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Lethal bloat syndrome in two lemur species associated with *Clostridium perfringens* infection at Tierpark Berlin

Tödlich verlaufendes Aufblähungs-Syndrom in Zusammenhang mit *Clostridium perfringens* -Infektionen bei zwei Lemuren-Arten im Tierpark Berlin

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Summary

In 2019 and 2020 five cases of a bloat syndrome occurred in the lemur stock of Tierpark Berlin. It is very likely, that this syndrome was caused by a *Clostridum perfringens* infection. The authors describe each of these five cases in detail and give recommendations for the therapy and prophylaxis of this potentially lethal condition.

Keywords: Lemurs, bloat syndrome, symptoms, pathology, therapy, *Clostridium perfringens*, *Eulemur*

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Introduction

Tierpark Berlin (Germany) has kept a large collection of lemur species for many years. Since 2012 the endangered red-collared brown lemur (*Eulemur collaris*) has been held there. The species was first reared successfully in Germany in 2019 at Tierpark Berlin. In the same year, Tierpark Berlin received, for the first time in its history, the critically endangered blue-eyed black lemur (*Eulemur flavifrons*) on recommendation of the EAZA Ex situ Programme (EEP) coordinator. This lemur is the flagship species of the conservation organisation Association Européenne pour l'Étude et la Conservation des Lémuriens (AEECL), which has been financially supported by Tierpark Berlin for many years. The diet of the lemurs at Tierpark Berlin consists of vegetables and apple. From time to time, they receive browse. Bark chips are used as substrate to cover the floor in the inside exhibit. The ground of the outside enclosure is covered with topsoil mainly overgrown with grass.

Pond et al. (1982) described an acute gastric dilation in 21 Old World monkeys (OWM), which were wild-caught and kept for experimental studies. The syndrome occurred after food restriction followed by ad libitum feeding (biscuit-type diet with a high amount of carbohydrates) or associated with anaesthesia. In four of these cases, *Clostridium perfringens* was isolated from the intestine. Pathologic examination revealed an atonic stomach, greatly distended with gaseous fermented ingesta and in some cases rupture of the stomach. Terio et al. (2018) mentioned an acute gastric dilation or "bloat syndrome" caused by a *Clostridium perfringens* infection in OWM and New World monkeys (NWM) after overeating and drinking, following anaesthesia or after disturbances of the gastric flora induced by antimicrobial treatment. This syndrome is a medical emergency and, if left untreated, leads to acute shock and death. Acute gastric dilation was also described by Abee et al. (2012) and Yasuda et al. (2015) in OWM and NWM. Williams (2002) published eight cases of *Clostridium difficile* infections in lemurs associated with diarrhoea and partial bloating of the abdomen at the Duke Lemur Center in North Carolina (USA). However, the authors failed to find any reports of a bloat syndrome in lemurs caused by *Clostridium perfringens*.

The following report describes five cases of a bloat syndrome in three blue-eyed black lemurs and two red-collared brown lemurs at Tierpark Berlin.

Case reports

1st case (January 2019): 1.0 blue-eyed black lemur (*Eulemur flavifrons*) "Olivier", 20 years old

Tierpark Berlin received this animal on 31/08/2018 from Cologne Zoo (Germany). Until 06/01/2019, the lemur showed normal behaviour and appetite. On this day, "Olivier" ate only half of the daily ration and had bloody diarrhoea in the afternoon. The lemur received injections of meloxicam (anti-inflammatory drug, 2.0 mg/kg BW Metacam® 2% s.c.) and amoxicillin (antibiotic, 7.5 mg/kg BW Amoxicillin WDT® 15% s.c.). The following day, "Olivier" exhibited strange behaviour: He chewed food items without swallowing them, followed by spitting out little pieces of food. Furthermore, the lemur seemed to be bloated. Parasitological analysis of faecal samples showed only few oxyurid eggs in fresh stool. Quick tests for *Giardia*, *Cryptosporidium* and *Entamoeba histolytica* were negative. The lemur received injections of enrofloxacin (antibiotic, 5.0 mg/kg BW Enrofloxacin® 2.5% s.c.) and vitamins (0.5 ml Ursovit® AD3EC s.c.). Additionally, he received an infusion consisting of glucose and sodium chloride and a spot-on with selamectin (anti-parasitic, 7.5 mg/kg BW Stronghold® Katze). On the morning of 08/01/2019, the animal was found dead. Pathological findings included petechial and regional haemorrhages into the wall of the small and large intestine (Fig. 1). The mucosa of the intestine was not affected. Histology revealed an erosive, partly ulcerative enteritis associated with a dysbacteriosis. Endoparasites were not found. The liver had hepatocellular necrosis. In a subsequent bacteriological investigation, *Escherichia coli* (different phenotypes) and alpha-haemolytic streptococci were isolated in severe growth from the small and large intestine. *Salmonella* or *Yersinia* (both from enrichments) as well as *Clostridia* (in anaerobic cultures, including *Clostridium perfringens*) were not detected.

Fig. 1: Digestive tract of 1.0 blue-eyed black lemur "Olivier" at necropsy. Photo: A. Pauly.

2nd case (March 2019): 1.0 blue-eyed black lemur (*Eulemur flavifrons*) "Cesar", 11 years old, son of "Olivier"

This lemur was obtained on 21/02/2019 from Mulhouse Zoo (France) as a new partner for the remaining female "Zazou" after the death of "Olivier". On 04/03/2019, the animal suffered from anorexia, vomitus and watery diarrhoea and showed the strange behaviour of spitting out small pieces of food (as mentioned above). After immobilisation with medetomidine (0.1 mg/kg BW Sedator® i.m.) and ketamine (10.0 mg/kg BW Ketamin 10% WDT® i.m.), blood was drawn and radiographs were taken. The stomach was filled with food and the intestine was bloated. Blood values (haematology and chemistry) were in normal range, except values for sodium, chloride, albumin and total protein, which were below normal values. Therapy was initiated immediately with daily infusions of sodium chloride and glucose, antibiotics (enrofloxacin (5.0 mg/kg BW Enrofloxacin® 2.5% s.c.) and cefovecin (8.0 mg/kg BW Convenia® s.c.)) and metoclopramide (0.5 mg/kg BW BID MCP-ratiopharm® p.o.) to accelerate the gastro-intestinal passage. A slight improvement of the symptoms was observed in the following days. The lemur ate small amounts of food and no longer had diarrhoea. Unexpectedly, "Cesar" was found dead in the morning on 09/03/2019. During necropsy, a rupture of the small intestine without detectable marginal bleeding and a fibrinous serositis with a large amount of brownish fluid in the abdominal cavity were found (Figs. 2 and 3). There were no foreign objects in the intestine. Histologically, a severe lympho-histiocytic infiltration in the small intestine and hepatocellular necrosis was recorded. In a subsequent bacteriological investigation *Escherichia coli* and *Enterococcus* species were isolated in severe growth from liver, spleen and urine and from the small and large intestines. *Salmonella* or *Yersinia* (both from enrichments) were not detected, but *Clostridium perfringens* was cultured in severe growth from small and large intestines together with other concomitant anaerobic bacteria (i.e., *Clostridium*, *Fusobacterium* and *Bacteroides* species). *Clostridium*-like bacteria were also detected histologically in the blood vessels from different organs.

