health, Iowa State University reported to the Center for Disease Control (CDC) that 93,000 cases could be tracked back to reptiles, a 7% incidence of RSS.

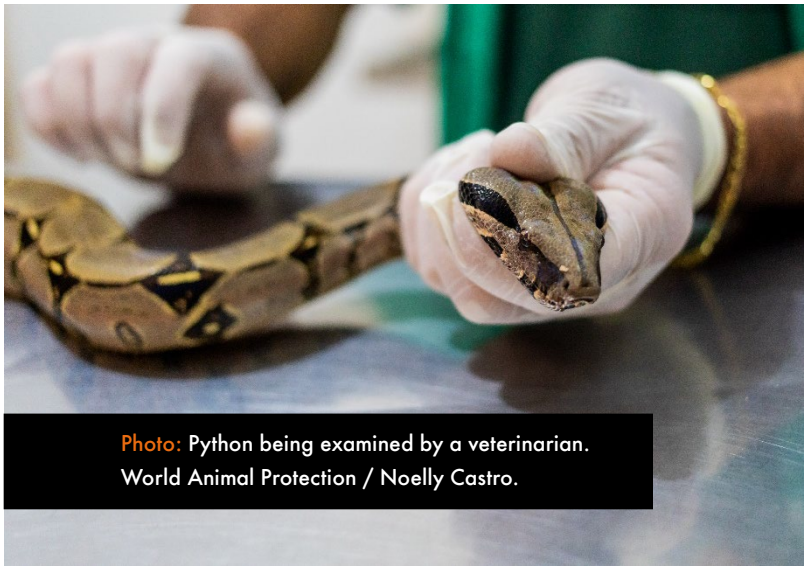


Photo: Python being examined by a veterinarian. World Animal Protection / Noelly Castro.

CASE STUDY: While current incidence rates appear to have diminished (as we show below), outbreaks still occur. The public Health Agency of Canada reported 8 national animal-related salmonella outbreaks in the past 10 years, with 7 linked to reptile keeping. The most recent outbreak of reptile related salmonella was reported in 2023, with 45 cases directly related to snakes and feeder rodents. Nine people were hospitalized, and one death was reported.[a]

There are two different kinds of risks related to salmonella given the persistence of both trade in reptiles and a large population of reptile pets. One is the probability of zoonotic emergence of variants of concern. The second is the role of reptiles as an antibiotic-resistant salmonella reservoir as the use of antibiotics is widespread in breeding facilities, shops, and long-distance transport.[38]

[c] USDA (United States Department of Agriculture). USDA ERS—Cost Estimates of Foodborne Illnesses. (2014). Available online at: https://www.ers.usda.gov/ data- products/cost- estimates- of- foodborne- illnesses.aspx.

Invasive Alien Species (IAS)

This term refers to non-native wild species that have become established in new geographic areas due to their ability to grow fast and spread rapidly outcompeting local populations, producing negative impacts on ecosystems, biodiversity, and local species.[39] IAS are one of the leading causes of wild species population decline and extinction,[4] and responsible for the decline of 42% of threatened and endangered species in the U.S.[40] IAS are introduced by human activities as animals are moved into new locations via escape, are accidentally or intentionally released, or are inadvertently transported; one of the well-established pathways of introduction is the use of animals as pets.[d] Globally, it is estimated that over the past 50 years the economic cost of invasive species has been $1.3 trillion USD, an estimation that is continually increasing.[41]

The global cost of invasive herpetofauna has reached $17.0 billion USD per year, $6.3 billion USD for amphibians, $10.4 billion USD for reptiles.[43] The majority of these costs are accrued to only two species, the brown tree snake (*Boiga irregularis*) and the American bullfrog (*Lithobates catesbeianus*), with $10.3 and $6.0 billion USD in costs, respectively. Pimentel et al. estimated the costs of invasive species in the U.S. at $120 billion USD per year.[44] Fantle-Lepczyk et al. corrected this figure down to $19.94 billion per year, with a cumulative total of $4.52 trillion from 1960 to 2020 (USD at 2017 prices). [45]

Crystal-Ornelas et al. detailed the costs of invasive alien species in the U.S. at $1.22 trillion USD considering only observed damages from high-reliability estimates, with an average annual cost of $1.21 billion for reptiles and $9.29 million for amphibians.[40] They also found that annual cost associated to IAS went from $2 billion USD per year in the 1960s to over $26 billion USD per year from 2010 up to now.

