



# Captive Agamid lizards in Germany: Prevalence, pathogenicity and therapy of gastrointestinal protozoan and helminth infections

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## ABSTRACT

Reptiles are becoming popular pets in many parts of the world. They are also known to harbor numerous gastrointestinal parasites. We used faecal smears to examine 748 stool samples from 14 different agamid lizard species. In addition, we used coproantigen ELISA tests (11 samples) and immunofluorescence assays (IFA) (19 samples) to detect reptile *Cryptosporidium* infections. In 28 cases, veterinarians requested therapy to treat oxyurid- and/or *Isospora amphiboluri*-infections and resent fecal samples after proposed therapy and anti-parasitic treatments had been applied. We also performed complete dissections of 24 deceased agamas in order to specify protozoan and helminth parasite infections.

Overall, the examined fecal samples contained 6 different taxa. Oxyurids (Pharyngodonidae) were the most prevalent nematodes (41.2%), followed by *I. amphiboluri* (17.0%), *Entamoeba* spp. (0.8%), *Choleoecimeria* spp. (0.5%), *Trichomonas* spp. (0.3%), *Cryptosporidium* spp. (0.3%) and *Strongyloides*-like nematodes (0.1%). *I. amphiboluri* infections were significantly more prevalent (Chi-square test:  $\chi^2 = 21,5$ ,  $df = 1$ ,  $P < 0.001$ ) in juvenile agamid lizards (31.9%) than in adults (14.2%). One of 11 (9.1%) coproantigen ELISA-examined samples was positive for *Cryptosporidium*. In 10.5% of the samples we found oocysts of *Cryptosporidium*. Thirteen (54.2%) of necropsied agamid lizards were infected with endoparasites and it is likely that three (12.5%) of them died due to severe parasitic infections. 74.0% of the samples that were submitted after therapy had been applied were negative. The high prevalences and pathological findings of several clinical parasitoses observed in these exotic reptiles calls for more detailed investigations on agamid gastrointestinal parasite fauna.

## 1. Introduction

Agamid lizards (Agamidae) are becoming more popular as domestic pets worldwide. Roughly half a million juvenile bearded dragons are bred annually in the United States [1,2,10]. Agamid lizard species can be infected by a variety of gastrointestinal parasites. These include diverse species of protozoans, nematodes, cestodes, pentastomids, acanthocephalans and trematodes [3–9].

All reptiles show high prevalences for different gastrointestinal parasitoses in captivity [10,11]. This widespread presence of gastrointestinal parasitoses may be related to the high tenacity of certain reptilian exogenous parasitic stages and monoxenous parasitic life-cycles [9,12]. In addition, risk factors (such as age, poor hygiene conditions and nutrition) might cause parasitic infections to result in clinical diseases [13]. As such, poor hygiene housing conditions might lead to

massive, clinically relevant parasite burdens with frequent re- and superinfections of monoxenous parasites [14,12,15]. Inland bearded dragons (*Pogona vitticeps*) are known to be co-infected with several parasite species and viruses [16,17]. More importantly, the following reptile-borne zoonoses have so far been well documented: *Salmonella enteritidis* [18,19], pentastomid- (i. e. *Porocephalus*, *Armillifer* and *Railietiella*) [20,13,21–23], cestode-infections [24,25] as well as the reptilian mite *Ophionyssus natricis* ([26,4,13]), and to be considered when handling these exotic pets.

Recent European parasitological investigations have found high prevalences of endoparasite infections for inland bearded dragons in captivity. Schmidt-Ukaj et al. [27] reported high prevalences in a retrospective study with clinical patients and Rataj et al. [10] examined imported dead agamid lizards in Slovenia. Pasmans et al. [14] investigated captive and wild reptiles, but not considering commensalism

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and/or parasite-derived pathogenicity. Our large-scale investigation aims to provide current data on the prevalence of gastrointestinal endoparasites in domestic agamid lizards in Germany. It covers a representative number of animals ( $n = 748$ ) and 14 different lizard species (Agamidae) overall. In addition, we performed necropsies and histopathological examinations on deceased agamid lizards ( $n = 24$ ), which generated parasitic baseline data within these pets.