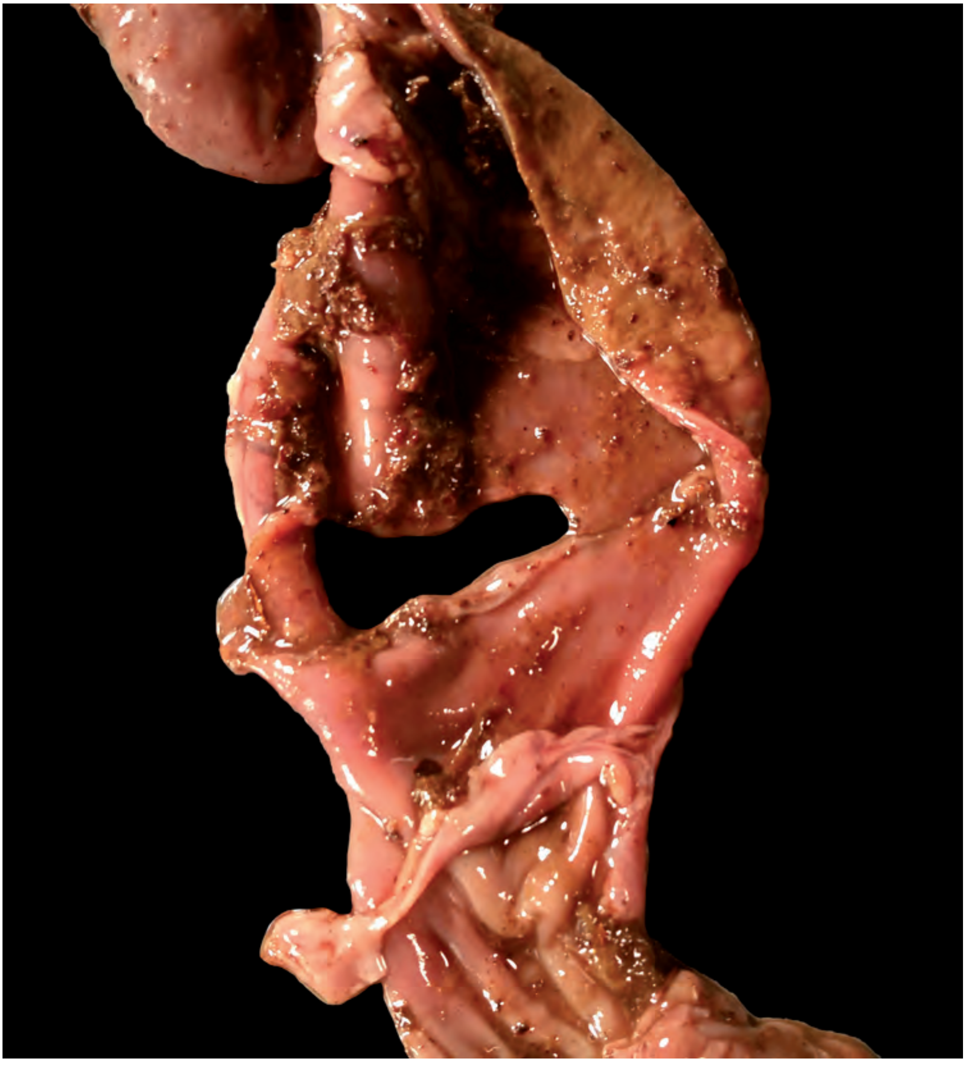

Fig. 2: Rupture of the small intestine of 1.0 blue-eyed black lemur "Cesar". Photo: A. Pauly.

Fig. 3: Situs of 1.0 blue-eyed black lemur "Cesar" at necropsy. Note the distended intestine and the brownish fluid in the abdominal cavity. Photo: A. Pauly.

3rd case (April 2019): 0.1 blue-eyed black lemur (*Eulemur flavifrons*) "Zazou", 20 years old

Tierpark Berlin received this female on the same day as the male "Olivier". She came from La Palmyre Zoo (France). After "Olivier's" death, she lived together with the new male "Cesar". "Zazou" harmonised very well with both males. On 14/01/2019, six days after "Olivier" passed away, a fresh stool sample of "Zazou" was taken and no pathogenic bacteria were detected (result of the bacteriological examination: physiological intestinal flora). The female showed normal behaviour and appetite until 20/04/2019. Over a period of five days, "Zazou" was inconspicuous in her behaviour in the morning, than she refused to eat the whole amount of her diet in the afternoon and was further observed to be very calm. Additionally, she was observed to apparently drink more water than before. Her vulva was slightly opened and she appeared pregnant. On 23/04/2019, another stool sample was checked for pathogenic bacteria and parasites. Only a few oxyurid eggs were detected. The lemur was treated with fenbendazole (anti-parasitic, 25.0 mg/kg BW Panacur® PetPaste p.o.) over a period of three days. Gestation diabetes was suspected after a urine stick was positive for glucose on 27/04/2019. In the afternoon of the same day, "Zazou" choked and vomited severely. She was anaesthetised with midazolam (0.2 mg/kg BW Midazolam-ratiopharm® i.m.) and ketamine (10.0 mg/kg BW Ketamin 10% WDT® i.m.) for x-ray examination. Her stomach was fully filled with food and the intestine contained large amounts of gas (Fig. 4). Anaesthesia was prolonged with isoflurane (1.5 % Isofluran CP®, 1 l O2/min) for laparotomy. The blood vessels of the stomach were highly injected and no peristaltic movement in the whole digestive tract was detectable (Fig. 5), not even after stimulating the intestine with sodium chloride. A gastro- and enterotomy to remove food and gas were performed. Additionally, the lemur received infusions with sodium chloride and glucose, cefovecin (antibiotic, 8.0 mg/kg BW Convenia® s.c.) and prednisolone (cortisone, 1.0 mg/kg Prednisolonacetat® i.m.). Despite the successful surgery, the lemur died three hours

Fig. 4: Ventrodorsal radiograph of 0.1 blue-eyed black lemur "Zazou". Note the distended stomach filled with food and gas and the gas-filled intestine. Photo: A. Pauly.

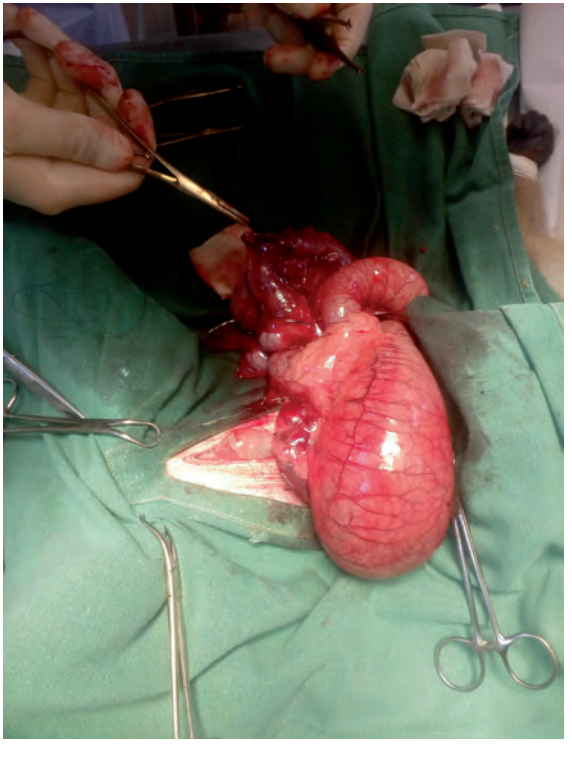

Fig. 5: Gastric dilation of 0.1 blue-eyed lemur "Zazou" during laparotomy. Note the injected blood vessels. Photo: A. Pauly.

later with shock symptoms. Pathohistology revealed diffuse oedema within the mucosa of the small intestine and a diffuse lymphocytic to histiocytic enteritis in the large intestine. In a subsequent bacteriological investigation, *Escherichia coli* (two phenotypes), *Streptoccocus* species and Gram-negative anaerobic species were isolated in severe growth. *Salmonella* or *Yersinia* (both from enrichments) were not detected, as well as *Clostridia* (in anaerobic cultures, including *Clostridium perfringens*).

4th case (May 2019): 1.0 red-collared brown lemur (*Eulemur collaris*) "Tonik", 9 years old

The animal was obtained from Plzeň Zoo (Czech Republic) in 2012. On 29/05/2019, the lemur showed the strange behaviour of chewing and spitting out food items as mentioned in the reported blue-eyed black lemur cases. He was treated with doxycycline (antibiotic, 10.0 mg/kg Doxycyclin-ratiopharm®SF i.m.), prednisolone (cortisone, 1.0 mg/kg Prednisolon-acetat® i.m.) and glucose infusion the following day. In the morning of 31/05/2019, "Tonik" was found dead in the indoor exhibit. This male red-collared brown lemur lived together with

Fig. 6: Ulcerative and fibrinous gastritis of 1.0 red-collared brown lemur "Tonik". Photo: A. Haake.

two females of the same species in the former enclosure of the blue-eyed black lemurs for around three weeks. The inside exhibit was thoroughly cleaned and disinfected before the transfer of the red-collared brown lemur group with p-chlor-m-cresol (Neopredisan®, 4 % for 1 h). In necropsy, the stomach and intestine were massively distended with gas. In addition, a severe ulcerative and fibrinous gastritis (Fig. 6) and a severe ulcerative and diphtheroid enteritis of the small and large intestine (Fig. 7) were observed. In a subsequent bacteriological investigation, *Escherichia coli* and *Enterococcus hirae* were isolated in severe growth. *Salmonella* or *Yersinia* were not detected, but *Clostridum perfringens* (toxovar A) was cultured anaerobically in severe growth from the intestine.

Fig. 7: Ulcerative and diptheroid enteritis of jejunum, colon and rectum of 1.0 red-collared brown lemur "Tonik". Photo: A. Haake.

5th case (February 2020): 1.0 red-collared brown lemur (*Eulemur collaris*) "Thierry", 2 years old

Tierpark Berlin received this lemur on 14/08/2019 from Plzeň Zoo (Czech Republic) as a new breeding male after "Tonik" passed away. Until 09/02/2020, "Thierry" showed no clinical abnormalities. On this day, the lemur was apathetic and anorexic. He was observed chewing food items without swallowing. A bloating of the abdomen was not seen. Due to previous experience with the other lemurs (cases 1-4), an infection caused by *Clostridium perfringens* was suspected. "Thierry" was immediately treated with metronidazole (antibiotic, 50 mg/kg Eradia® p.o.) and received infusions with sodium chloride and glucose to accelerate the elimination of potentially, already absorbed *Clostridium*-toxins. The second day after the start of therapy the lemur recovered partially and was observed to forage slowly, consuming the whole amount of the daily food ration. On 11/02/20, he additionally received a mixture of filtered faeces from the healthy female mixed with water to build up a physiological microbiome in his intestine. After ten days of treatment with metronidazole (50 mg/kg Eradia® p.o.), the lemur was considered to have totally recovered. On 18/02/20, he received a second faecal transplantation to boost his physiological microbiome.