Photo: Red-eared slider.

CASE STUDY: An example of an IAS is the red-eared slider (*Trachemys scripta*). This semi-aquatic turtle, native to south-central U.S. became a very popular pet during the 1980s and 1990s. After being traded by the millions it is now invasive everywhere in the world (with the exception of the Antarctica), including in almost all U.S. States and in the Canadian provinces of Ontario, Quebec and British Columbia.[a] They are exceptionally adaptable omnivores that feed on a broad range of species of plants, insects, fish and tadpoles and can have a deep disrupting effect in the ecosystem balance, taking over native turtle species' habitats, introducing parasites to new environments like salmonella, ranavirus and other parasites.[42] The red-eared slider continues to be traded as pet.

[d] IPBES, 2023, p. 26

Greenhouse gases (GHG)

Finally, a third hidden environmental cost to examine is the level of emissions of GHG attributed to the trade and ownership of A&R as pets. The latest report from the Intergovernmental Panel on Climate Change (IPCC) presents indisputable evidence that climate change is accelerating. Global warming is affecting the integrity and resilience of all ecosystems on the planet more severely than expected.[46] The limit of an increase in average temperature of 1.5°C, with respect to the average of the pre-industrial era, will be exceeded with high probability by 2040.[47] If this trajectory continues, the increase in temperature will put the functioning of the systems that support life on the planet at existential risk. Emissions associated to pet ownership have been estimated for dogs and cats[48,49] but not for A&R used as pets. Energy costs are very important in the case of A&R pets which require artificial habitats. With energy prices on the rise in the last years, many reptile pet owners have been reported to dump their pets.[e]

Photo: Long-tailed lizard. Shutterstock.

[e] "Energy costs force owners to give up their pet reptiles," BBC News, 10 June 2022, https://www.bbc.com/news/uk-england-61720142

Results

Benefits

International trade in live A&R

Between 2016 and 2020 the U.S. imported on average 755 thousand live reptiles and 3.2 million live amphibians according to LEMIS data. Of the latter, we estimate approximately 490 thousand were destined for the pet trade. In Canada, the CBSA reported annual imports of 72 thousand live reptiles and 47 thousand live amphibians on average per year for the period 2014-2020 exclusively for the pet industry. In accordance, the North American pet industry imports 1.3 million amphibians and reptiles every year, at an average cost of $7.9 to $11.3 million USD, as a lower bound estimate. 87% of these import value corresponds to the U.S. alone. Table 1 below summarizes these results and include import data from the UN-Comtrade database (as this source only reports for live reptiles, the estimate for amphibians is an extrapolation, as explained in the Materials and Methods section).

According to this database, average annual imports during 2016-2019 amount to 559 thousand amphibians and 858 thousand reptiles and $11.4 million USD, slightly higher than the estimates from LEMIS. We use this second figure as an upper bound estimate of import value of live A&R.

The import value of $11 million USD can be considered as the annual economic benefit accrued to the exporting agents participating in the trade. This is a minor component of the total benefits of the trade in A&R, as we will see below. But it is very important to note that only a small fraction of these benefits are reaped by a huge number of local collectors, since most of the value remains in the hands of international traders. Using the data reported in Robinson et al. on marketing margin at different stages of the trade chain of A&R in Madagascar[14], we calculate that the share of local collectors in the commercial revenue of A&Rs is in average 1.66% (standard deviation = 1.2%), 8.39% for intermediaries (sd = 6.7%), and 90.18% for exporters (sd = 7.16%).