## 2. Materials and methods

### 2.1. Fecal samples

From November 2015 through December 2016, we performed coprological analyses of 748 fecal samples. These samples originated from 14 different agama species and enabled to generate representative prevalence data (online Supplement). Examined fecal samples originated either from animals owned privately, submitted by German attending veterinarians or by German zoos, which had been referred to Exomed GbR laboratory in Berlin, Germany. In order to identify both protozoan and helminth stages, we performed direct saline fecal smears for general parasitological diagnosis according to Barnard and Upton [28]. Further details on sample origin as well as on agamid lizard species are listed in Table 1. Clients were asked to provide a printed form containing the individual animal's signalment (i. e. species, gender, age), husbandry circumstances (e. g. origin, time in owner's possession), previous parasitological examinations and anthelmintic treatments. At Exomed GbR laboratories, the forms were labeled with a reference number matching that of the stool sample and refrigerated at 4 °C.

A uniform solution was prepared by mixing 10 g of feces at a ratio of 1:1 with 0.9% saline solution, carefully placed on glass cover slides with a 50 ml pipette and covered with cover slips (22 × 22 mm; Nunc). A 100× and/or 400× magnification was used for microscopy (Axio Imager M1<sup>®</sup>, Zeiss, Jena) examination. The metazoan parasite stages found in examined fecal samples included trematode- (Plagiorchiidae) and nematode-eggs as well as protozoan stages such as trophozoites, cysts and oocysts and were identified based on previous morphological/metric descriptions as reported elsewhere [13,3,28–34]. Samples were classified as 'positive' when at least one stage of a potentially pathogenic endoparasite was found in fecal smears. Samples containing exclusively less pathogenic or facultative reptilian parasites (e. g. *Nyctotherus* sp. and flagellated protozoa) were classified as 'negative' according to previous reports [4,28,34,35].

In 28 cases, attending veterinary surgeons additionally requested

**Table 1**  
Examined fecal samples of agamid lizards and origin of senders (total  $n = 755$ ).

Lizard species	Common name	No. examined	Origin (private/ vet/zoo)
<i>Pogona vitticeps</i>	Central bearded dragon	630	505/113/12
<i>P. henrylawsoni</i>	Lawson's dragon	83	70/12/1
<i>Physignathus cocincinus</i>	Chinese water dragon	12	6/3/3
<i>Uromastyx</i> sp.	Spiny tailed lizard	10	9/0/1
<i>Trapelus savignii</i>	Savigny's agama	3	3/0/0
<i>Phrynocephalus</i> sp.	Toad-headed agama	3	3/0/0
<i>Gonocephalus</i> sp.	Gonocephalus agama	3	0/1/2
<i>Agama agama</i>	Common agama	2	2/0/0
<i>Clamydosaurus kingii</i>	Friilled lizard	2	1/1/0
<i>Leiolepis</i> sp.	Butterfly agama	2	0/0/2
<i>Calotes bachae</i>	–	2	0/0/2
<i>Stellagama stellio</i>	Starred agama	1	1/0/0
<i>Bronchocela cristatella</i>	Green crested lizard	1	1/0/0
<i>Ph. lesueurii</i>	Australian water dragon	1	0/0/1

the testing of therapy efficacy [for oxyurids 40–80 mg/kg febantel/pyrantel (Welpan<sup>®</sup>, Bayer) p. o. or 100 mg/kg fenbendazol (Panacur<sup>®</sup>, MSD) p. o. and for *Isospora* 5% toltazuril, 10 mg/kg p. o., repeated after 14 days (Baycox<sup>®</sup>, Bayer)] [35,36] and sent another stool sample for examination once therapy had been applied.