Results

All affected lemurs (n=5) showed the same unknown behaviour at the beginning of the disease (chewing food without swallowing, followed by spitting out little pieces of the food items or vomiting). In four cases, a bloating of the abdomen was observed. In each of the four dead lemurs, Escherichia coli was detected in the intestinal tract. However, an additional whole genome-based characterisation of three different Escherichia coli isolates from two lemurs (0.1 blue-eyed black lemur "Zazou" and 1.0 red-collared brown lemur "Tonik") revealed the presence of genetically distinct strains (phylogenetic group: A, B1 and B2) and virulence gene profiles that do not point to enteropathogenic *Escherichia coli* or other known pathovars. *Escherichia coli* as well as *Streptococcus* spp. and *Enterococcus* spp. are probably part of the indigenous microbiota. In two of the described cases, *Clostridium perfringens* was isolated. All dead lemurs exhibited signs of the bloat syndrome as described in the literature for OWM and NWM. An overview of clinical symptoms, the clinical course and the results of the bacteriological and pathological examinations of the described cases at Tierpark Berlin can be found (see Table 1).

Discussion

Clostridium perfringens is an anaerobic Gram-positive bacterium that can cause enterotoxaemia with acute gastric dilation in humans and nonhuman primates (Brack, 1987). It is able to form permanent stages; these spores are resistant to heat and can survive for a long time in the environment. Direct transmission from animal to animal was not observed. The minimal time period between two affected lemurs was around one month. This does not coincide with this acute clinical picture.

Clostridium perfringens was isolated from the intestine of only two out of five lemurs with symptoms of a bloat syndrome. However, it is very likely, that the presence of *Clostridium perfringens* or toxins produced by the bacterium were associated with this syndrome in the lemurs. This hypothesis is based on the following observations:

1. The clinical appearance and pathological findings in all five cases are identical to those described in the literature (Pond et al., 1982, Terio et al., 2018, Abee et al., 2012, Yasuda et al., 2015).

2. No food restriction or change in diet during the entire time occurred and not one of the lemurs was anaesthetised before developing the bloat syndrome. These reasons are listed as causal for developing a bloat syndrome in the literature (Terio et al., 2018).

3. The long time period between two infections provides a strong indication that the lemurs picked up spores from the soil or environment of the enclosure. Direct transmission from animal to animal is not assumed. The inside exhibits were cleaned and disinfected after the death of the last blue-eyed black lemur twice with p-chlor-m-cresol (Neopredisan®, 4% for 1 h), which is effective against the spores of *Clostridium perfringens*.

4. The successful treatment of the second affected red-collared brown lemur with metronidazole, an antibiotic highly effective against *Clostridium*, and his recovery after a short period.

Tab. 1: Clinical symptoms, clinical course, results of the bacteriological and pathological examination of the affected lemurs.

Case	Clinical symptoms	Clinical course	Bacteriology	Pathology
1.0 "Olivier"	chewing food without swallowing, followed by spitting out little pieces of the food items; bloody diarrhoea abdominal bloating	died	+++ *Escherichia coli* (different phenotypes) +++ alpha-haemolytic *Streptococcus* sp. (small and large intestine)	petechial and regional haemorrhages (wall of small and large intestine, mucosa not affected), erosive and ulcerative enteritis, hepatocellular necrosis
1.0 "Cesar"	chewing food without swallowing, followed by spitting out little pieces of the food items; vomitus; watery diarrhoea; abdominal bloating	died	+++ *Escherichia coli* +++ *Enterococcus* sp. (liver, spleen, urine, small and large intestine) +++ *Clostridium perfringens*, *Clostridium* sp., *Fusobacterium* sp., *Bacteroides* sp. (small and large intestine)	intestinal gas distention, rupture of small intestine, fibrinous serositis, lympho-histiocytic enteritis of small intestine, hepatocellular necrosis
0.1 "Zazou"	vomitus; abdominal bloating; no peristaltic movement in the whole digestive tract	died	+++ *Escherichia coli* (two phenotypes), +++ *Streptococcus* sp., +++ Gram-negative anaerobic species (small and large intestine)	oedema in the mucosa of small intestine, lympho-histiocytic enteritis of large intestine
1.0 "Tonik"	chewing food without swallowing, followed by spitting out little pieces of the food items; abdominal bloating	died	+++ *Escherichia coli*, +++ *Enterococcus hirae*, +++ *Clostridium perfringens* (toxovar A) (small and large intestine)	Gastrointestinal gas distention, ulcerative and fibrinous gastritis, ulcerative and diphtheroid enteritis of small and large intestine
1.0 "Thierry"	chewing food without swallowing, followed by spitting out little pieces of the food items	survived	-	-

+ 1 to 30 colonies of bacteria, ++ 30 to 100 colonies of bacteria, +++ > 100 colonies of bacteria

5. Similar cases occurred at the Duke Lemur Center (NC, USA) due to an infection with *Clostridium difficile*. Four of the eight described cases were blue-eyed black lemurs (*Eulemur flavifrons*) (Williams, 2002).

Considering the cases at the Duke Lemur Center and Tierpark Berlin, it is striking that most of the lemurs affected by a *Clostridium* enterotoxaemia belonged to two species, *Eulemur flavifrons* and *Eulemur collaris*. Tierpark Berlin has kept seven lemur species since 1984 and never had cases of this disease until introducing the blue-eyed black lemur into its collection. There were no changes in the feeding and hygiene regime either, which seems to indicate that the blue-eyed black lemur and the red-collared brown lemur are probably highly susceptible for this disease. Spores of *Clostridia* can survive in the soil for a very long time. Despite the thorough disinfection of the inside exhibit with Neopredisan®, two more lemurs became ill, indicating that the lemurs might have picked up spores from the topsoil of the outside enclosure.

Conclusions

It is strongly recommended by the veterinary advisor of the EAZA Prosimian TAG (Dr. Andreas Pauly, Tierpark Berlin, Germany) to immediately treat a lemur, showing symptoms of the described disease (chewing food without swallowing, followed by spitting out little pieces of the food items or vomiting), with metronidazole and to give the animal infusions to accelerate the elimination of the potentially absorbed toxins. If therapy is initiated too late, e.g. later than half a day after the first typical symptoms, the lemur will probably succumb to the disease within a few days. A faecal transplantation from a healthy lemur is very helpful to build up a physiological microbiome in the harmed intestine. This can support the recovery. To further prevent *Clostridum perfringens* infections in zoological collections, it is recommended to use a vaccine, if available. The production of an inactivated vaccine from one of the isolated bacterial strains is a viable option. After the successful treatment and recovery of the last infected red-collared brown lemur, all lemurs at Tierpark Berlin were vaccinated twice with Covexin 10® (0.05 ml per animal) at an interval of four weeks. Covexin 10® includes ten different toxoids of *Clostridium* species, among others toxoid A. No side effects from this vaccination were observed to date (June 2020).

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Zusammenfassung

In den Jahren 2019 und 2020 traten insgesamt fünf Fälle eines Aufblähungs-Syndroms bei zwei Lemuren-Arten, Blauaugenmaki (*Eulemur flavifrons*) und Halsbandmaki (*Eulemur collaris*), im Tierpark Berlin auf. Als Leitsymptome zeigten die Tiere reduzierten Appetit und eine Aufblähung des Abdomens. Die Lemuren bissen vom Futter kleine Stücke ab und schluckten diese nicht ab, sondern spuckten sie zerraspelt wieder aus. Vier der fünf Tiere starben trotz in-

tensiver Therapie innerhalb weniger Tage. Bei zwei der verstorbenen Tiere konnte post mortem ein starker Befall mit *Clostridium perfringens* nachgewiesen werden. Bei einem Tier konnte das Toxovar A isoliert werden. Dieses Bakterium kann durch Bildung von Toxinen zu schwerwiegenden Entzündungen und Lähmungen im Verdauungstrakt führen. Untermauert wurde der Verdacht auf eine *Clostridium perfringens*-Enterotoxämie der verstorbenen Tiere durch einen im Februar 2020 erkrankten Halsbandmaki, der ähnliche Symptome wie die verstorbenen Lemuren zeigte. Dieses Tier konnte erfolgreich mit Metronidazol, einer Infusions-Therapie und durch Gabe von Kottransfusionen eines gesunden Tieres gerettet werden. Aufgrund der vorliegenden Fälle erhielten alle Lemuren des Tierpark Berlin zweimalig eine Clostridien-Impfung. Es wurden bis dato (Juni 2020) keine Nebenwirkungen der Impfung beobachtet.

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DER ZOOLOGISCHE GARTEN

Heists, hoisters and herpetofauna: safeguarding zoological collections from thievery

Raub, Diebe und Herpetofauna: die Sicherung zoologischer Sammlungen vor Diebstahl

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Abstract

As one of their many core responsibilities, zoological parks are entrusted with safeguarding their animal collections from a broad range of hazards and threats. Many zoos and related facilities have experienced thefts of collection animals over the past century, with reptiles and amphibians ranking among the most targeted animal groups. This article discusses general trends in reptile and amphibian thefts from zoos and related facilities and provides an historical overview of noteworthy thefts from these institutions dating back to the late 19th Century, with a particular focus on some of the more brazen and outlandish incidents primarily in English-speaking countries. Based on this review, I conclude with a discussion of how zoological parks can improve upon how they display and safeguard their herpetological collections from theft.

Keywords: Zoos, theft, reptiles, amphibians, thieves, herpetology, security

Introduction

Zoological parks have many responsibilities that extend well beyond providing optimal care for their animals and offering memorable experiences to their visitors. In addition to protecting staff and visitors from potentially dangerous species through effective exhibit design and containment measures, zoos and aquariums must also protect their animals and infrastructure from a variety of hazards and threats ranging from extreme weather events and natural disasters to

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erratic individuals seeking to cause harm to collection animals, zoo buildings and exhibits, or sometimes even themselves. Physical barriers such as windows, fences, railings and moats are every bit as important for containing visitors and bad-actors as they are for the animals themselves.