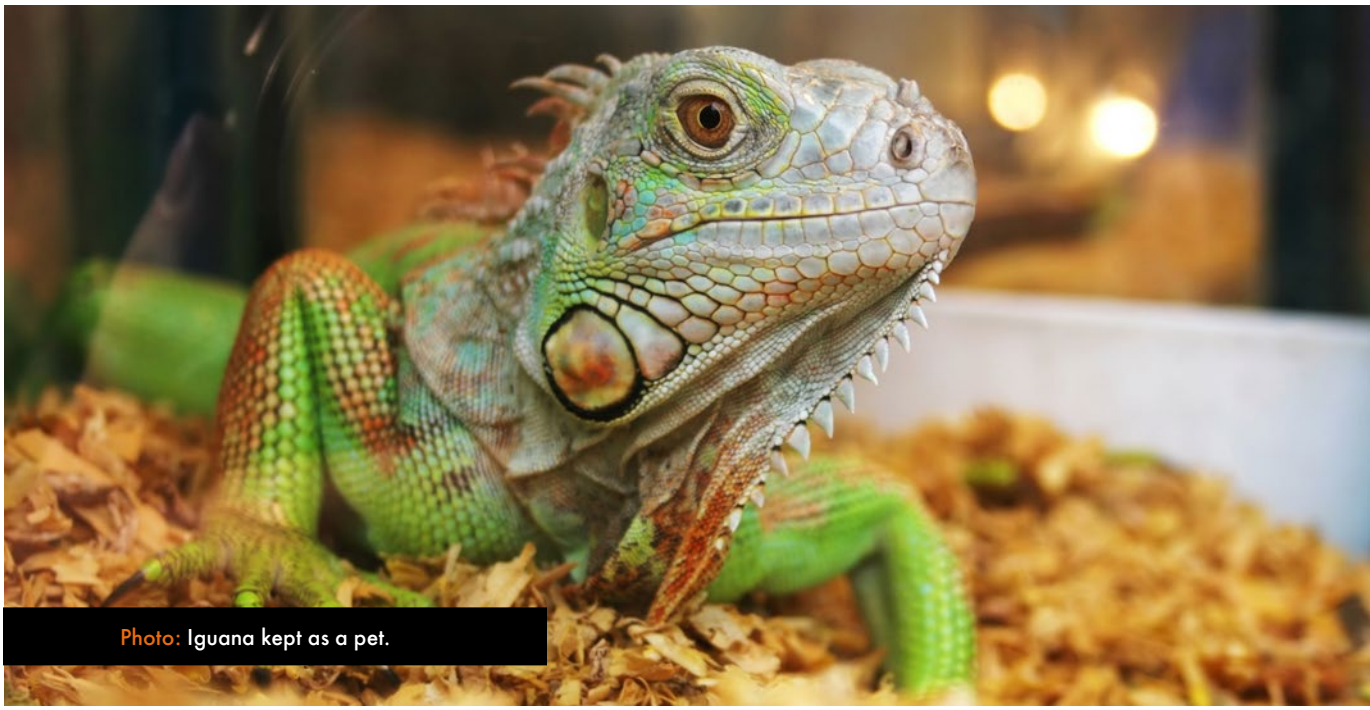


Photo: Iguana kept as a pet.

Table 1: North America annual imports of live A&R for the pet industry

Class	Total (lower bound)		U.S. (annual average 2016-2020)		Canada (annual average 2014-2020)	
	Animals	Import value (USD)	Animals	Import value (USD)	Animals	Import value (USD)
Reptiles	827,891	7,522,980	755,257	6,862,967	72,633	660,013
Amphibian	538,863	418,363	491,587	381,659	47,276	36,704
Total	**1,366,753**	**7,941,343**	**849,665**	**6,936,263**	**119,909**	**696,717**

	Total (upper bound)	
	Animals	Import value (USD)
Reptiles	858,805	10,794,877
Amphibian	558,984	600,318
Total	1,417,788	11,395,195

Table 1. Annual imports of live amphibian and reptiles for the pet industry in number of animals and value of imports. The first estimate for the total for North America is the sum of values processed from LEMIS (U.S.) and the CBSA (Canada). The number of amphibians imported into the U.S. for the pet industry was calculated from the ratio of amphibians to reptiles in Canadian imports, which includes only trade for the pet industry. The value of imports for Canada was obtained by multiplying the number of imported animals by the average unit price at species level in the U.S. Upper bound totals are based on UN-Comtrade imports for the U.S. and Canada for the period 2016-2019, commodity code 10620 "Live reptiles, incl. snakes & turtles". The number of amphibians is extrapolated in the same proportion as in the lower bound estimate.

We estimate that the population of A&R kept as pets in the U.S. lies currently between 3.3 and 8.5 million animals. For Canada, the estimated reptile pet population in 2019 was 463 thousand animals.[52] If we assume that Canadians own amphibians in the same proportion to reptiles as in the U.S., there would be around 57 thousand pets of this class in Canada. As a result, the total A&R pet population in North America is estimated in a rounded range between 3,880,000 and 9,000,000 animals.

