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Original Article

Endoparasites of pet reptiles and amphibians from exotic pet shows in Texas, United States

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ABSTRACT

Reptiles and amphibians are becoming increasingly more common in the exotic pet trade and as such veterinary care is also rising. Parasitic infections can pose a serious threat to pet reptiles and amphibians and are a common finding in these exotic pets. The purpose of the present study was to determine the species composition of parasites among reptiles and amphibians entering the pet industry. Excreta were collected from 283 reptiles and amphibians (181 geckos, 23 chameleons, 21 frogs, 16 tortoises, 11 snakes, 1 caiman, and 31 other lizard species), representing 58 different species. Samples were collected from animals being sold at exotic pet shows in Texas, USA, where breeders from throughout the United States gathered to showcase their exotic pets. Excreta samples were tested using double centrifugation flotation with Sheather's sucrose solution. Endoparasites were identified in 51.9% of samples. The most prevalent helminth parasite among reptiles and amphibians were Pharyngodonidae (44.5%) nematodes. Oocysts of coccidians such as *Isospora*, *Eimeria,* and *Choleoeimeria*, and cysts of the ciliate *Nyctotherus* were also identified. The prevalence rates of endoparasites among animal groups ranged from 0 to 87.5%. The highest prevalence of infection was found in Testudines (87.5%), followed by Chamaeleonidae (87%), other lizards (76.7%), Amphibia (71.4%), Serpentes (63.6%), and then Gekkonidae (55.2%). No endoparasites were detected in the one Crocodylia sampled. Our results show that parasitic infections, many of which can cause clinical disease and mortality, are common in exotic reptiles and amphibians being sold or traded as pets in the United States, underlining the need for veterinary care and routine diagnostic screening for parasitic infections.

1. Introduction

Reptiles and amphibians are one of the most popular groups of exotic pets, and over the years have become quite common (Mendoza-Roldan et al., 2020). Ownership in the United States has increased in recent years, with 2.9% of households owning reptiles in 2016, up 17% in the past five years (American Veterinary Medical Association, 2012). This increase puts the estimated pet reptile population at 6 million across the United States (American Veterinary Medical Association, 2012). Many of these enter the pet trade through private breeders, exotic pet shops, or vendors that import wild-caught animals (Mendoza-Roldan et al., 2020; Stringham et al., 2021). Recent studies from different countries have demonstrated that endoparasites in reptiles and amphibians are quite common and often at a high prevalence (Papini et al., 2011; Wolf et al., 2014; Rom et al., 2018; Hallinger et al., 2019; Kehoe et al., 2020). While, some of these endoparasites may not have deleterious impacts on animal health, various helminths and protozoans have been associated with clinical gastrointestinal disease and mortality in several reptile and amphibian species (Machin, 2015; Klingenberg, 2000; Divers et al., 2019; Garner and Jacobson, 2021). Among the most common endoparasites of pet reptiles and amphibians are nematodes, specifically Pharyngodonidae (Oxyurida), and coccidian protozoans (Barnard and Upton, 1994; Klingenberg, 2000; Papini et al., 2011; Kehoe et al., 2020).

At reptile shows, breeding operations, and exotic pet stores, reptiles that are imported from different regions of the world live in close proximity, so the chance of developing new infections is possible, particularly with parasites that have a direct life cycle. It is of utmost importance for the health and management of these species to identify the pathogens present. Routine screening is also an important component to monitor reptiles and amphibians for recently acquired parasitic infections to allow for appropriate intervention before new animals are introduced and the parasites are spread further to other individuals. The aim of this study was to estimate the level of gastrointestinal parasite infection and assess parasite species composition among a variety of

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Table 1
Scientific name, common name, and number of hosts screened, positive, and prevalence of endoparasite infections.