While most reptiles and amphibians in zoological parks are typically displayed behind glass, they have not been totally immune from the actions of malicious individuals. Noteworthy examples include, but are not limited to the time in 1962 when a deranged man broke into the St Louis Zoo's (US) herpetarium and smashed out many of the building's exhibit windows with a large hammer, including several that housed venomous snakes (Anonymous, 1962a, b), the time in 2004 when a naked man climbed over a glass partition in the Bronx Zoo's (US) World of Darkness building to interact with the exhibit's adult pair of broad-snouted caiman (*Caiman latirostris*) (Mcgurk, 2004), and the time in 2008 when a seven-year-old boy broke into the Alice Springs Reptile Centre (AU) at night, bludgeoned several lizards and turtles, then fed several collection animals to the facility's large saltwater crocodile (*Crocodylus porosus*) (Marks, 2008). Although incidents like these tend to be few and far between when compared to those involving zoo mammals and their exhibits, a far more common threat to herpetofauna in zoological parks has been the theft of collection animals.

Thefts of collection animals in general, but reptiles and amphibians in particular, have been problematic for zoological parks and related facilities for more than a century, although it appears that such incidents have become less common in recent years. In this account, I review various cases and discuss general trends of reptile and amphibian thefts from zoos and related institutions primarily in English-speaking countries over the last 120+ years, with a particular focus on some of the more brazen, outlandish and noteworthy incidents. Based on this review, I then conclude with a discussion of some of the ways in which zoological parks can improve upon how they display and safeguard their herpetological collections.

General trends among zoo thefts

There is no single commonality among the various reptile and amphibian thefts that have occurred in zoos over the past 120 years, although some general trends are evident. The most recognizable trend is that the perpetrators – at least those that have been apprehended – are almost exclusively male, and while children as young as 10 years-old and grown adults have also been apprehended in connection to these crimes, teenagers make up the overwhelming majority of offenders.

Species that are rare or difficult to acquire through the private keeping sector and commercial trade are frequently targeted by thieves. In North American and European zoos, Australian species rank high among those taken, whereas in Australian institutions non-indigenous taxa such as American alligators (*Alligator mississippiensis*) and tortoises have been targeted. Although high-value specimens have been stolen on numerous occasions, many commonly kept species of little monetary value have also been taken from zoos. This dichotomy reflects different categories of thieves targeting zoological collections ranging from the well-informed in search of specific species or specimens that command high prices on the black market, to those with apparent limited familiarity with species that are only after large or impressive specimens such as large constrictors or alligators – possibly for their own personal collections, to uninformed, opportunistic thieves looking for anything they can quickly peddle for a quick sale.

Some institutions have been targeted by thieves more frequently than others. For example, the New York Zoological Park's (now the Bronx Zoo) reptile house, a facility long-renowned for its large and diverse collection and important herpetological programs, has experienced several thefts over its 120+ year history (Anonymous, 1923a, b, 1934a, b, c, d; Cooper, 1999; Brazaitis, 2003). The London Zoological Gardens (now London Zoo; UK) (Anonymous, 1924, 1967c, d, e, f), San Diego Zoo (US) (Anonymous, 1962c, 1986a, b) and others have also been impacted on multiple occasions. Some smaller, lesser-known facilities have also been heavily impacted; for example, the Long Island Reptile Museum (US) experienced many thefts over its brief nine-year existence (see Mendyk, 2015). In some cases, thefts have been inside jobs involving current or previous zoo staff members or volunteers (Anonymous, 1939a, b, 2013b).

What becomes of the reptiles and amphibians stolen from zoological parks? Sometimes stolen individuals are returned shortly after being taken (Anonymous, 1986b, 2002, 2007a; Cooper, 1999); on a few occasions, the animals were not only returned, but returned with remorseful letters accompanying them (Anonymous, 1982, 2002). In a few instances, animals were abandoned by thieves shortly after their removal, ultimately leading to the animals' deaths (Anonymous, 1939a, b, 1970). Some specimens have successfully been recovered by law enforcement or zoo officials following investigations or tip-offs from the public (Anonymous, 1934a, b, d, 1985b, 1990b, 1998, 2018b; Boylan, 2011). For those that are not recovered, these animals probably experience mixed fates. Depending on the species, its rarity and its value on the black market, some are likely sold to high-end collectors and private hobbyists, whereas more common species are probably kept by the thieves or sold inexpensively to inexperienced keepers and likely end up experiencing short lifespans.

A history of zoo thefts

Lizards

Lizards can be vulnerable targets for theft in zoological collections on account of their generally small body sizes, allowing them to be seized and carried away with little effort or resistance. Many different lizard taxa have been targeted and stolen from zoos over the past century (Tab. 1). Iguanas of the genus *Brachylophus* are highly sought-after by smugglers and illicit traders (e.g. Smith, 2011); in 1992, two Lau banded iguanas (*Brachylophus fasciatus*) were stolen from Taronga Zoo (AU) when thieves broke out the window to their enclosure overnight. The iguanas were eventually found by police abandoned inside a telephone booth ten days later following an anonymous tip (Boylan, 2011). Boylan (2011) also recounted a conspiracy theory concocted by the same police department which asserted that the theft was an elaborate hoax – a publicity stunt put on by the zoo!

Several helodermatids have been stolen from zoos over the last several decades (Lipman, 1973; Anonymous, 1981; Mendyk, 2015; T. Ziegler, pers. comm.). A crocodile lizard (*Shinisaurus crocodilurus*) and a New Caledonian giant gecko (*Rhacodactylus leachianus*) were stolen from the Long Island Reptile Museum in the early 2000s (Mendyk, 2015). Two Jackson's chameleons (*Trioceros jacksoni*) were taken from the San Diego Zoo in 1986 (Anonymous, 1986a), and three shingleback skinks (*Tiliqua rugosa*) and two blue-tongued skinks (*Tiliqua* sp.) were stolen from the Overton Park Zoo (now the Memphis Zoo [US]) in 1967 (Anonymous, 1967a, b).

Varanid lizards appear to be one of the more heavily targeted lizard groups, with several species stolen from zoos over the last several decades. A Bengal monitor (*Varanus bengalensis*) and an emerald tree monitor (*V. prasinus*) were taken from the Long Island Reptile Museum in the late 1990s (Mendyk, 2015). A captive-bred blue tree monitor (*V. macraei*), one of the first of its kind to be hatched at the zoo, was taken together with a *Heloderma suspectum* from the Cologne Zoo (DE) (Ziegler, 2008; Ziegler et al., 2009) and *V. griseus* and *V. prasinus* were taken from the Sedgwick County Zoo (US) (Strimple, 1997). Despite the inability of most private keepers to

Tab. 1: Summary of lizard thefts from zoological parks, primarily in English-speaking countries.

Institution	Country	Year	Species	Reference
Overton Park Zoo (Memphis Zoo)	US	1967	*Tiliqua rugosa, Tiliqua* sp.	Anonymous, 1967a,b
California Alligator Farm	US	1973	*Heloderma suspectum*	Lipman, 1973
Hellabrunn Zoo	DE	1973	"emerald lizards" - species not specified	Anonymous, 1973b
New York Zoological Park (Bronx Zoo)	US	1974-1975	*Ameiva* sp.	Brazaitis, 2003
Crandon Park Zoo	US	1981	*Heloderma exasperatum*	Anonymous, 1981
Sedwick County Zoo	US	1985	unspecified species	Anonymous, 1985b
		1997	*Varanus griseus, V. prasinus*	Strimple, 1997
San Diego Zoo	US	1986	*Trioceros jacksoni*	Anonymous, 1986a
Taronga Zoo	AU	1992	*Brachylophus fasciatus*	Boylan, 2011
Long Island Reptile Museum	US	1995-2004	*Heloderma suspectum, Shinisaurus crocodilurus, Rhacodactylus leachianus, Varanus prasinus, V. bengalensis*	Mendyk, 2015
Cologne Zoo	DE	2008	*Varanus macraei, Heloderma suspectum*	Ziegler, 2008; Ziegler et al. 2009; T. Ziegler, pers. comm.
Surabaya Zoo	ID	2011	*Varanus komodoensis*	Anonymous, 2011a,b
Fresno Chaffee Zoo	US	2013	*Varanus exanthematicus*	Anonymous, 2013a
Pierrelatte Crocodile Farm	FR	2015	*Varanus komodoensis*	Anonymous 2015a,b
New York Zoological Park (Bronx Zoo)	US	1974-1975	*Ameiva* sp.	Brazaitis, 2003
Long Island Reptile Museum	US	1995-2004	*Heloderma suspectum, Shinisaurus crocodilurus, Rhacodactylus leachianus, Varanus prasinus, V. bengalensis*	Mendyk, 2015

properly accommodate the species, the Komodo dragon (*V. komodoensis*) is probably the most coveted of all varanid lizards, with a strong black market demand for the species and price tag that can exceed $22,000 (USD) (Anonymous, 2015a, b). Juvenile *V. komodoensis* have been stolen from at least two zoological facilities over the past decade including the Surabaya Zoo (ID) (Anonymous, 2011a, b) and the Pierrelatte Crocodile Farm (FR) (Anonymous, 2015a, b); these specimens more than likely ended up in the illicit pet trade, where other illegally sourced *V. komodoen*sis have recently surfaced (Anonymous, 2018a; Sy & Lorenzo, 2020).