Consumer products for A&R kept as pets

Based on these population ranges, we obtained estimates of the total expenses incurred by A&R pet owners, which include food, supplies, non-surgical veterinary costs, medications, and toys. These expenses are an estimate of the final demand for consumer products for A&R kept as pets, which represents a major component of the economic benefits received by retailers, wholesalers, and manufacturers involved in the A&R pet industry. On average, the supply chain of consumer products for A&R used as pets would receive and average annual revenue in the range of $1.3 and $3 billion USD.

There are reasons to believe that these numbers for consumer products for A&R pets are overestimated. As a reference, PetSmart total revenue in 2019 was $5.3 billion. Assuming A&R pets' prevalence in U.S. households is between 1.6 % and 5% of pets (AVMA[51] and APPA,[50] respectively), and total revenue in the pet industry (all species) is $20 billion,[7] the expenses in consumer products for A&R pets should be in the order of $310-$970 million. For consumer products of A&R pets to be in the range of $1-$3 billion USD, these pets should be 2 to 5 times more expensive to maintain than the average pet. While A&R often require specialist equipment, such a high cost seems unlikely given their much lower weight (as consumption is much likely a function of the pet's weight). The lower estimate seems to be more realistic. As per the causes of overestimation, it is likely that average expenses of A&R pets from the APPA 2023 survey are exaggerated. For example, while our estimate implicitly assumes that all owners incur in all categories of expenses, **the APPA survey notes that many owners avoid some of the costs, for example, only 15% of owners used medications, and only 40% bought toys.**

Even when considering lower value estimates between $300-$1,000 million USD for expenses in A&R pet consumer products, there is little doubt that it is several times larger than the import value of live animals, which we estimated to be in the order of $7.9 to $11.3 million USD per year. The key point is that the economic value of live A&R species sold as pets represents between 0.8% and 3.5% of the total economic value of the stream of products captured by the industry, considering these last conservative estimates. But this does not mean that the selling of live animals is unimportant, from the point of view of the industry. The demand of consumer products for A&R pets clearly depends on the population of pets. In order to maintain the population of pets, this industry segment surely finds an incentive in the continuous selling of live animals, and perhaps more crucially, on attracting new owners. Additional incentives like using exotic live animals' exhibition as an attraction to increase "foot-traffic" in the superstores may also play a role.

Costs

Live animal imports

LEMIS data indicate that between 2000 and 2020 the U.S. imported 108,010,896 live individual amphibians and reptiles pertaining to 1,693 species and 732 genera. In addition, the same source indicates that over 1,000 different U.S. importers participate in the trade of live A&R originating from 176 different countries. Table 2 below shows the main 20 countries of origin of imported A&R, which account for 93.6% of total imports for the period.

Imports of A&R to the U.S. come from tropical regions in Southeast Asia, Central and South America, and Western Africa. Southeast Asia appears as the main source, since the three largest trade hubs (Taiwan, Hong Kong and Singapore) together with Indonesia and Thailand add up to 58% of total imports.

Only 20 species account for 82.8% of the trade in terms of number of animals (Table 3). More than half of total imports belong to two amphibian species the bullfrog *Rana catesbeiana* (which is imported in large numbers despite being endemic to North America) and the western dwarf clawed frog, *Hymenochirus curtipes*. These species are in great demand for their use in chemical and medical industries and are traded in large shipments comprising thousands of specimens (most likely as larvae). **The most traded reptiles are green iguanas (*Iguana iguana*), ball pythons (*Python regius*), leaf-toed geckos (*Hemidactylus sp.*), Asian water dragons (*Physignathus concincinus*) and bearded dragons (*Pogona viticeps*).**

Table 2: **U.S. imports of live amphibians and reptiles by country of origin, 2000-2020.** (source: own calculations based on LEMIS)

country of origin	number of animals	percentage
Taiwan	29,623,993	27.43%
Hong Kong	11,067,153	10.25%
Singapur	7,978,782	7.39%
China	7,288,794	6.75%
Ecuador	7,150,977	6.62%
Indonesia	7,019,129	6.50%
Vietnam	5,878,550	5.44%
Mexico	5,370,579	4.97%
El Salvador	3,535,259	3.27%
Brazil	2,757,868	2.55%
Dominican Rep	1,845,297	1.71%
Togo	1,738,980	1.61%
Thailand	1,559,727	1.44%
Tanzania	1,480,378	1.37%
Colombia	1,350,066	1.25%
South Korea	1,346,389	1.25%
Ghana	1,300,649	1.20%
Nicaragua	1,110,233	1.03%
Benin	932,290	0.86%
Egypt	806,109	0.75%