Scientific Name	Common Name	Number	Positive	Prevalence (%)
Gekkonidae	**Geckos**	**181**	**100**	**55.2**
Eublepharis macularius	leopard gecko	54	24	44.4
Eurydactylodes agricolae	chameleon gecko	1	0	0.0
Gekko badenii	golden gecko	3	3	100.0
Gekko vittatus	white line gecko	2	1	50.0
Goniurosaurus hainanensis	Hainan cave gecko	3	2	66.7
Hemitheconyx caudicinctus	African fat tailed gecko	2	2	100.0
Paroedura pictus	Madagascar big head gecko	1	1	100.0
Ptychozoon kuhli	flying gecko	2	2	100.0
Rhacodactylus auriculatus	gargoyle gecko	15	8	53.3
Rhacodactylus chahoua	chahoua gecko	3	1	33.3
Rhacodactylus ciliatus	crested gecko	90	52	57.8
Rhacodactylus leachianus	leachianus gecko	1	0	0.0
Uroplatus fimbriatus	giant leaf tail gecko	3	3	100.0
Uroplatus phantasticus	satanic leaf tailed gecko	1	1	100.0
Chamaeleonidae	**Chameleons**	**23**	**20**	**87.0**
Brookesia minima	pygmy leaf chameleon	1	1	100.0
Chamaeleo calyptratus	veiled chameleon	8	7	87.5
Chamaeleo hoehnelii	helmeted chameleon	1	1	100.0
Chamaeleo jacksonii	Jackson's chameleon	1	0	0.0
Chamaeleo senegalensis	Senegal chameleon	2	2	100.0
Furcifer lateralis	carpet chameleon	3	3	100.0
Furcifer pardalis	panther chameleon	7	6	85.7
Sauria	**Other lizards**	**30**	**23**	**76.7**
Abronia graminea	emerald alligator lizard	1	0	0.0
Agama agama	crown agama	1	0	0.0
Anolis barbatus	Cuban false chameleon	2	1	50.0
Cnemidophorus lemniscatus	rainbow whiptail	1	0	0.0
Corucia zebrata	monkey-tailed skink	1	1	100.0
Gerrhosaurus major	African plated lizard	1	1	100.0
Iguana iguana	iguana	1	1	100.0
Lialis burtonis	legless lizard	1	1	100.0
Pogona henrylawsoni	Rankin's dragon	1	1	100.0
Pogona vitticeps	bearded dragon	13	12	92.3
Tilqua scincoides	blue-tongued skink	3	1	33.3
Tupinambis teguixin	gold tegu	1	1	100.0
Uromastyx geyri	Saharan uromastyx	2	2	100.0
Varanus jobiensis	peach throat monitor	1	1	100.0
Ophidia	**Snakes**	**11**	**7**	**63.6**
Corallus hortulanus	Amazon tree boa	1	1	100.0
Epicrates cenchria maurus	Columbian boa	1	1	100.0
Gongylophis colubrinus	Kenyan sand boa	1	0	0.0
Lampropeltis getula	king snake	2	2	100.0
Morelia spilota	carpet python	1	1	100.0
Python regius	ball python	5	2	40.0
Testudinata	**Tortoises/Turtles**	**16**	**14**	**87.5**
Centrochelys sulcata	sulcata tortoise	3	2	66.7
Chelonoidis carbonaria	red footed tortoise	2	1	50.0
Terrapene carolina	box turtle	2	2	100.0
Testudo graeca	spur-thighed tortoise	3	3	100.0
Testudo hermanni	Hermann's Tortoise	1	1	100.0
Testudo horsfieldii	Russian Tortoise	5	5	100.0
Crocodillia	**Crocodillia**	**1**	**0**	**0.0**
Caimaninae	caiman	1	0	0.0
Amphibia	**Amphibians**	**21**	**15**	**71.4**
Agalychnis callidryas	red eye tree frog	2	1	50.0
Agalychnis moreletii	black eye tree frog	2	0	0.0
Centrolenidae	glass frog	2	2	100.0
Ceratobatrachus guentheri	Soloman Island leaf frog	1	1	100.0
Ceratophrys ornata	Pacman frog	3	3	100.0
Dendrobatidae	poison dart frog	1	1	100.0
Dyscophus	tomato frog	4	3	75.0
Litoria caerulea	white tree frog	1	1	100.0
Polypedates leucomystax	golden tree frog	3	1	33.3
Trachycephalus resinifictrix	milk tree frog	2	2	100.0
All reptiles and amphibians		**283**	**147**	**51.9**

Table 2
Specific parasites identified, prevalence, and number positive for each host species.