Snakes

Snakes have by far been the most frequently stolen group of herpetofauna from zoological parks over the past century (Tab. 2), with boids (Anonymous 1986b, 2011c; Mendyk, 2015), particularly boa constrictors (*Boa constrictor* and *B. imperator*), appearing to be the most commonly taken species (Anonymous, 1942, 1958, 1969a, 1973a, 1981, 1989a). A 10-year-old boy was charged with the theft of a boa and bull snake (*Pituophis catenifer sayi*) from the Lincoln Park Zoo (US) in 2002 (Pierre, 2002). A 20-year-old man was arrested for the theft of a boa and several other reptiles from the Fresno Chaffee Zoo's Discovery Center (US) in 2013; in addition to the animals, he also took children's toys, the phone system and a security monitor (Anonymous, 2013a). Several red sand boas (*Eryx johnii*) have been stolen from Indian zoological parks over the last decade (Anonymous, 2011c, 2013b). In 2013, four *E. johnii* went missing from the Chhatbir Zoo (IN); two of the animals mysteriously reappeared back in their enclosures several days later, alerting authorities that the theft was an inside job (Anonymous, 2013b).

Pythons have also been heavily targeted. In 1949, a 13-year-old boy was arrested for breaking into the reptile house at the Belle Vue Zoological Gardens (UK) and attempting to steal a large python; he later admitted to stealing four tortoises from the collection as well (Anonymous, 1949). Six ball pythons (*P. regius*) including the only known breeding pair of the species in zoos at the time and their captive-bred offspring were stolen from the Denver Zoo (US) in 1979 (Anonymous, 1979). The Jardin des Plantes (FR) experienced two break-ins over a 10 day period in 1984, resulting in the theft of several snakes including three 3 m-long pythons (Anonymous, 1984). Many

Tab. 2: Summary of snake thefts from zoological parks, primarily in English-speaking countries. *unsuccessful attempt.

Institution	Country	Year	Species	Reference
New York Zoological Park (Bronx Zoo)	US	1923*	*Naa naja, Naja haje*	Anonymous, 1923a,b
		1934	*Chilabothrus strigilatus, Pituophis melanoleucus, Coluber* sp., *Epicrates cenchoa, Pantherophis guttatus, Nerodia erythrogaster*, and additional unspecified species	Anonymous, 1934a,b,c,d
		1974-1975	*Morelia viridis, Pantherophis obsoletus, Epicrates cenchoa, Python regius, Pituophis catenifer sayi, Boa constrictor, Python sebae*	Brazaitis, 2003
		1987	*Crotalus cerastes, Agkistrodon taylori, Sistrurus miliarius,* several unspecified boas and pythons	Anonymous, 1987a,b
Port Elizabeth Snake Park	ZA	1925	*Bitis arietans, Dispholidus typus*	FitzSimons, 1925a,b
Forest Park Zoo (Fort Worth Zoo)	US	1942	*Boa constrictor*	Anonymous, 1942
Belle Vue Zoological Gardens	UK	1949	*Python* sp.	Anonymous, 1949
Griffith Park Zoo	US	1958	*Boa constrictor, Morelia spilota spilota*	Anonymous, 1958
San Diego Zoo	US	1962	*Python regius*	Anonymous, 1962c
		1986	*Boa constrictor*	Anonymous, 1986a
		1986	*Lichanura trivirgata*	Anonymous 1986b
London Zoological Gardens (London Zoo)	UK	1967	*Morelia viridis, Bitis rhinoceros* or *B. gabonica, B. arietans, Eryx* sp.	Anonymous, 1967c,d,e,f
Overton Park Zoo (Memphis Zoo)	US	1967	*Morelia spilota* ssp., *Antaresia childreni*	Anonymous, 1967a,b
Rome Zoo	IT	1969	*Boa constrictor,* unspecified python species	Anonymous, 1968a
Oakland Zoo	US	1971	*Python* sp.	Anonymous, 1971
Hellabrunn Zoo	DE	1973	*Simalia amethestina*, additional unspecified species	Anonymous, 1973b
Roger Williams Park Zoo	US	1973	*Boa constrictor*	Anonymous, 1973a
Denver Zoo	US	1979	*Python regius*	Anonymous, 1979
Dallas Zoo	US	1980	*Sonora aemula*	Murphy, 2015
Crandon Park Zoo	US	1981	*Boa constrictor*	Anonymous, 1981
Fort Worth Zoo	US	1982	*Acrantophis madagascariensis, Morelia spilota* spp., *Lampropeltis pyromelana*	Anonymous, 1982
Smithsonian National Zoological Park	US	1983	*Bitis gabonica*	Franklin, 1983; Milloy, 2002; Murphy and Xanten, 2007
Jardin des Plantes	FR	1984	*Python* sp.	Anonymous, 1984
Parque del Este Zoo	VZ	1985	unspecified species	Anonymous, 1985a
Sedwick County Zoo	US	1985	*Boa constrictor*, other unspecified species	Anonymous, 1985b
Dyreparken Zoo	NO	1989	*Boa constrictor*	Anonymous, 1989a
Lincoln Park Zoo	US	2002	*Boa constrictor, Pituophis catenifer sayi*	Pierre, 2002
Long Island Reptile Museum	US	~2002	*Sanzinia madagascariensis*	Mendyk, 2015
Lowry Park Zoo (Zoo Tampa)	US	2004	*Agkistrodon contortrix*, other unspecified species	Vansickle, 2004
Mumbai Zoo	IN	2011	*Eryx johnii*	Anonymous, 2011c
Chhatbir Zoo	IN	2013	*Eryx johnii*	Anonymous, 2013b
Djurparken Zoo	SE	2013	*Trimeresurus* sp.	Anonymous, 2013c
Fresno Chaffee Zoo	US	2013	*Boa constrictor*, *Python regius*	Anonymous, 2013a
Canberra Reptile Zoo	AU	2019	*Antaresia stimsoni, Morelia spilota cheyni*	Hayne, 2019

Australian pythons have been taken from North American, European and Australian institutions (Anonymous, 1958, 1973b; Hayne, 2019). In a true stroke of irony, the director of the Overton Park Zoo was alerted by staff of the theft of several Australian species while he was away attending a conference specifically focused on reducing rare animal thefts in zoos (Anonymous, 1967a, b).

By comparison, colubrids have not been targeted nearly as frequently as boids and pythons, although several noteworthy incidents have occurred. A prized collection of nine snakes referred to by curator Raymond Ditmars as “the star pieces of the collection” at the time, were stolen from the New York Zoological Park over the course of two nights in 1934; the locks to their enclosures had been picked (Anonymous, 1934a, b, c). Following a tip-off from a nearby high school’s administrative assistant, Ditmars and reptile keeper Fred Taggart visited the school, finding the zoo's missing Bahamian boa (*Chilabothrus strigilatus*), Florida pine snake (*Pituophis melanoleucus*), and "striped Arizona racer" (possibly *Coluber bilineatus* or *C. taeniatus*) in a biology classroom. Days later, a suitcase was found in a closet at the school which contained the remaining missing snakes, a "spotted racer" from Colima, Mexico (*Coluber* sp.?), a South American "red-banded snake" that had been gifted to Ditmars' daughter by noted Brazilian snake venom toxicologist Dr. Vital Brazil, a Venezuelan rainbow boa (*Epicrates cenchoa*) that had been living at the zoo for 15 years, a corn snake (*Pantherophis guttatus*), a red-bellied water snake (*Nerodia erythrogaster*), and a South American boa (species unspecified) that was deceased (Anonymous, 1934a, b, d).

As recounted by Brazaitis (2003) in his book, *You Belong in a Zoo!*, some 40 snakes and an *Ameiva* were stolen from the Bronx Zoo's reptile house over a span of several weeks in late 1974 and early 1975 by a 15-year-old working in concert with several friends and the owner and manager of a nearby pet store. The thieves entered the reptile house at night in a number of ways, including through an unlocked window and through an exhaust fan port in the roof of the building. From the ventilation port, the smaller-framed 15-year-old crawled along an air-conditioning duct and then dropped down into a room where keys to all of the snake enclosures were kept. Among the snakes taken were several boas, an African rock python (*P. sebae*) that was later returned to its enclosure at the zoo one night by the thieves due to its apparent aggressiveness, three green tree pythons (*Morelia viridis*), a black rat snake (*Pantherophis obsoletus*), *E. cenchoa*, *P. regius* and *P. catenifer sayi*. The stolen *M. viridis* were part of a U.S. Customs Agency investigation and were being housed at the zoo while the case was being built. Of the forty snakes that were stolen, only 15 were eventually recovered from the pet store. Several animals had already been sold and could not be recovered, one juvenile boa had been flushed down the toilet by the teenager's grandmother and an adult boa had escaped from the apartment and was run over by a bus on the street outside the building.