Table 3: **U.S. imports of live amphibian and reptile species, 2000-2020.** (source: own calculations based on LEMIS)

species	number of animals	percentage
Rana catesbeiana	42,714,951	39.5%
Hymenochirus curtipes	16,261,740	15.1%
Bombina orientalis	4,868,810	4.5%
Iguana iguana	3,954,202	3.7%
Rana forreri	3,591,952	3.3%
Cynops orientalis	2,687,550	2.5%
Python regius	1,954,611	1.8%
Hemidactylus sp.	1,834,351	1.7%
Xenopus laevis	1,696,690	1.6%
Hymenochirus boettgeri	1,361,611	1.3%
Physignathus concincinus	1,322,036	1.2%
Takydromus sexlineatus	1,041,558	1.0%
Triturus sp.	1,030,622	1.0%
Pogona vitticeps	959,225	0.9%
Rana pipiens	919,793	0.9%
Trionyx sinensis	814,021	0.8%
Litoria caerulea	676,670	0.6%
Trachemys scripta	639,747	0.6%
Hymenochirus boulengeri	556,103	0.5%
Cynops pyrrhogaster	541,047	0.5%

Imports of A&R sold at superstores

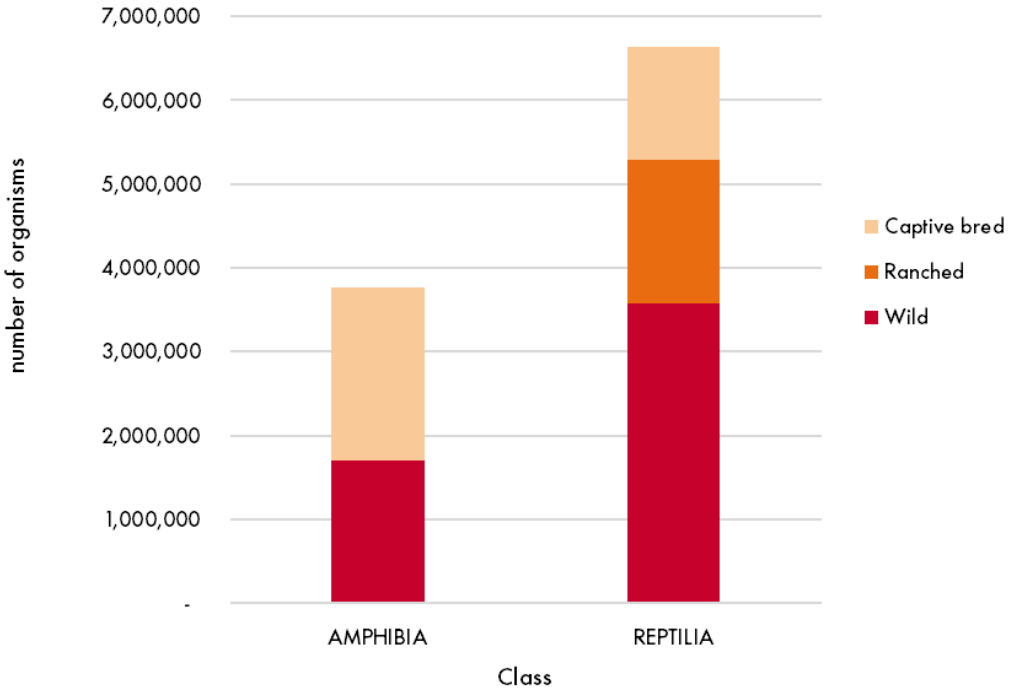
In general terms, the imports of the 35 species sold by superstores,[f] account for over 10.5 million animals between 2000 and 2020. The species were bought by approximately 1,000 importers from about 1,820 exporters in 115 different countries. These imports account for 9.8% of the total A&R animals imported but represent 26% of the total value of imports over the same period.

The trade in these 35 species shows a cyclical pattern, increasing from 2000 to 2008, then decreasing until 2017, and rising again in 2018-2019, to an average of 520 thousand animals per year. The number of species traded fluctuates at around 25 each year, as some species disappear from the trade and others are incorporated.

In terms of source and conservation status of these 35 species, a striking result is that the percentage of wild sources and threatened populations are both higher than for the trade in live A&R as a whole. Almost half of imported amphibians and more than half of imported reptiles of these 35 species come from wild populations (figure 2).