### 2.2. Agamid lizard necropsies

A total of 24 agamid lizard corpses were necropsied at Exomed GbR laboratory (Table 3, online supplementary data). In addition to these necropsies, anamnestic data were collected and pathohistological examinations were performed. Firstly, a visual inspection of the whole digestive tract was conducted to detect large endoparasites. Afterwards, the intestinal content (chymus) of each dissected animal was examined by direct saline fecal smears. Morphological identification of helminths was performed under a light microscope equipped with a digital camera (Axio Vision M1<sup>®</sup>, Zeiss, Jena). External examinations and necropsies were performed as described by Terrell and Stacy [37].

### 2.3. Microbiology

If requested, feces or coelom swabs were inoculated for bacterial and fungal cultivation and further pathogen isolation on sheep blood agar (5%) MacConkey agar besides Sabourand dextrose agar (SDA) (BioMerieux, Charbonnier les Bains, France). Bacterial isolates were diagnosed by Gram staining, oxidase- and catalase-tests as well as a commercially available API 20E/NE kits (BioMerieux, Charbonnier les Bains, France) as described previously for reptiles [34,38].

### 2.4. Immunofluorescence assay (IFA), coproantigen ELISA and carbol-fuchsin staining

As requested by owners/zoos, we examined 19 fecal samples using a commercially available IFA (*Cryptosporidium* IF Test<sup>®</sup>, Crypto Cel, Cellabs Pty Ltd., Brookvale, Australia) with a slightly modified protocol to the one provided by the manufacturer. Thus, we used fluorescein-labelled mouse monoclonal antibodies raised specifically against *Cryptosporidium* antigens [39]. In addition, these 19 scat samples were also stained with carbol-fuchsin for *Cryptosporidium*-oocyst detection according to Heine [40].

For 11 samples and as requested by owners/zoos, also a commercially available coproantigen ELISA (Oxoid ProspecT<sup>®</sup>, *Cryptosporidium* Microplate Assay, Virotech Diagnostics GmbH) was used in order to detect *Cryptosporidium*-specific antigens (CSA). This coproantigen ELISA detects CSA of different host species, including reptiles and wild mammals ([41–43]).

## 3. Results

In total, we recorded seven different parasite species (Tables 2 and 3), of which oxyurid eggs were the most prevalent metazoan parasitic stages in our samples (41.2%). In contrast, only one sample (0.1%) contained *Strongyloides*-like eggs. Illustrations of selected parasitic stages and histopathological findings are presented in Fig. 1 and 2. Neither cestode nor pentastomid stages were present in the examined fecal samples. All nematode species found in this survey have pathogenic significance for agamas. Neither seasonal variations of egg shedding nor frequency of oxyurid infections were detected, since most lizard samples were sent to us prior to hibernation.

Protozoan parasites, on the other hand, were more pronounced and in total five taxa were found (Table 2). Apicomplexan *I. amphiboluri* oocysts were the most prevalent stages and diagnosed in 127 samples (17.0%). We detected lower prevalence for protozoan cysts of *Entamoeba* spp. (0.8%), oocysts of *Choleoecimeria* spp. (0.5%), trophozoites of *Trichomonas* spp. (0.2%) and oocysts of *Cryptosporidium* spp. (0.3%). Prevalence for *Nyctotherus* sp. and flagellated protozoa reached 12.0%.

**Table 2**  
Number and percentage of positive agamid lizards regarding infection with gastrointestinal endoparasites (total n = 747; 372 positive and 375 negative).