Parasite	Positive	Prevalence	Host species
Nematode			
Pharyngodonidae	126	44.5%	African fat tailed gecko (1) African plated lizard (1) Amazon tree boa (1) bearded dragon (10) blue tongue skink (1) chahoua gecko (1) Columbian boa (1) crested gecko (37) Cuban false chameleon (1) flying gecko (2) gargoyle gecko (8) giant leaf-tailed gecko (2) gold tegu (1) golden gecko (2) helmeted chameleon (1) legless lizard (1) leopard gecko (22) milk tree frog (2) monkey tailed skink (1) Pacman frog (3) panther chameleon (2) peach throat monitor lizard (1) pygmy leaf chameleon (1) Rankin's dragon (1) red footed tortoise (1) Solomon island leaf frog (1) sulcata tortoise (1) tomato frog (2) veiled chameleon (4) white line gecko (1)
Tachygonetria	12	4.2%	Hermann's tortoise (1) Russian tortoise (5) Saharan uromastyx (1) spur-thighed tortoise (3) sulcata tortoise (2)
Strongyloididae (*Rhabdias/Strongyloides*)	13	4.6%	African plated lizard (1) Cuban false chameleon (1) golden gecko (1) Hainan gecko (2) milk tree frog (2) Pacman frog (2) peach throat monitor lizard (1) white tree frog (1)
Capillaridae	1	0.4%	Solomon island leaf frog (1)
Camallanoidea	1	0.4%	box turtle (1)
Spirurida	3	1.1%	legless lizard (1) milk tree frog (1) Senegal chameleon (1)
Strongylid	4	1.4%	gold tegu (1) Senegal chameleon (1) Solomon island leaf frog (1) crested gecko (1)
Ascaridida	8	2.8%	blue tongue skink (1) box turtle (1) milk tree frog (1) panther chameleon (3) pygmy leaf chameleon (1) veiled chameleon (1)
Protozoa			
Eimeria	19	6.7%	bearded dragon (10) carpet chameleon (2) crested gecko (1) giant leaf-tailed gecko (3) golden gecko (2) Pacman frog (1)
Isospora	7	2.5%	carpet chameleon (1) helmeted chameleon (1) Rankin's dragon (1) veiled chameleon (4)
Choleoeimeria	4	1.4%	giant leaf tailed gecko (1) legless lizard (1) pygmy leaf chameleon (1)

(*continued on next page*)

Table 2 (*continued*)

Parasite	Positive	Prevalence	Host species
Nyctotherus	13	4.6%	satanic leaf tailed gecko (1) bearded dragon (1) blue tongue skink (1) Cuban false chameleon (1) giant leaf tailed gecko (2) golden gecko (1) leopard gecko (2) panther chameleon (1) Rankin's dragon (1) Saharan uromastyx (2) veiled chameleon (1)
Spurious			
Mycoptes musculinus	5	1.8%	ball python (1) carpet python (1) Columbian boa (1) king snake (2)

reptiles and amphibians in the United States exotic pet trade.

2. Materials and methods

From January 2018 to February 2020, freshly voided excreta samples were collected from a variety of different reptile and amphibian species (Table 1) being sold at various exotic pet shows in Texas, USA. All individuals sampled were reported apparently healthy by the owner and were collected with owner consent; only voluntarily voided excreta was collected. Samples were transported to the Diagnostic Parasitology Laboratory at Texas A&M University in coolers with icepacks, and stored refrigerated at 4 °C until processing. For sample preparation, excreta were weighed and then examined using a double-centrifugation sugar flotation procedure as described (Zajac and Conboy, 2012). Sheather's sucrose solution with a specific gravity of 1.25 was used as the flotation solution. All fecal flotation slides were observed under a light microscope with 40-200× magnification, with 400× magnification used as necessary. Parasite diagnostic stages were identified by trained laboratory personnel.

3. Results

A total of 283 excreta from 58 species of reptiles (n = 262) and amphibians (n = 21) were examined. Just over half of all individuals tested were positive for at least one parasite (147/283; 51.9%); co-infections were evident in 43/147 (29.3%) of positive individuals, and spurious parasites were observed in 4/283 (1.4%) of tested individuals. Of the 58 reptile and amphibian species sampled, 41 (70.7%) tested positive for at least one parasite. Within general groups of reptiles, the prevalence of endoparasites was as follows: 61% (143/234) of lizards, including Gekkonidae, Chamaeleonidae, and other lizards (prevalence per group in Table 1); 64% (7/11) of snakes (Serpentes); 88% (14/16) turtles (Testudines); and in amphibians 71% (15/21) of all sampled individuals were infected with intestinal parasites. Details of hosts and samples screened as well as endoparasite prevalence are listed in Table 1. Specific parasites identified, their associations, and number positive for each host type can be found in Table 2.