Murphy (2015) recounted the theft of a filetail ground snake (*Sonora aemula*) from the Dallas Zoo's (US) reptile house that occurred in 1980 during an open house reception for colleagues attending that year's meeting of the American Society of Ichthyologists and Herpetologists. Thirty snakes (species not identified) were stolen from the Parque del Este Zoo in Caracas, Venezuela, in 1985. The thieves also managed to swipe 100 live mice in the heist, apparently to ensure that the snakes would not go hungry (Anonymous, 1985a).

In 1982, a thief broke into the Fort Worth Zoo's (US) reptile house by entering through a skylight, stealing 10 rare snakes from the collection including a Madagascan ground boa (*Acrantophis madagascariensis*), a carpet python (*M. spilota* spp.), and several Arizona mountain kingsnakes (*Lampropeltis pyromelana*). The snakes were left on the home doorstep of curator Dave Blody the following day, along with a typewritten letter apologizing for the burglary (Anonymous, 1982). A skylight was also used to gain access to a room housing several snakes at the Lowry Park Zoo (now Zoo Tampa; US) in 2004, where a copperhead (*Agkistrodon contortrix*) and two non-venomous colubrids were taken (Vansickle, 2004). Several snakes and lizards stolen from the Sedgwick County Zoo (US) in 1985 were eventually recovered by authorities from Texas pet stores; the 24-year-old charged with the theft was also wanted by authorities in connection to the burglary and theft of several snakes from the Abilene Zoo (Anonymous, 1985b).

In 1987, sixteen snakes valued at an estimated $17,000 (USD) including several boas and pythons, a sidewinder (*Crotalus cerastes*), a Taylor's cantil (*Agkistrodon taylori*) and two pygmy rattlesnakes (*Sistrurus miliarius*) were stolen from the Bronx Zoo by a thief who forced open a door into the reptile house. All specimens were eventually recovered from a Brooklyn apartment following a tip-off to police. A 17-year-old was apprehended as he arrived at the apartment building carrying a bag full of feeder mice for the stolen snakes; he and the apartment's 27-year-old owner, both members of the New York Herpetological Society, were charged with several offenses (Anonymous, 1987a, b).

Despite the inherent risks, venomous snakes have been popular targets of thieves, with some of these thefts ranking among the more elaborate and outlandish herpetological heists in zoos. In 1923, a burglar broke in to the New York Zoological Society's reptile house and attempted to steal two Egyptian cobras (*Naja haje*) and two Indian cobras (*N. naja*) (Anonymous 1923a, b). Upon the reptile keepers' arrival at the building the following morning, they found tools, splinters, sawdust, burnt match ends and a hole that had been bored through the tin-lined wooden door of the cobra exhibit (Fig. 1). Fortunately, prior to abandoning their efforts to breach the enclosure, the offender stuffed the hole they had made with cheese cloth, which ultimately prevented the cobras' escape. Perplexed that anyone would want to steal such dangerous specimens, zoo director William Hornaday noted he would "give at least $4.50" to know what possessed the perpetrator to attempt such a feat. In response to Hornaday's questioning, an editorial piece published in the New York Times (Crummy, 1923) suggested the perpetrator may have sought the snakes so that they could be envenomated, which would then qualify them for a doctor's prescription for whiskey as treatment – a reflection of the extreme perceived lengths at which people would go to source spirits during the era of alcohol prohibition in the United States. Under suspicion for the attempted theft was a "tall, bearded East Indian snake worshipper" who frequented the zoo's reptile house to pray in front of the king cobra (*Ophiophagus hannah*) exhibit – so frequently that keeper staff would stop their daily routines to keep a watchful eye on the man. Following the break-in, two police officers were temporarily assigned as body guards to the king cobra (Anonymous, 1923b).

Upon his return from a trip abroad in 1925, Frederick FitzSimons, then director of the Port Elizabeth Museum and Snake Park (ZA), noticed that the number of snake specimens on display in the park appeared low and did not match up with the facility's inventory according to acquisition and death records kept on the collection (FitzSimons, 1925a, b). Initially, a park attendant was suspected of having stolen the missing specimens (Fig. 2), but this changed when a group of puff adders (*Bitis arietans*) and boomslangs (*Dispholidus typus*) was delivered to the park by some local collectors shortly after FitzSimons' return. Park attendants noticed upon releasing the specimens into the park's large snake pits (Fig. 3) that they did not behave in the same manner that freshly wild-caught specimens usually did when released. According to FitzSimons, instead of lunging and striking at the keeper or fleeing to the moat or other refugia, these animals remained sedentary or moved about the pit with apparent familiarity of their surroundings. After one of the collectors returned to the park a week later with another group of snakes, FitzSimons stationed three watchmen on guard at night waiting for the suspected thief to return. FitzSimons also secretly hand-marked some 100 snakes in the park with ventral scale clippings so that he could easily identify them should they later turn up in a collector's offerings. The thief struck again the night after the last watchmen shift was disbanded, showing up at the park the following day with a bag of twelve snakes, five of which had FitzSimons' markings. When confronted about the marked snakes, the man pleaded ignorant, but when FitzSimons reached for the telephone to call for the police, he admitted guilt and pleaded to be let go. The man was subsequently charged and sentenced to a month's hard labor (FitzSimons, 1925a, b).

Scaling a 7.6 m wall with a ladder to the private offices above the reptile house, where he then pried open a window and dropped down 2.4 m to the floor below (Anonymous, 1967c, d, e), a 16-year-old was responsible for several successive thefts at the London Zoo in 1967 totaling 26 snakes. Among the snakes taken were three green tree pythons (*Morelia viridis*), a Gaboon viper (*Bitis rhinoceros* or *B. gabonica*), six *B. arietans*, and 14 sand boas (presumably *Eryx* sp.) (Anonymous, 1967c, d). Seventeen of the snakes were eventually recovered alive, but the

Fig. 1: New York Zoological Park reptile keeper John Toomey inspects a hole bored through the door of a cobra exhibit in an attempted theft in 1923. Photograph courtesy of Michael Burger.

Fig. 2: A Port Elizabeth Snake Park attendant was initially suspected of stealing snakes from the collection in 1925 before it was learned that a thief was sneaking in at night to steal animals from the park's open pits.

Fig. 3: Port Elizabeth Snake Park snake pit, 1925.

other nine had died. At the perpetrator's residence, police also found two pythons that had gone missing from the zoo earlier that year (Anonymous, 1967f).

In 1983, two Gaboon vipers (*B. gabonica*) were stolen from the Smithsonian National Zoological Park's (US) reptile house by a 16-year-old, who entered into the building at night by breaking out the glass front door with a rock (Franklin, 1983; Milloy, 2002). He then smashed out the windows to the *B. gabonica* and cottonmouth (*Agkistrodon piscivorus*) exhibits, but only took the former, placing them in a plastic garbage bag he pulled from a nearby trash can. On his way home, the teenager was bitten on the shoulder by one of the *B. gabonica* as he slung the plastic bag over his shoulder while stepping off a city bus. At the hospital, he required extensive antivenom therapy which depleted the zoo's stockpile of the serum and required additional vials to be secured from the Bronx, Staten Island, Philadelphia and Baltimore Zoos. After spending three weeks in the hospital, the teenager eventually made a full recovery. Although some members of the public suggested that he be given a job at the zoo afterwards because of his passion for snakes, this sentiment was not shared by zoo staff and was not realized (Murphy & Xanten, 2007).

Tuatara

Tuatara (*Sphenodon punctatus*) are rare in zoological collections outside of their native New Zealand, and while only a handful of zoological facilities have maintained this species abroad, it too has been targeted by thieves on at least one occasion. After experiencing two other break-ins within a six-month period, the California Alligator Farm (US), which displayed a pair of *S. punctatus* for over nine years in the 1970s (Murphy & Matson, 1986), experienced a subsequent burglary in March of 1973 where various lizards and snakes were taken, including several *Heloderma*. The facility's tuatara exhibit's window had also been smashed, but the single *S. punctatus* kept at the time was later found hiding in a ceramic pot in the back of its enclosure. The curator noted that a struggle appeared to have occurred at the exhibit and suspected that the tuatara may have bitten the perpetrator to avoid capture (Lipman, 1973).

In New Zealand, three juvenile *S. punctatus* were stolen from the Southland Museum and Art Gallery in 2013 (Dillon, 2013). A burglar gained access to the museum's "tuatarium" by peeling up its roof and then proceeded to tear up hide boxes and tunnels in the enclosure. Although it was first thought that an adult female that was part of a breeding program for the species had also been taken, it was later found safe inside its burrow. The infrared security system that had been installed two weeks prior to the incident apparently failed and did not trigger the alarm. Smith (2011) also mentioned the theft of tuatara from another museum menagerie by a noted wildlife trafficker, although no specific details about the incident were given.

Crocodilians

Most crocodilians are poorly suited for private reptile collections on account of their large adult sizes, spatial requirements and formidability. Nevertheless, various crocodilians – mostly juvenile specimens, have been stolen from zoological parks (Tab. 3). In 1970, a juvenile Sunda Gharial (*Tomistoma schlegelii*) was taken from its heated outdoor exhibit at the Jacksonville Zoo (now the Jacksonville Zoo and Gardens; US) and then discarded in some bushes on zoo grounds when the thieves were approached by security. It was found deceased the next day, likely from exposure to subfreezing overnight temperatures; its jaws and legs were bound with rope and a peace sign was painted on its dorsum (Anonymous, 1970). Three juvenile Chinese alligators (*Alligator sinensis*) and two Siamese crocodiles (*C. siamensis*) were taken from the St. Augustine Alligator Farm (US) in 1990 (Anonymous, 1990b); the three *A. sinensis* were later found in a paper bag on the side of a road and recovered by the facility following an anonymous tip, but the *C. siamensis* were never recovered. A meter-long *A. sinensis* was taken from an open-air exhibit at the Ellen Trout Zoo in 2006 (Anonymous, 2006).