Parasite species	No. of positive (%)	Host species (n)
Oxyurid nematoda (Pharyngodonidae)	308 (41.2)	<i>Pogona vitticeps</i> (274), <i>Pognoa henrylawsoni</i> (22), <i>Uromastix</i> sp. (5), <i>Trapelus savignii</i> (2), <i>Stellagama stellio</i> (1), <i>Physignathus cocincinus</i> (1), <i>Leirolepis</i> sp. (1), <i>Agama agama</i> (1), <i>Calotes bachae</i> (1)
<i>Isospora</i> sp.	127 (17.0)	<i>P. vitticeps</i> (107), <i>P. henrylawsoni</i> (19), <i>Trapelus savignii</i> (1)
<i>Entamoeba</i> sp.	6 (0.8)	<i>P. vitticeps</i> (6)
<i>Choleoimeria</i> sp.	4 (0.5)	<i>P. vitticeps</i> (4)
Flagellated protozoa ( <i>Trichomonas</i> sp.)	2 (0.3)	<i>P. vitticeps</i> (1), <i>P. cocincinus</i> (1)
<i>Cryptosporidium</i> sp.	2 (0.3)	<i>P. vitticeps</i> (1), <i>P. henrylawsoni</i> (1)
<i>Strongyloides</i> -like	1 (0.1)	<i>Bronchocela cristatella</i> (1)

and 9.6%, respectively. *I. amphiboluri* infection rates varied with age (Chi-square test:  $\chi^2 = 21.5$ ,  $df = 1$ ,  $P < 0.001$ ), in which adult individuals were less frequently infected (14.2%) when compared to juvenile agamas younger than one year of age (31.9%).

In total, 13 dissected agamas (54.2%) were positive for endoparasite infections (Table 3) and four lizards (16.7%) died due to severe parasitic infections such as entamoebiasis (4.7%), oxyuridosis and isosporosis (4.7%), plagiogochiosis (4.7%) and choleoimeriosis (4.16%). Other etiological causes identified for the deaths of these 13 agamid lizards included bacterial infections [*Stenotrophomonas maltophilia* and/or *Salmonella* spp. (septic salmonellosis; (33.3%)], adenovirus infections (4.2%), systemic *Paecilomyces* sp. mycosis (4.16%), and non-infectious diseases [gout disease (12.5%), bite wounds (4.2%), intestinal invaginations (8.3%) and pre-ovulation egg bounds (4.2%)]. In two agamid lizards (8.3%), the cause of death was not clearly identified. One *P. vitticeps* showed severe *post-mortem* myiasis infestation with fly maggots which were not identify to species level.

One of 11 agamid lizard (9.1%) was found positive for CSA detected via coproantigen ELISA, and two of 19 samples were positive for *Cryptosporidium* oocysts (10.5%) via IFA. For these two samples, we also identified *Cryptosporidium*-oocysts via carbol-fuchsin stained fecal smears [40,28].

#### 4. Discussion

Gastrointestinal endoparasites in captive agamas have been investigated in several European countries in the past ([14,8,10,44]). Prevalence of oxyurid infections in captive herbivorous reptiles has been reported to be as high as 43–62% [14,34]. This finding is consistent with the high oxyurid prevalence observed in our study (41.18%). Moreover, oxyurid genera-related studies have revealed the presence of *Parapharyngodon*, *Pharyngodon*, *Alaeuris* and *Thelandros* in agamid lizards [8,45–47]. Oxyurid infections have rather low pathogenic effects on parasitized reptiles and have evolutionary adapted to the posterior gut microhabitat [45,11,48]. Nevertheless, massive pinworm infections resulting in clinical oxyuridosis can also lead to severe malabsorption in reptiles [12,34,35]. Accordingly, reptile oxyuridosis is considered an important parasitosis, particularly under terrarium conditions with poor hygiene standards [12,14]. It is worth noting that the youngest oxyurid-positive animal in our study was 2 months old, while the oldest was 15 years old. This suggests that all ages can be affected by these nematode species. In terms of oxyuridosis therapy, both fenbendazole- or febantel/pyrantel pamoate-treatments seemed to be efficient and compatible. In 17/25 cases (68.0%) agamid lizards ceased oxyurid egg shedding after these therapies.

In contrast to oxyurids, prevalence of heterakids was very low in our study compared to reported prevalences of 0.6–1.5% [8,14]. Common reptilian heterakid genera include *Spinicauda*, *Strongyluris* and *Meteterakis*, which are also known to parasitize agamid lizards [32,47,49,50].