Regarding the conservation status, 63% of the trade in terms of specimens comes from species reported as Least Concern, 19% are Near Threatened, and 17% are Vulnerable. Although none of the 35 species are categorized as Critically Endangered, PetSmart sells *Testudo spp* tortoise genus, without specifying species; at least one species of the *Testudo* genus is critically endangered (*Testudo Kleinmanni*). The red-footed tortoise (*Chelonoidis carbonarus*), and the African sideneck turtle (*Pelomedusa subrufa*) are the only species that have not been assessed by the IUCN Red List.

Figure 2: **U.S. imports of live amphibians and reptiles 2000-2020, 35 species sold at superstores, by source (number of animals).**



[f] Anolis barbatus, Anolis carolinensis, Anolis sagrei, Ceratophrys aurita, Ceratophrys calcarata, Ceratophrys cornuta, Ceratophrys cranwelli, Ceratophrys ornata, Ceratophrys sp., Chamaeleo calyptratus, Chelonoidis carbonarius, Chlamydosaurus kingii, Correlophus ciliatus, Dyscophus antongilii, Dyscophus guineti, Dyscophus insularis, Eublepharis macularius, Graptemys pseudogeographica, Hyla cinerea, Hymenochirus boettgeri, Lampropeltis sp., Litoria caerulea, Pantherophis guttatus, Pelomedusa subrufa, Physignathus concincinus, Pogona vitticeps, Python regius, Takydromus sexlineatus, Testudo graeca, Testudo hermanni, Testudo horsfieldii, Testudo kleinmanni, Testudo marginata, Trachemys scripta, and Xenopus laevis.

Table 4 below presents the import numbers, source, conservation status and population trends for the 30 of the 35 species sold at superstores for which this information is available. We identified 9 species that face some level of threat and decreasing population trends (marked as red), as well as 7 species that despite belonging to the category of least concern, have either decreasing or unknown populations (marked as yellow).

Table 4: U.S. imports of live amphibians and reptiles (number of animals) 2016-2020, by course and conservation status. (source: own calculations based on LEMIS).

threatened
risky trend

Taxon	Wild	Ranched	Captive bred	% Wild	red list category	population trend	CITES
Trachemys scripta	270,025	-	10,955	0.96	Least Concern	Stable	
Physignathus concincinus	147,313	-	2,788	0.98	Vulnerable	Decreasing	
Takydromus sexlineatus	117,068	-	5,170	0.96	Least Concern	Stable	
Testudo horsfieldii	60,355	2,200	2	0.96	Vulnerable	NA	II
Hymenochirus boettgeri	31,322	-	242,190	0.11	Least Concern	Unknown	
Litoria caerulea	27,102	-	6,648	0.80	Least Concern	Stable	
Pelomedusa subrufa	22,760	92	896	0.96	NA	NA	III
Ceratophrys cranwelli	18,382	-	20,836	0.47	Least Concern	Decreasing	
Pogona vitticeps	18,288	3	595,846	0.03	Least Concern	Unknown	
Chelonoidis carbonarius	7,015	-	9,250	0.43	NA	NA	II
Python regius	5,338	145,428	17,010	0.03	Near Threatened	Decreasing	II
Anolis sagrei	2,556	-	-	1.00	Least Concern	Stable	
Ceratophrys cornuta	2,073	-	7	1.00	Least Concern	Stable	
Dyscophus guineti	1,834	-	1,217	0.60	Least Concern	Decreasing	II
Chlamydosaurus kingii	1,115	-	2,592	0.30	Least Concern	Unknown	
Xenopus laevis	1,035	-	25,546	0.04	Least Concern	Increasing	
Pantherophis guttatus	1,018	-	30,754	0.03	Least Concern	Stable	
Eublepharis macularius	837	-	3,236	0.21	Least Concern	Stable	
Dyscophus insularis	625	-	-	1.00	Least Concern	Decreasing	II
Correlophus ciliatus	360	-	1,834	0.16	Vulnerable	Decreasing	
Ceratophrys ornata	315	-	16,667	0.02	Near Threatened	Decreasing	
Hyla cinerea	188	-	-	1.00	Least Concern	Stable	
Chamaeleo calyptratus	2	-	24,468	0.00	Least Concern	Stable	II
Anolis barbatus	1	-	7	0.13	Near Threatened	Unknown	
Ceratophrys aurita	-	-	18	-	Least Concern	Unknown	
Dyscophus antongilii	-	-	606	-	Least Concern	Decreasing	I
Graptemys pseudogeographica	-	-	676	-	Least Concern	Unknown	III
Testudo graeca	-	-	376	-	Vulnerable	NA	II
Testudo hermanni	-	-	6,765	-	Near Threatened	Decreasing	II
Testudo marginata	-	-	175	-	Least Concern	Stable	II

This brief analysis confirms the notion that the retail segment of superstores has a leading position in the trade. But more importantly, it shows that the range of species these retailers accommodate in the market rely to a large extent on wild, threatened and decreasing populations.