Nematodes were the most common endoparasite identified with a prevalence of 56.5% (n = 160/283) and protozoans were identified in 15.2% (n = 43/283) of individuals. Within each specific group nematodes were more commonly detected than protozoans. More specifically within Gekkonidae 91% (n = 91/100) of endoparasite infections were nematodes and the remaining 9% were protozoan parasites. Chamaeleonidae had a larger overall percentage of protozoan endoparasites making up just over half off all infections 55.0% (n = 11/20) and nematodes constituting 45% (n = 9/20) of the endoparasites. Similarly, protozoan endoparasites accounted for 65.2% (n = 15/23) of infections in other lizards with nematodes the remaining 34.8% (n = 8/23). Among both Serpentes and Testudines no protozoans were detected, and all endoparasite infections were with nematodes only, while in Crocodylia no parasites were detected. Endoparasite infections in Amphibia were 95.2% (n = 20/21) nematodes and just 4.8% (n = 1) protozoans.

Regarding specific nematodes detected, Pharyngodonidae (Oxyurida) was the most prevalent family of parasitic nematodes identified infecting 44.5% (n = 126/283) of reptiles and amphibians screened. Among the Pharyngodonidae pinworms, five different morphologies of eggs and five morphologies of worms were present, and co-infections with the different pinworm morphologies were also evident (Fig. 1). These five different pinworm egg morphologies likely indicate different pinworm species, but only one could be identified to genus. This pinworm was determined to be *Tachygonetria* and was found in tortoises and a Saharan spiny-tailed lizard. Other nematode eggs identified included Ascaridida (n = 8/283; 2.8%), *Rhabdias* (Strongyloididae) (n = 11/283; 3.9%), strongyle type eggs (n = 4/283; 1.4%), Spirurida (n = 3/283; 1.1%), as well as one individual each infected with Capillaridae eggs and Camallanoidea nematodes (Fig. 1). No cestode eggs or proglottids nor trematode eggs were found in any of the examined excreta samples.

Species of reptiles and amphibians passing ascarid eggs in their excreta included: the blue tongue skink, box turtle, milk tree frog, as well as panther, pygmy, and veiled chameleons (Table 2). The legless lizard, Senegal chameleon, and milk tree frog were species of reptiles and amphibian infected with Spirurida, with reptilian infections likely *Physaloptera*. Species of amphibians infected with Capillaridae and Camallanoidea were a Solomon Island leaf frog and a box turtle, respectively. Strongyle-type eggs were detected in both reptiles and amphibians including a Senegal chameleon, crested gecko, gold tegu, Solomon Island leaf frog.

Protozoan parasites were detected in 15.2% (n = 43/283) of reptiles and amphibians tested. *Eimeria* was the most commonly identified protozoan parasite, and the second most common parasite identified overall, with 6.7% (n = 19/283) of reptiles and amphibians testing positive. Other protozoans identified included the coccidians *Isospora* and *Choleoeimeria* were found in 2.5% (n = 7/283) and 1.4% (n = 4/283) of reptiles and amphibians, respectively (Fig. 2). Additionally, the ciliate *Nyctotherus* was identified in 4.6% (n = 13/283) of reptiles and amphibians.

Species of reptiles infected with *Eimeria* included: the bearded dragon, giant leaf tailed gecko, golden gecko, carpet chameleon, crested gecko, and a single amphibian the Pacman frog. *Choleoeimeria* was only identified in reptiles in this study and included the giant leaf tailed gecko, legless lizard, pygmy leaf chameleon, and satanic leaf tailed gecko. *Isospora* was identified in four reptile species–Rankin's dragon, helmeted chameleon, carpet chameleon, and the veiled chameleon. Coinfections with different coccidian species occurred in the giant leaf tailed gecko which was infected with both *Eimeria* and *Choleoeimeria*,