There was only one trematode infection, diagnosed in a dissected half-year old female Chinese water dragon (*Physignathus cocincinus*). Pathological findings included general oedema, anaemia and associated hepatitis as well as nephritis associated with high numbers of

potentially pathogenic bacteria (i. e. *Aeromonas hydrophila*/*Chryseobacterium indologenes*) in the animal's coelom. Recently, Okulewicz et al. [8] described a similar case of trematode infection for another Chinese water dragon and suspected *Metaplagiorchis* sp. as species based on morphological/morphometric similarities.

Furthermore, several authors have focused on gastrointestinal apicomplexan coccidians in reptiles [2,30,51,52]. So far, several *Isospora* species have been described in diverse agamid genera ([30,31,53,54]). Consequently, intestinal damages might result in severe reptilian isosporosis manifesting clinical symptoms such as diarrhoea, anorexia, weight loss and progressive apathy [2,4,10]. As seen in closely related coccidian infections of mammals, reptilian isosporosis is considered a self-limiting disease unless no re-infections occur [55,56]. In our study, the youngest *I. amphiboluri*-infected animal was only 2 months old and the oldest 25 years, which suggests that all ages can be affected. However, the *I. amphiboluri* prevalence observed in juvenile/pre-adult agamid lizards varied with age (Chi-square test:  $\chi^2 = 21.5$ ,  $df = 1$ ,  $P < 0.001$ ). Adult individuals were infected less frequently (14.2%) than juveniles younger than one year of age (31.9%). This phenomenon may be linked to the lack of immunity in juvenile lizards as suggested by Walden [2]. For therapy of agamid isosporosis, the anticoccidial drug toltrazuril has been suggested ([57]; Walden, 2009).

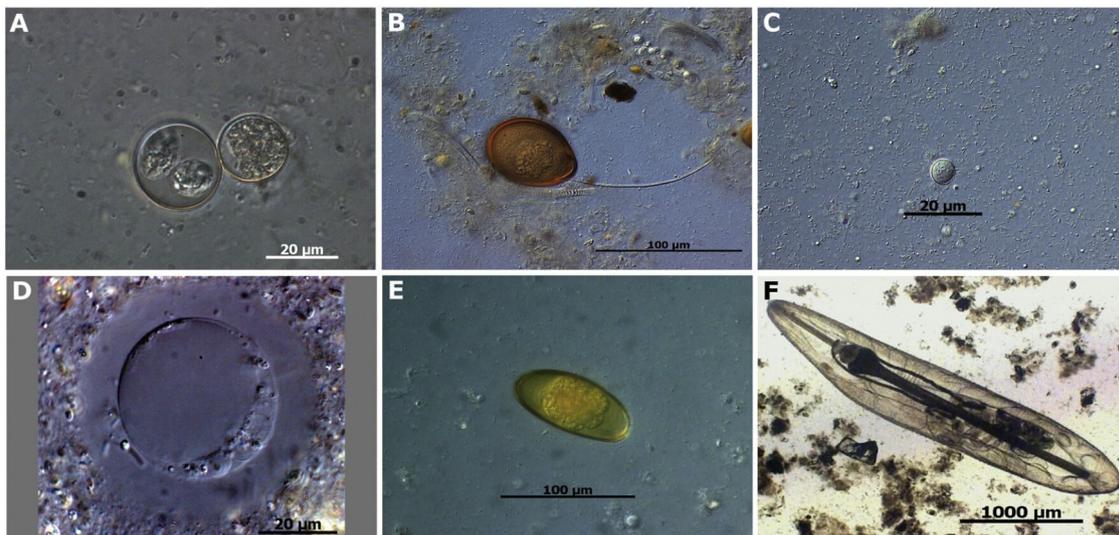
Conversely to *I. amphiboluri*, prevalence of *Choleoimeria pogonae* in our study was very low (0.53%). Monoxenous *Choleoimeria* species form endogenous meront- and gamont-stages in epithelial host cells of gall bladder in reptiles [2,58,59]. *Choleoimeria* spp. can also induce lesions such as focal pseudo stratification, epithelial hypertrophy and cell degeneration in gallbladder epithelium [2,59]. Severe *Choleoimeria*-derived pathogenicity was underlined by pathological findings. Consequently, we detected a manifested choleoimeriosis in one neotropical inland bearded dragon (*P. vitticeps*) which appeared with a green-yellow marbled liver and an adamant-dilatated gallbladder.