Perhaps not surprising given their ubiquity as a display species in zoological parks throughout the world (Ziegler et al., 2017), American alligators (*A. mississippiensis*) have been the most frequently stolen crocodilians from zoos. Two former zoo employees were arrested for stealing two

Tab. 3: Summary of crocodilian thefts from zoological parks, primarily in English-speaking countries.

Institution	Country	Year	Species	Reference
Pacific Park Menagerie	US	1907	*Alligator mississippiensis* (white individual, possibly leucistic)	Anonymous, 1907
Belle Vue Zoological Gardens	UK	1939	*Alligator mississippiensis*	Anonymous, 1939a, b
Grant Park Zoo (Zoo Atlanta)	US	1960	*Alligator mississippiensis*	McCartney, 1960
Jacksonville Zoo (Jacksonville Zoo and Gardens)	US	1970	*Tomistoma schlegelii*	Anonymous, 1970
Crandon Park Zoo	US	1983	*Melanosuchus niger, Crocodylus johnstoni, Mecistops cataphractus*	Anonymous, 1983
Beardsley Zoo	US	1989	*Alligator mississippiensis*	Anonymous, 1989b
St Augustine Alligator Farm	US	1990	*Alligator sinensis, Crocodylus siamensis*	Anonymous, 1990b
San Francisco Zoo	US	1997	*Caiman latirostris*	Anonymous, 1997
Dudley Zoo	UK	2000	*Osteolaemus tetraspis*	Probert, 2000
Ellen Trout Zoo	US	2006	*Alligator sinensis*	Anonymous, 2006
Bergen Aquarium	NO	2008	*Paleosuchus trigonotus*	Anonymous, 2008
Federal University of Mato Grosso Zoo	BR	2008	*Alligator mississippiensis* (albino individuals)	Duffy, 2008
Hunter Valley Zoo	AU	2012	*Alligator mississippiensis*	Anonymous, 2012
Australian Reptile Park	AU	2013	*Alligator mississippiensis*	Anonymous, 2013d
Audubon Zoo	US	2015	*Tomistoma schlegelii*	This study
Arkansas Alligator Farm and Petting Zoo	US	2015	*Alligator mississippiensis*	Anonymous, 2015c
Canberra Reptile Zoo	AU	2019	*Crocodylus johnstoni*	Hayne, 2019

alligators from the Belle Vue Zoological Gardens in 1939. After taking the animals home with them, the thieves did not know what to do with them. After trying to leave them on the doorstep of the zoo's head keeper, they were abandoned behind a railing in some snow and both died from exposure to freezing temperatures (Anonymous, 1939a, b). In 1960, a ca. 36 kg alligator was stolen from the Grant Park Zoo (now Zoo Atlanta; US) by a group of teenagers and then released in the swimming pool of a nearby hotel. As part of their sentence, the offenders were forced to work for several days at the zoo (McCartney, 1960). A "milk white" *A. mississippiensis* (possibly leucistic; Mendyk et al., in prep) was stolen from a small menagerie at Pacific Park in Long Beach, California (US) in 1907; the theft occurred on the same morning that Ringling Brothers Circus offered to purchase the specimen for a large sum of money (Anonymous, 1907). In Brazil, seven albino alligators, then worth an estimated $68,000 (USD), were stolen from the Federal University of Mato Grosso Zoo in 2008 (Duffy, 2008). In Australia, *A. mississippiensis* have been stolen from the the Hunter Valley Zoo (Anonymous, 2012) and the Australian Reptile Park (Anonymous, 2013d).

Chelonians

Chelonians have also been popular targets for theft in zoos (Tab. 4). At a small menagerie exhibition referred to as the "zoo" on Michigan Avenue in Chicago (US) in 1897, a two meter-long, 225 kg sea turtle (likely a leatherback, *Dermochelys coriacea*) that was eventually destined for the Field Museum mysteriously disappeared from its exhibit overnight and was never recovered. Some suspected that the animal had been sold to local soup houses or comb factories (Anonymous, 1897a, b).

At the London Zoo, a juvenile "one-bearded grieved terrapin" (*Podocnemis unifilis*) collected from the Upper Amazon was stolen from the reptile house in 1924; its terrarium's window had been smashed out (Anonymous, 1924). In 1999, two Egyptian tortoises (*Testudo kleinmanni*) – the first specimens of the species to be hatched at the Bronx Zoo in 1996 as part of a conservation breeding program – were stolen from the zoo's reptile house when thieves removed the glass from the top of its display case (Cooper, 1999). The specimens were safely returned to the zoo a few days later, after a man phoned the police alerting them that he unwittingly purchased the

Tab. 4: Summary of chelonian thefts from zoological parks, primarily in English-speaking countries.

Institution	Country	Year	Species	Reference
Michigan Avenue Menagerie, Chicago	US	1897	*Dermochelys coriacea*	Anonymous, 1897a, b
London Zoological Gardens (London Zoo)	UK	1924	*Podocnemis unifilis*	Anonymous, 1924
Philadelphia Zoo	US	1962	*Pseudemys rubriventris*	Anonymous, 1962d
Toronto Zoo	CA	1990	*Stigmochelys pardalis*	Anonymous, 1990a
Ampijoroa Chelonian Captive Breeding Center	MD	1996	*Astrochelys yniphora*	Smith, 2011
New York Zoological Park (Bronx Zoo)	US	1999	*Testudo kleinmanni*	Cooper, 1999
Southport Zoo	UK	2002	tortoise species not identified	Anonymous, 2002
Perth Zoo	AU	2011, 2016	*Astrochelys radiata*	Anonymous, 2018b
Shoalhaven Zoo	AU	2014	*Stigmochelys pardalis*	Anonymous, 2014
Riverview Park and Zoo	CA	2017	*Terrapene carolina*	Anonymous, 2017a
Santa Fe College Teaching Zoo	US	2018	*Terrapene carolina bauri, Gopherus polyphemus*	Rodriguez, 2018
Buffalo Zoo	US	2020	*Chelonoidis carbonaria*	Culver, 2020

stolen tortoises from two young men he met in a park (Williams, 1999). A pair of small tortoises (species not identified) was stolen from the Southport Zoo (UK) in 2002; soon after their taking, the animals were returned to the zoo via a taxi that the thief paid for, along with a hand-written apology letter (Anonymous, 2002).

At the Philadelphia Zoo (US) in 1962, a teenager plucked a 20 cm long red-bellied turtle (*Pseudemys rubriventris*) from the zoo's open turtle pit. He later appeared at the zoo's security gate claiming that he wanted to give it to the zoo, but then used the turtle to bludgeon the 79-year-old security guard, knocking him unconscious before robbing him of $100 (Anonymous, 1962d).

Thieves extracted two box turtles (*Terrapene carolina*) from an aviary at the Riverview Park and Zoo (CA) by cutting through the aviary's wire mesh; both animals were returned to the zoo less than a day later (Anonymous, 2017a). Most recently, a red-footed tortoise (*Chelonoidis carbonaria*) was stolen from the Buffalo Zoo's (US) rainforest exhibit while it was closed during the COVID-19 pandemic; the perpetrator also assaulted a security guard before leaving with the tortoise (Culver, 2020).

In 1996, more than 70 plowshare tortoises (*Astrochelys yniphora*), reputed to be the rarest tortoise in the world, were stolen from an ex situ breeding facility managed by the Jersey Wildlife Preservation Trust in Ampijoroa, Madagascar, by cutting the surrounding fence to their pens (Smith, 2011). Thirty five of the juveniles taken were recovered by authorities in the Netherlands later that year, with two more individuals recovered in the United States the following year (Smith, 2011).

With no indigenous tortoises and the private keeping of exotic herpetofauna prohibited throughout the country, the only tortoises legally held in Australian collections are maintained in zoological parks. Even with no easy outlet for thieves to offload stolen tortoises, several have been taken from Australian zoos in just the last decade. In 2014, eight leopard tortoises (*Stigmochelys pardalis*) were stolen from the Shoalhaven Zoo, despite all being microchipped and having numbers engraved on their shells (Anonymous, 2014). Two radiated tortoises (*Astrochelys radiata*) were stolen from the Perth Zoo over the span of several months in 2011; a third individual was taken from the zoo in 2016, but was returned to police just days after its theft. The other two individuals were eventually recovered in 2018 through rather unusual circumstances. One was found by police in the backyard of a residence of a man that had reported a burglary; the second tortoise, which had been taken from the backyard, was recovered at the home of a 35-year-old woman who was subsequently arrested for trespassing and theft of the already stolen tortoise. The man in original possession of the tortoises was also charged with several counts of possession of stolen property (Anonymous, 2018b).