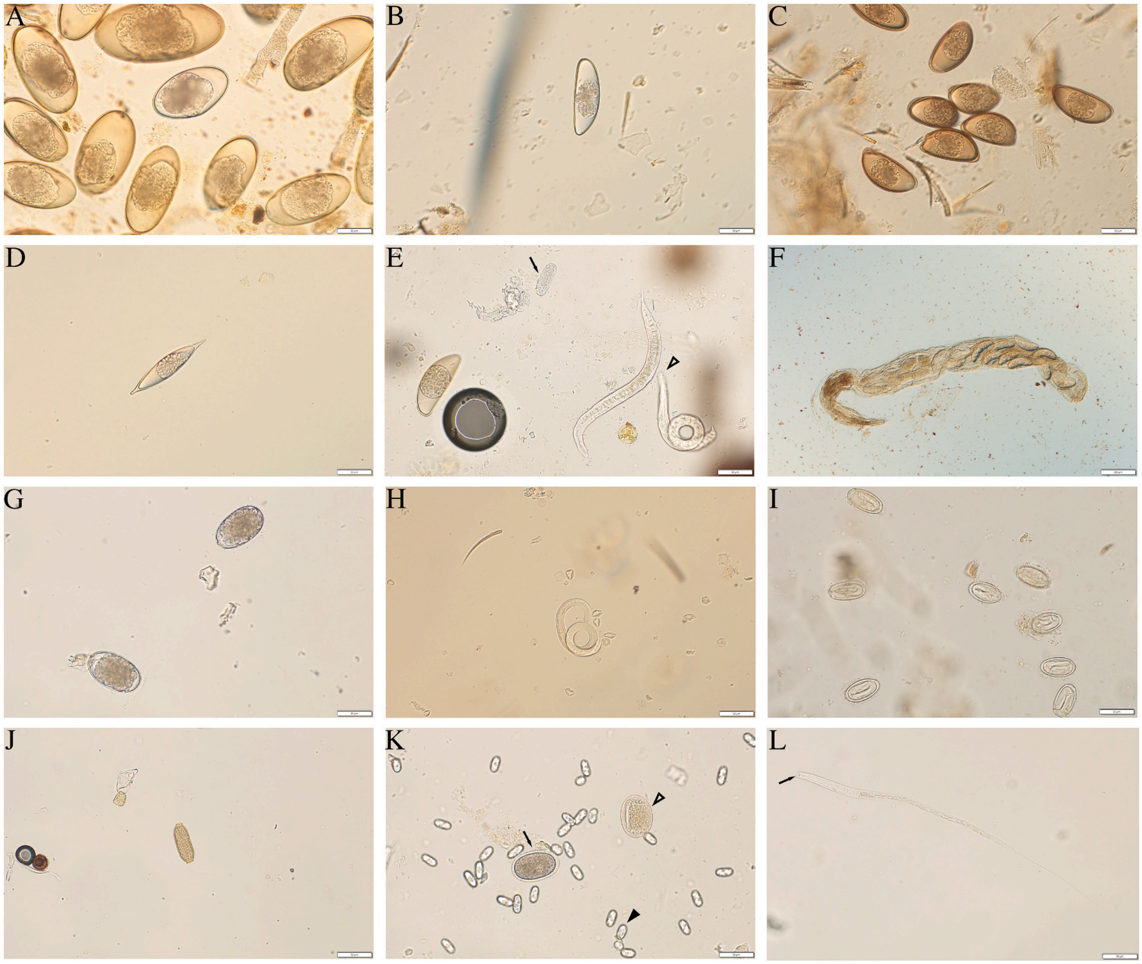

Fig. 1. Selected images of nematode parasites of reptiles and amphibians.
A. *Tachygonetria* eggs from a Russian tortoise. B. Clear pinworm egg from a leopard gecko. C. Brown pinworm eggs from an African fat tailed gecko. D. Long pinworm egg from a gargoyle gecko. E. Tan pinworm egg from a peach throat monitor lizard F. Adult pinworm shed in the feces with visible eggs in the uterus from a Saharan uromastyx. G. Strongyle type egg from a Solomon Island leaf frog. H. *Rhabdias* worm shed in the feces from a Hainan cave gecko I. Spirurid egg from a Senegal chameleon. J. Capillaridae egg from a Solomon Island leaf frog. K. Coinfection in a panther chameleon, Ascarid egg, arrow; degraded ascarid egg, open arrowhead; *Choleoeimeria* in the background, out of focus, closed arrowhead. L. Camallanoidea from a box turtle, note the chitinized plates in the buccal cavity (arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and the carpet chameleon, which was infected with both *Eimeria* and *Isospora.* Spurious parasites, specifically eggs of *Myocoptes musculinus*, a rodent mite, were identified in 1.8% (n = 5/283) of individuals, specifically three different snake species: the king snake, ball python, and carpet python (Fig. 3).

4. Discussion

The results of the present study demonstrate that endoparasites in pet reptiles and amphibians at exotic pet trade shows in Texas are quite common, with 51.9% of all individuals surveyed infected with one or more endoparasite. Several surveys have reported prevalences of endoparasite infections ranging from 47.3–88.5% of animals depending on the reptile or amphibian species surveyed (Rataj et al., 2011; Cervone et al., 2016; Rom et al., 2018; Papini et al., 2011). The findings of the present study fall within these previously reported ranges. Also, when considering specific groups of reptiles and amphibians the prevalence of intestinal parasites in the present study aligns well with these previous reports. A survey of parasitic infections among pet reptiles in Slovenia found 88.5% of turtles, 76.1% of lizards, and 47.3% of snakes infected with endoparasites (Rataj et al., 2011), which is similar to the reported prevalence from Texas. Regarding the most common parasites found infecting reptiles and amphibians, as in the present survey, nematodes more specifically Pharyngodonidae were most the common endoparasite detected in surveys carried out in Italy, Slovenia, and Poland (Rataj et al., 2011; Rom et al., 2018; Cervone et al., 2016; Papini et al., 2011).