In two cases, (0.3%), we also found potentially pathogenic, enteric flagellated protozoan genera such as *Proteromonadida*, *Reteromonadida*, *Diplomonadida*, *Oxymonadida* and *Trichomonadida* in very high numbers. Nonetheless, the literature considers many of these flagellates as opportunists rather than pathogens, living as commensals within intestinal tract of reptiles [4,60]. High intestinal flagellate burdens can impact on weak and/or young reptiles if enteric microbiota changes through diet and gastrointestinal pH values, conditions which can lead to massive flagellate replication [9,35] causing anorexia, enteritis, ulceration, mucosal perforation and incrustated cloaca [4,60].

We found *Cryptosporidium* spp. oocysts by light microscopy analysis and confirmed infections additionally by IFA and carbol-fuchsin staining techniques. *Cryptosporidium* is known to infect several different species of reptiles resulting in clinical symptoms associated with mid-body swelling through hypertrophic gastritis and bronchopneumonia in snakes as well as proliferative enteritis in common leopard geckos (*Eublepharis macularis*) [28,61,62]. Moreover, *Cryptosporidium* has been reported to occur asymptotically in inland bearded dragons and other lizards [33,63,64]. The zoonotic potential of reptile-derived *Cryptosporidium* species has been discussed in past decades, but seems unlikely to occur [34,65,66].

**Table 3**  
Necropsied species of agamid lizards regarding endoparasite infection and cause of death (total  $n = 24 / 14$  positive and gastrointestinal parasites detected).