Human health

Expected costs of reptile related salmonella (RRS) infections are estimated within a range of $7 million to $103 million USD per year, averaging $43 million. These figures result from observed rates of RRS of 1.95% in non-hospitalized cases, 3.11% of hospitalized and post hospitalized cases, and 0.65% of hospitalizations resulting in death (USDA, Economic Research Service). In the lower bound estimate, hospitalizations account for 76.7% of the total cost of salmonella infections, while in the upper bound case, 72% of the costs are associated with premature deaths.

The Center for Disease Control (CDC) establish a direct link of salmonella infections to reptile pet ownership in most salmonella outbreaks as "Private home/residence" of "Child day care" are the confirmed setting for 84% of outbreaks between 2009 and 2021. However, zoonotic diseases are the outcome of sometimes complex, interplaying sources, like transmission through a second species, infection through contact with other classes of animals, among others.[30] Given that risks on human and animal health are high and consequences irreversible, the same considerations should be weighed in context of precaution and prevention.

As noted above, A&R used as pets are vectors of numerous bacterial and viral diseases other than salmonella that affect both humans and other animals (e.g., encephalitis, herpes and West Nile viruses, leptospirosis). **The estimates on health risks must then be considered as a lower bound estimate of the actual health costs associated with the trade and owning of these species.**

This account of health costs does not consider the potential positive impact of perceived emotional benefits of A&R ownership on the owner's health. For example, the respondents to the APPA National Pet Ownership Survey (2023) recognize benefits like "Fun to watch" (57%), "Quiet" (39%), "Relaxation" (38%), "Live a long time" (37%) and "Good for children, teach responsibility". While these benefits may not be negligible, their subjective nature makes it difficult to measure them. **These sorts of benefits should however be assessed in terms of the possible alternatives to obtain the same or similar benefits that do not pose pressure on wild populations, constantly expand the range of species traded, perpetuate the risk of over-exploitation, and cause a significant risk to public health.**

Photo: A ball python in the wild. R. Andrew Odum / Getty Images

Invasive alien species (IAS)

The estimated costs per year of amphibian and reptile invasive alien species we obtained for North America can be divided in observed and potential costs. Observed costs range from $1.2 billion to $2.2 billion USD (high and low reliability respectively). Potential costs add up to $8.7 billion (high reliability of sources) with an additional $2 million USD in potential costs with low reliability (see table 5 below). Considering only costs with high reliability of estimates, both observed and potential, yields $9.9 billion per year.

The costs of A&R IAS in Canada and the U.S. comprise both one-time and potentially ongoing costs, the latter being two or three orders of magnitude higher than the former. This illustrates the permanent, long-lasting nature of damage produced by A&R IAS in the region's ecosystems, economic activities, and local biodiversity. Including all costs (one-time and ongoing, observed and potential) yields an overall sum of $12 billion USD per year.

Crystal-Ornelas et al. estimate of $1.2 billion USD per year as the cost of A&R IAS in the U.S. corresponds to the more restrictive criteria of considering only observed damages from high reliability sources (as in table 5).[40] Choosing this category of cost as the reference is coherent with a decision-making process focused on finding the minimum cost of the management response. In other words, if IAS cost $1.2 billion per year, it would be rational to invest a similar amount every year in control and restoration. **However, if the response is centered on the precautionary principle, the decision maker must in principle consider the highest value as the proper measurement of risk.**

A cost estimation, that includes potential damages and not only observed ones, is more in line with the precautionary principle, as it recognizes that there is a positive (though possibly small) probability of ongoing damages being extremely costly. Because costs of emergencies can be very high, very small changes in the estimated probabilities of occurrence of those events can change the relevant cost distribution radically, and the method for assessing the policy. For example, the prevention of health hazards provides large cost-savings in the long run. For this reason, we argue that the annual cost of reference of IAS for these two particular animal classes in Canada and the U.S. must include the full range of costs based on highly reliable estimates, with a lower bound of $1.2 billion (observed damages) and an upper bound of $9.9 billion USD (both observed and potential damages).