Additionally, the present study represents the largest survey of endoparasites infecting crested geckos, *Correlophus ciliatus,* (n = 90, Table 1) to date. There is limited data regarding the intestinal parasite fauna of crested geckos, which is not surprising considering this particular exotic pet has increased in popularity three-fold in the last two decades, and a trends survey found it to be the most popular pet reptile globally and in North America (Valdez, 2021). Crested geckos are relatively new to the pet industry and were thought to be extinct for over a century until a wild population was discovered in New Caledonia in 1994 (Mayer et al., 2011; Valdez, 2021). Crested geckos are easily bred and maintained in captivity which likely contributes to their growing popularity (De Vosjoli, 2012). The data that is available on crested gecko parasites indicates that crested geckos are susceptible to and can succumb to endoparasite infection. A recent report describes a die-off of crested geckos (n = 5/10) due to the introduction of an ascarid parasite, *Hexametra angusticaecoides*, from wild-caught Madagascan mossy geckos (*Uroplatus sikorae*) sharing a terrarium (Barton et al., 2020). A previous report of parasitic infections in crested geckos surveyed smaller numbers of individuals and reported a slightly lower prevalence of infection (n = 11/26; 42.0%) than in the current study (n = 52/90; 58.0%) (Papini

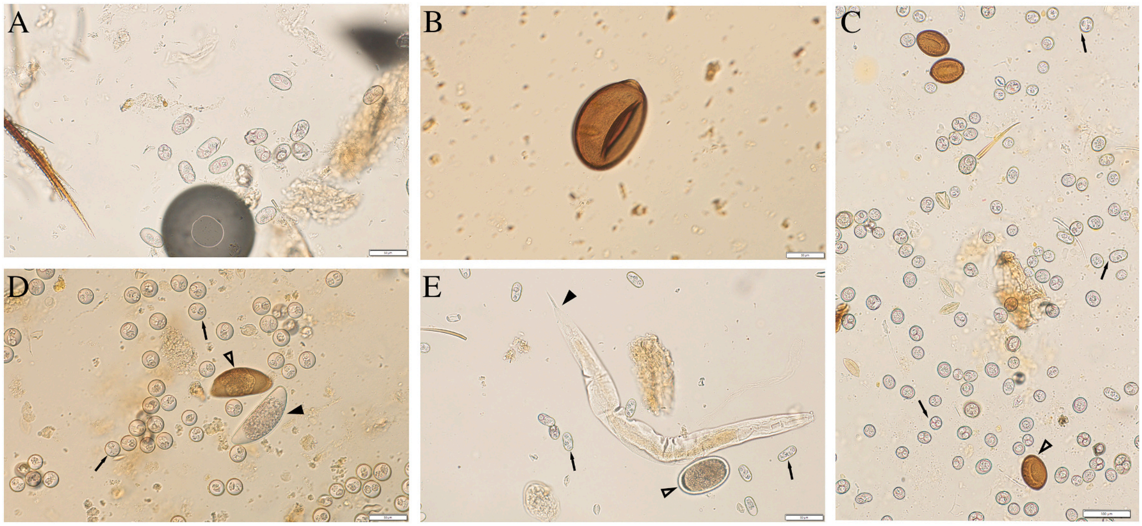

Fig. 2. Selected images of protozoan parasites of reptiles and amphibians.
A. *Isospora* oocysts from a veiled chameleon. B. *Nyctotherus* from a Saharan uromastyx. C. *Eimeria*, note the four sporocysts inside the sporulated oocysts, arrow; *Nyctotherus* cysts, open arrowhead. D. Coinfection in a bearded dragon, *Isospora* oocysts, note the two sporocysts inside the oocyst, arrow; brown pinworm egg, open arrowhead; clear pinworm egg, closed arrowhead. E. Coinfection in a pygmy leaf chameleon, *Choleoeimeria* oocysts, arrow; adult pinworm shed in feces, closed arrowhead; ascarid egg, open arrowhead. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