lizard species	parasitic infection	isolated bacteria (coeloma)	cause of death	pathological-anatomical /histo-pathological findings
<i>Pogona vitticeps</i>	Pharyngodontidae (++)	*	gout	nephrosis /gout
<i>P.vitticeps</i>	Pharyngodontidae (++)	*	gout	visceral gout
<i>Uromastyx</i> sp.	<i>Entamoeba</i> sp. (+)	*	Entamoebiasis	parasitic caused enteritis andhepatitis
<i>P.vitticeps</i>	Pharyngodontidae (++)	<i>Stenotrophomonas maltophilia</i> (++++), <i>Salmonella enterica</i> ssp. (++++)	Salmonellosis	atonical intestinal obstruction/dilatation, hepatitis, lung edema
<i>P.henrylawsoni</i>	Pharyngodontidae (++)	<i>S. maltophilia</i> (++++), <i>S. enterica</i> ssp. (++++)	Salmonellosis	microabscess-forming hepatitis with central necrosis, nematodes in intestinal lumen
<i>P.vitticeps</i>	-	-	Salmonellosis	enteritis, hepatitis
<i>P.vitticeps</i>	-	<i>Enterobacter faecalis</i> (++++), <i>E. cloacae</i> (++++), <i>S. enterica</i> ssp. (++++)	Salmonellosis	enteritis, hepatitis
<i>P.vitticeps</i>	-	<i>S. maltophilia</i> (++++), <i>S. enterica</i> ssp. (++++)	Salmonellosis	-
<i>P.vitticeps</i>	-	*	Systemic mycosis	systemical,chronical, granulomatosal mycotic nephritis, hepatitis and enteritis associated with necrosis ( <i>Paecilomyces</i> sp.)
<i>Gonocophthalmus</i> sp.	-	<i>S. maltophilia</i> (++++)	bacterial infection	interstitial lung edema, enteritis and hepatitis
<i>P.vitticeps</i>	Pharyngodontidae (++)	<i>S. maltophilia</i> (++++), <i>S. enterica</i> ssp. (++++)	Adenovirus infection	fly grubs, inclusion bodies in hepatocytes, chron. Hepatitis / pneumonia
<i>Leiolepis</i> sp.	-	<i>S. maltophilia</i> (++++), <i>S. enterica</i> ssp. (++++)	Bacterial infection	cachectic, bacterial enteritis and hepatitis
<i>P.vitticeps</i>	-	*	Intestinal invagination	invagination and rupture of intestines
<i>Clamydosaurus kingi</i>	-	*	Gout	pale mucosa, visceral gout, hepatitis, nephrosis, myocarditis
<i>Hydrosaurus</i> sp.	<i>Strongyluris</i> sp. (++++)	*	Bite wound	chronical hepatitis, bite wound (throat) associated with muscle necrosis
<i>Leiolepis</i> sp.	-	<i>E. faecalis</i> (++++)	Intestinal invagination	PAS-pos structures in the skin ( <i>Chrysosporium</i> sp.), bacterial hepatitis, sand obstipation, intestinal invagination
<i>Leiostelis</i> sp.	-	*	unknown	neurological signs, coordination problems
<i>Uromastyx</i> sp.	Pharyngodontidae (++)	*	Intestinal invagination	-
<i>P.vitticeps</i>	<i>Choleoimertia</i> sp. (++)	*	Choleoimertiosis	green-yellow marbeled liver, adamant-dilatated gallbladder, gas-filled intestines, high-grade tubulonephritis
<i>P.vitticeps</i>	Pharyngodontidae (++)	*	unknown (autolytic)	-
<i>Agama agama</i>	Pharyngodontidae (++)	<i>Pseudomonas fluorescens</i> (++++), <i>S. enterica</i> ssp. (++++)	Preaovulatory eggbound	serositis / adhaesions / inflammation of ovaries and oviduct/ free vitellin inside coeloma
<i>P.vitticeps</i>	Pharyngodontidae (++) , <i>Isospora</i> sp. (++)	<i>P. fluorescens</i> (++++), <i>S. enterica</i> ssp. (++++)	Oxyuridosis, Isosporosis	autolytic, cachectic, hepatitis and nephritis
<i>Physignathus coarctatus</i>	<i>Plagiorchiidae</i> (++)	<i>Aeromonas hydrophila</i> (++++), <i>Chryso bacterium indologenes</i> (++++), <i>S. enterica</i> ssp. (++++), <i>Klebsiella</i> sp. (++++)	Digenea infection	general edema, anemia, sec. inflamm. of liver/gut
<i>P.vitticeps</i>	Pharyngodontidae (++)	-	Salmonellosis	poor nutritional condition, pneumonia, nephritis, hepatitis