Table 5: **IAS of amphibians and reptiles in the U.S. and Canada. Summary of costs by quality of estimate. (source: Invacost database)**

Cost estimate per year (USD)		Reliability		
		High	Low	Total
Probability	Observed	1,231,949,218	2,260,359,939	3,492,309,157
	Potential	8,685,049,503	2,188,658	8,687,238,161
	Total	**9,916,998,721**		

Greenhouse Gas (GHG) Emissions

The costs derived from GHG emissions associated with the trade and ownership of A&R kept as pets are estimated to be in the range of $35.4 million to $134 million USD per year. Lower (upper) bound estimates, consider the lower (upper) bound estimates for pet population, emission intensity of transport, and electricity consumption. We consider two cost scenarios, corresponding to two different levels of social carbon costs per ton of CO_2 eq. 99% of the estimated carbon costs come from the energy consumption required for the maintenance of captive A&R per year. GHG emissions produced in the production of food, equipment and appliances are not considered.

Conclusion

Exotic pets, including amphibians and reptiles, do not exist in nature: they are a creation of an industry that provides access to live animals, special diets, and artificial habitats, thus enabling their existence as urban pets. Counter to conventional economic analysis, which understands consumer preferences as an externality (a condition pre-existent to analysis), markets do have a hand in shaping preferences, by framing or constructing consumption possibilities and influencing the process of cultural transmission.[53]

The A&R pet trade market model is only concerned with maximizing revenue, not through passively meeting consumer's demand for live A&R, but by actively stimulating the demand of a composite bundle of products associated to the maintenance of A&R as pets. The enormous differentials between prices of live animals and the costs of equipment and supplies, clearly suggests that the core of this business model is the sale of live A&R animals as a means for selling equipment and supplies. Protection against the hidden costs related to the A&R pet trade and ownership is not a concern to this market model.

The estimates of the A&R pet population in North America show no sign of diminishing, which suggests that demand for A&R pets will rather keep pace in the coming years. The time trends in the imports of live A&R suggest that reliance on imported animals diminished steadily between 2000 (a historical peak) and 2014, both in terms of number of specimens and money value. It is likely that the large inflow of imported A&R during the 1990s and early 2000 may have fed a local captive breeding industry in the U.S. which would be in position now to satisfy much of the demand for pets of these classes. Yet as we have shown, captive breeding is restricted to only a fraction of the animals in demand**. A&R for pets will continue to be sourced in the wild, with a corresponding sustained pressure on local wild populations. Sustaining the 'business-as-usual' level of demand for A&R to be kept as pets will continue to impose very large costs to North American people, ecosystems, and endemic species.**

Price increases of 44% and 175% in the mean unit prices for A&R (respectively) could be a short-term expression of the disruption of supply chains and increased demand as a result of the SARS-CoV-2 pandemic. However, at closer examination it seems evident that the trend reversal was already occurring since 2018, suggesting the sharp increase in import values and unit prices after 2016 could be an indicator that a new expansionary cycle may be in the making. There is some evidence that online trade is rapidly gaining traction as a dominant platform for trading A&R to be kept as pets,[11] which could have also contributed to demand increases by expanding it into new market niches. Online sales pose a challenge to regulation, given the huge variety of species traded without any control online. It is thus of crucial importance that these trends are monitored and verified, especially in the online market segment which totally lacks monitoring and regulation.

A significant finding from the Cost Benefit Analysis is the highly unequal international distribution of costs and benefits. **While the potential costs of ecological disruption can be very high in the countries and regions of origin of wild A&R species, the direct producers (local hunters and breeders) get a minimal fraction of the benefits.**

A major conclusion regarding the management of hidden ecological and health costs related to the A&R pet trade is that prevention is cheaper than restoration. For example, the costs of managing IAS mainly rests on the distinct objectives of management, depending on the area impacted.[39] Prevention and preparedness occur before any area is impacted. Early detection and eradication may take place before impacts spread. Containment can prevent the impacted area to continue growing to its ecological potential. Control and restoration will normally entail much higher costs, but it is the last management option once spread has occurred. Management is largely ineffective in marine and water connected systems once establishment has occurred. To the extent that amphibians and reptiles are more closely related to connected water systems than other vertebrates, the impacts associated to IAS pertaining to these classes would be correspondingly less responsive to containment, control, and restoration, and correspondingly more costly.

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