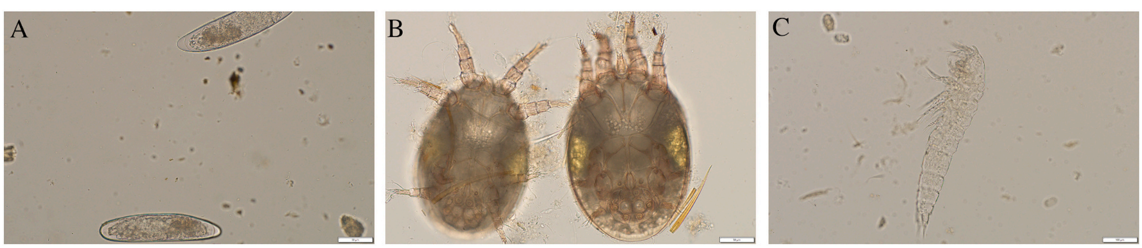

Fig. 3. Selected images of spurious and pseudoparasites recovered from reptiles and amphibians.
A. *Myocoptes musculinus* from a king snake. B. Nonparasitic mites from a Pacman frog. C. Arthropod from a red-eyed tree frog. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

et al., 2011).

At reptile shows, species are housed in close proximity and depending on the particular species they are co-housed with other reptile or amphibian species (personal observation). Often less-aggressive species such as bearded dragons (*Pogona vitticeps*), chameleons, and chelonians are kept in communal tanks which increases the opportunity for parasite transmission. Interestingly, the prevalence of parasites among these groups in the present study were the highest of any animals surveyed at 92% ($n = 12/13$), 87% ($n = 20/23$) and 88% ($n = 14/16$), respectively. However, it must be noted that these are relatively small sample sizes for each animal type. The propensity for co-housing and other similar husbandry practices may actually promote and increase the likelihood of parasitic infections in captive reptiles and amphibians (Pasmans et al., 2008; Papini et al., 2011).

For example, oxyurids are common in reptiles and amphibians but rarely pathogenic unless present in large numbers. In heavy infections they can cause anorexia and even death in a variety of pet reptiles and amphibians (Marcus, 1981; Goldberg and Bursey, 1992; Loukopoulos et al., 2007; Machin, 2015; Kehoe et al., 2020). Exotic pets in captivity are more likely to harbor parasites with direct life cycles, as no intermediate hosts are required for transmission. This likely explains the higher prevalence of oxyurids recovered from reptiles and amphibians in the present survey. Clinical signs may not be present until high intensity infections have established and can lead to enteritis, hemorrhagic ulcers, maldigestion, gastrointestinal obstruction, pneumonia, and even progress to death depending on the parasite species (Marcus, 1981; Loukopoulos et al., 2007; Ras-Norynska and Sokol, 2015; Garner and Jacobson, 2021). The presence of several pathogens, particularly endoparasites coupled with host transport and being on exhibit at an exotic pet show, may cause stress and lead to negative health effects for these animals. Stress can result in clinical signs of parasitic infections that have existed for quite some time but at previous subclinical levels (Rataj et al., 2011). Alternatively, endoparasites may cause no clinical signs until a certain threshold or overabundance is reached, presumably from repeated reinfection in the contaminated environment (Loukopoulos et al., 2007).

An example of a nematode parasite that does not have a direct life cycle, but can still be easily maintained in captive reptiles and amphibians are those in the order Spirurida. This is because several insect species can serve as intermediate hosts for spirurids, and as such infections may be quite common in reptiles and amphibians with insects as a component of their diet (Girling and Raiti, 2004). The present study found a low prevalence (1.1%) of spirurid eggs in three different hosts: the legless lizard (*Lialis burtonis*), milk tree frog (*Trachycephalus resinifictrix*), and Senegal chameleon (*Chamaeleo senegalensis*). However, a slightly higher prevalence of infection (6.3%) with spirurid parasites has been described in another survey of pet reptiles (Rataj et al., 2011). Adult worms can cause inflammation and even obstruction of the gastrointestinal tract if infections are left untreated (Klingenberg, 2000; Garner and Jacobson, 2021).