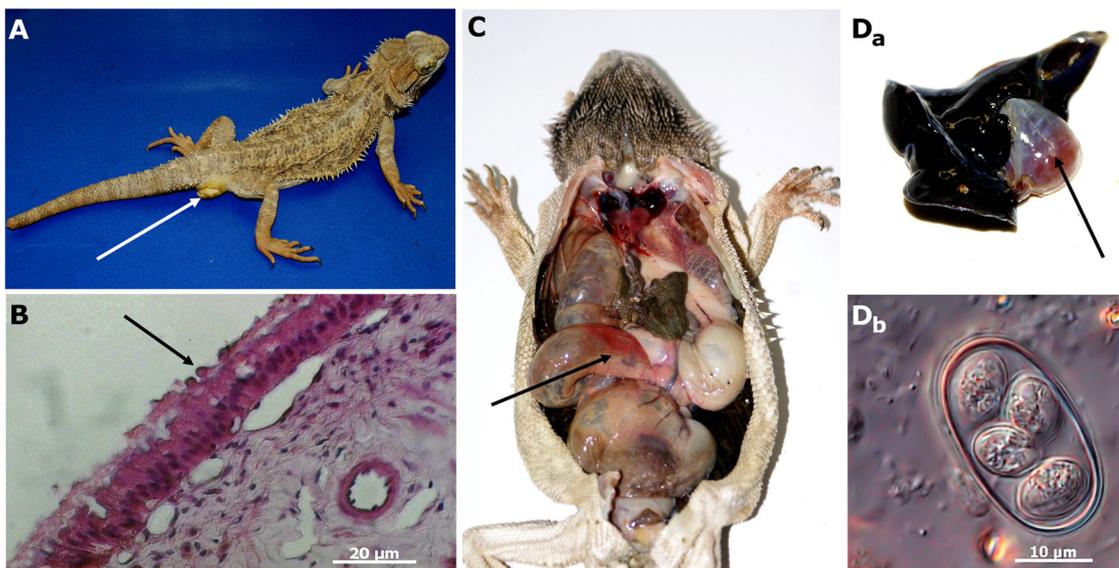


**Fig. 1.** A *Isospora amphiboluri*: sporulated and unsporulated *I. amphiboluri*-oocysts shed by a dwarf bearded dragon (*Pogona henrylawsoni*). Notice *I. amphiboluri*-sporulated oocyst containing two sporocysts with four sporozoites each. B *Nyctotherus* sp.: Bean-shaped cyst shed by an inland bearded dragon (*P. vitticeps*). C *Entamoeba* sp.: Amoeba cyst shed by an inland bearded dragon (*P. vitticeps*). D *Blastocystis* sp.: *Blastocystis* sp. cyst with parietal nuclei and a large central vacuole (*Pogona vitticeps*). E Oxyurid ova: plum-shaped eggs containing a morula stage (*P. vitticeps*). F Adult oxyurid nematode: specimen was shed by an inland bearded dragon (*P. vitticeps*). Notice the prominent bulbus at the end of the oesophagus.

Ultimately, neither eggs of cestodes nor eggs of pentastomids were found in this epidemiological study. Reptiles act as definitive hosts for most well-known pentastomids and the genus *Raillietiella* may affect agamid lizards [6,20,21]. In this large-scale study ( $n = 748$ ), however, no agamas kept in Germany were diagnosed to be infected with pentastomids. One reason for this may be efficient captive breeding and the avoidance of wild animal imports. Therefore, at least bred captive agamid lizards should play a marginal role in pentastomid-derived human infections in Germany.

**5. Conclusions**

In our representative epidemiological survey of agamid lizards, we found several pathogenic parasite species. As a general recommendation, gastrointestinal parasitoses should always be considered in routine health screenings. If diagnosed, they should be correctly medicated, taking into account not only clinical signs but also prophylaxis. Applied fecal saline smears proved to be valid for detection of many relevant parasitic stages. Since the biology, epidemiology as well as pathogenesis of most parasites in reptiles is still not fully understood, further investigations are needed. Similarly the current lack of suitable herpetological therapy options calls for more research in the field of new



**Fig. 2.** A Cachectic inland bearded dragon (*P. vitticeps*): Lizard suffering from severe gastrointestinal parasitoses. Clinical manifested oxyuridosis combined with a severe isosporosis. Also, a secondary bacterial infection induced a cloacitis (indicated by arrow). B Histopathology of *Cryptosporidium*-infected gut mucosa: Please notice the tiny extracellular intracytoplasmatic *Cryptosporidium*-meronts (arrow) on the enteric mucosa of an inland bearded dragon (*P. vitticeps*). C Dissected inland bearded dragon (*P. vitticeps*): Severe enteritis caused by an oxyurid infection (arrow). Please also notice the degenerated liver. Da Dilated gall bladder: *Choleimeria pogonae* infection leading to cholestasis and cholangitis. Db Sporulated *Choleimeria pogonae*-oocyst: oval *C. pogonae*-oocyst containing 4 sporocysts with two sporozoites each.

drug development within the field of neglected herpetology medicine.

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## Conflict of interest statement

The companies Virotech Diagnostics, GmbH, Cellabs Pty Ltd. and BioMerieux did neither play a role in the study design nor in the collection, analysis and interpretation of generated data, nor in the decision to submit the manuscript for further publication. None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the manuscript.

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