Many species of coccidians can infect reptiles and amphibians (Barnard and Upton, 1994). The most common genera are *Eimeria* and

Isospora, both of which can be highly pathogenic in reptiles and amphibians (Barnard and Upton, 1994). While three genera of Coccidia (*Eimeria, Isospora,* and *Choloeimeria*) were identified, all sampled animals in the present study were reported to be apparently healthy by their owners. *Eimeria* was the second-most common parasite identified overall, with 6.7% of reptiles and amphibians testing positive. Coccidian infections, especially *Isospora*, are often exacerbated by poor hygiene and small enclosures due to the direct life cycle of the parasites and have the most profound impact on mortality in juveniles (Machin, 2015; Garner and Jacobson, 2021). Many reptiles are asymptomatic carriers of coccidians as adults, and clinical signs are generally seen only in juvenile or immunosuppressed animals and include diarrhea, dehydration, and death (Diaz-Figueroa and Mitchell, 2006; Barnard and Upton, 1994). *Choleoeimeria* infects the bile ducts and gallbladder of reptiles and is often quite pathogenic and cause liver and gallbladder lesions (Hallinger et al., 2019; Stöhr et al., 2021). In the present study *Choleoeimeria* was only detected in a few individuals, which aligns with other surveys that reported prevalence rates lower than 1% in surveyed animals (Hallinger et al., 2019).

The ciliate *Nyctotherus* is often recovered from herbivorous chelonians and some lizards, and is mainly considered non-pathogenic (Barnard and Upton, 1994). However, *Nyctotherus* has been known to cause serious disease in certain reptile species and in such cases, treatment is recommended (Machin, 2015). As with several other parasites identified in the present study, the life cycle of *Nyctotherus* is direct and transmission is via the ingestion of infective cysts (Barnard and Upton, 1994). In addition to commensals and other non-pathogenic parasites, there is also the possibility of spurious parasites being passed in the feces. Spurious parasites are parasite eggs or other diagnostic stages that may be found in the feces of a scavenger or predator host that do not infect and carry out a life cycle in that scavenger or predator host species (Zajac and Conboy, 2012). It is important to differentiate these spurious parasites from true parasites so that unwarranted interventions do not occur. An example of a spurious parasite that was readily detected in the present study, was the identification of snakes passing the rodent mite *Myocoptes musculinus* in the excreta. Given that snakes prey on or are fed rodents it is not surprising this mite was spuriously passed in almost half ($n = 5/11$; 45.5%) of surveyed snakes in this study. It is quite common to find captive snakes and other reptiles that prey on rodents passing *Myocoptes* as well as other rodent mites (Rinaldi et al., 2012; Wolf et al., 2014; Rom et al., 2018).

One limitation of the present study is that samples were not subjected to specific screening for the protozoans *Giardia* and *Cryptosporidium* which are important and common parasites of reptiles and amphibians (Terrell et al., 2003; Girling and Raiti, 2004). This was not the focus of the described survey because of cost and logistics associated with this additional testing. Previous research that specifically evaluated reptiles and amphibians for *Giardia* and *Cryptospordium* infections utilized additional diagnostic tests, such as specialty staining or immunofluorescence assays for their detection or only tested animals with previous clinical signs of gastritis (Papini et al., 2011; Rataj et al., 2011; Hallinger et al., 2019; Hallinger et al., 2020). Both *Giardia* and *Cryptosporidium* represent some of the many potentially zoonotic parasites that can routinely infect reptiles and amphibians (Mendoza-Roldan et al., 2020). Other zoonotic parasites of concern include *Sarcocystis*, pentastomids, and some Trombiculidae and Macronyssidae ectoparasites (Mendoza-Roldan et al., 2020). While none of these potentially zoonotic parasites were detected in the present study, absence of detection does not eliminate the risk of zoonosis. Pet reptiles and amphibians, especially those captured in the wild or even co-housed with animals originating from the wild should still be considered a possible source of zoonotic parasites and routinely screened and evaluated so prevention and control efforts can be maintained.

Taken together, our findings indicate that intestinal parasitism is a regular occurrence in pet reptiles and amphibians at exotic pet trade shows, even in animals considered apparently healthy. Unsurprisingly, the majority of endoparasites detected had direct life cycles, highlighting the ease of transmission in captivity and the ability for heavy infections to accumulate over time. This underscores the need for veterinary care and routine diagnostic screening of pet reptiles and amphibians even when animals appear otherwise healthy and show no overt signs of parasitism. Furthermore, this is the largest survey of crested gecko endoparasites published to date, providing much needed parasitologic data for an exotic pet that is quickly growing in popularity. Knowledge on the specific parasites infecting pet reptiles and amphibians will aid in the maintenance and overall health of exotic pet species and allow veterinarians to make more informed decision about the diagnosis and treatment of parasitic infections in their reptile and amphibian patients.

Ethical statement

No animal experimentation was conducted, all diagnostic samples used were voluntarily voided by animal hosts.

Declaration of Competing Interest

None of the authors of this paper has a financial of personal relationship with other people or organizations that could inappropriately influence or bias the content of this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vprsr.2021.100671.

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