Amphibians

Amphibians appear to be targeted less by thieves than other groups of herpetofauana, but some examples do exist, particularly rare species and unique specimens. For example, “Blue Moon”, a rare blue frog believed to be exhibiting a genetic aberration (possibly an axanthic American bullfrog, *Lithobates catesbiana*), was stolen from the Philadelphia Zoo in 1969 (Anonymous, 1969b). Two Japanese giant salamanders (*Andrias japonica*) valued at $40,000 80,000 (USD) were stolen from two Tokyo zoos in 1977; local searches of pet stores and food markets failed to turn up either specimen (Anonymous, 1977). Sixteen Chinese giant salamanders (*A. davidianus*) were taken from a Chinese zoo in 1998 and later recovered by police when they apprehended a gang that was attempting to sell them to local restaurants (Anonymous, 1998). Although not a zoological park, but still a fitting example illustrating the demand for rare and threatened amphibians, 253 Texas blind salamanders (*Eurycea rathbuni*) and 110 San Marcos salamanders (*E. nana*) – part of ex situ assurance colonies for the critically endangered species – went missing from the United States Fish and Wildlife Services’ San Marcos Aquatic Resources Center in 2016 (Hooks, 2017). An initial reward of $15,000 US was later increased to $20,000 for anyone with information about the theft (Anonymous, 2017b); as far as it can be determined, none of the missing animals were ever recovered.

Securing zoological collections

By now it should be apparent that there are many ways in which thieves have targeted, gained access to and successfully stolen reptiles and amphibians from zoological parks and related facilities over the past 120+ years. Many of these incidents may have been preventable with more stringent security measures in place, whereas others illustrate extreme circumstances that would not normally have registered on a zoo’s list of potential vulnerabilities. While zoos today are more prepared and less vulnerable than in years’ past, these compiled cases should serve as cautionary tales and perhaps an impetus for zoos and related institutions to periodically review, reevaluate and upgrade their current security measures to better safeguard their collections.

It is evident that many of the threatened and endangered species of herpetofauna maintained by zoological parks are highly sought after by private collectors, commercial dealers and black market traders and can command substantial dollar amounts through the illicit pet trade. Given the importance that many species and individuals in zoo collections play in conservation programs such as Species Survival Plans (SSPs) in AZA-accredited institutions in North America, EAZA Ex Situ Programs (EEPs) in EAZA-accredited institutions in Europe and Australasian Species Management Programs (ASMPs) in ZAA-accredited institutions in Australia and New Zealand, as well as various cooperative head-starting and repatriation programs, zoos cannot afford to lose any animals to theft. The genetic diversity that individuals in these populations contribute to conservation programs is irreplaceable and the loss of just a single individual could be devastating to these efforts. For other species and individuals that may not be prioritized for conservation, thefts can represent substantial losses of monetary investments, staff time and other resources, as well as impact ongoing biological studies and additional in-house activities.

Discouraging thefts and identifying stolen individuals

Beyond increasing physical security measures on zoo grounds and improving the ways in which species are housed and displayed (see below), it might befit zoos to take more proactive measures to discourage thefts from their collections through public outreach and transparency about common zoo management practices. For example, it may not be common knowledge or understood by members of the general public (including potential thieves) that most animals maintained in zoos today, even diminutive reptiles and amphibians, are individually implanted with Passive Integrated Transponder (PIT) tags, which assign a specific electronic serial number to an individual. With an implanted transponder, individual animals can easily be scanned and quickly traced back to a specific collection. For someone attempting to sell or offload stolen transpondered animals, PIT tags could be their undoing. Additionally, because PIT tags are typically embedded intramuscularly, their physical excision would be very difficult, if not impossible without causing significant harm and physical disfigurement to an animal. Publicizing this common identification practice to zoo visitors and followers on social media and in public educational outreach could serve as an effective method to de-incentivize theft before attempts are made.

Physically marking animals with conspicuous identifiers can have a similar discouraging effect. Although perhaps not as extreme as the engraved scarification employed to mark stolen ploughshare tortoises (*Astrochelys yniphora*) that were to be returned to Madagascar (see Smith, 2011), more subtle permanent markings including shell notching and engraving in chelonians (Plummer & Ferner, 2012), ventral scale clipping or marking in snakes (FitzSimons, 1925a; Brown & Parker, 1976), fluorescent tattoos (Petit et al., 2012) and visible implant elastomers (VIEs) in smaller lizards and amphibians (Nauwelaerts et al., 2000; Penney et al., 2001) could be highly effective. With visibly discernible markings that can be traced back to a specific individual in a specific zoological collection, it may be difficult for thieves to sell or offload stolen animals.

PIT-tagging and physically marking animals also provide ways of identifying stolen individuals should they eventually be recovered or turn up offered for sale. Maintaining detailed records of these identifiers can be crucial for establishing provenance (Mendyk & Block, in press) and for legal and forensic investigations of stolen animals (Cooper et al., 2018). As highlighted above, FitzSimons' (1925a) early experiment with ventral scale clippings proved to be a successful example of how individual markings can be used to identify and recover stolen specimens. In addition to human-made physical markings, detailed, accurate and regularly updated descriptive records and photographs of naturally-occurring identifiers such as unique body coloration, patterning and markings, scars, meristic irregularities and morphological asymmetries can further aid in the identification and recovery of stolen animals.

Increasing security

Security measures in zoological parks can take on many physical and electronic forms. Since many zoos are located in or adjacent to public parks that can attract unwelcomed attention and trespassers especially at night, regular security patrols of zoo grounds are important for deterring illicit activities. Considering the frequency at which zoo reptile house break-ins and thefts have occurred at night, nighttime patrols should regularly check the perimeters and access points to these buildings as well as outdoor exhibits and other areas used to house collection animals. To ensure that certain areas are being checked regularly, many zoo security teams now employ security iButtons which record and log when certain sites and checkpoints are visited during nighttime patrols.

With security alarm and video surveillance systems becoming more sophisticated, accessible and affordable in recent years, automated security systems have become a valuable tool for safeguarding zoo collections. Camera systems can be inconspicuous or cryptically disguised and employed at more vulnerable locations or exhibits most likely to be targeted, access doors, windows, rooftops and other potential points of ingress. Security alarm systems featuring sensors on all doors and windows as well as laser and infrared motion-tracking sensors are now frequently employed in zoo reptile houses and have proven to be effective theft deterrents, but only when they are used correctly. For example, although not publicized, in one particular incident that resulted in the loss of a rare and valuable specimen from a zoo reptile house, the theft could easily have been prevented had the department's managers been arming the security alarm system at night. Apparently they fell into the habit of not arming the system because they did not wish to wait around for the 60 second arming delay before leaving the building for the day!

Since many break-ins have involved the smashing of exterior windows or prying open of building doors and skylights, some added security and reinforcement to these areas may be useful. This may include upgrades to heavier-duty metal doors and framing with stronger reinforced locks and laminated glass windows (or even wire-infused glass). Preventing accessibility to rooftop areas may also be important if there are skylights, windows, doors, ductwork and other potential ingress points located in these areas. Keeping the exteriors of buildings clear of ladders, tools, instruments, debris and other objects that can be used to gain access to restricted areas is also important.

Doors leading to interior holding rooms and service corridors within the building should also feature heavy-duty locks and sturdy frames. Since many animals have been stolen from behind-the-scenes areas of reptile houses, enclosures in these areas can also benefit from secure individual locks – regardless of the species. Such second containment in off-exhibit areas offers additional security should such an area be breached.

Staff turnover is a reality faced by all zoos. Although costly, the departure of a staff member (as well as any interns or volunteers given similar access) may necessitate the changing of building locks and security system codes, since some break-ins and thefts have either been, or were suspected of being inside jobs perpetrated or facilitated by former staff and volunteers. Some zoos have switched to programmable keyless card entries for their buildings, thereby eliminating the need for costly rekeying of locks and allowing for strict control of who has access to buildings and other restricted areas. Careful background checks and screenings of prospective staff members, interns and particularly volunteers can also help prevent potential issues from arising from questionable individuals with ties to the commercial or illicit trade that may have ulterior motives.

Improving exhibit designs

Sound exhibit design and construction play a major role in reducing an institution's susceptibility to theft. Many of the above-mentioned incidents have involved breaking out exhibit windows to access animals, highlighting the importance of the type of glass used for exhibit windows and its thickness relative to the exhibit's overall dimensions. While simple plate glass was all that was available in the early days of Ditmars and his contemporaries, which could easily be shattered and busted out, today there are better, more secure alternatives for use in zoos. Laminated glass, which is comprised of two or more glass panes adhered together with a transparent vinyl sheet sandwiched between the layers, offers considerable advantages over traditional plate glass. In addition to its increased tensile strength, when cracked, laminated windows are held together and kept in place by the internal laminate sheeting, making it very difficult to fully break out to access an exhibit. Tempered glass, which is specially heat-treated to shatter into tiny fragments when compromised and often used in automobile passenger windows, should be avoided, even if laminated for added strength and integrity. When used in greater thicknesses, acrylic can also offer greater strength and protection over traditional plate glass, but is also easily-scratched, requiring regular maintenance and repair.

In addition to laminated glass, double-paned viewing windows are occasionally utilized in zoos as an added security measure. Here, a laminated glass window is permanently affixed in place on the public viewing side of an exhibit. On the other side, a movable glass-fronted enclosure – whether on casters (Fig. 3), a lazy Susan (Fig. 4) or on tracks suspended from the ceiling is pressed up against the public viewing window, creating a double window barrier that would be very difficult to break through. In some regulatory jurisdictions in the United States such as the state of Florida, zoos and related facilities are now required to utilize double-paned windows as a safety measure when publicly displaying venomous species in certain situations (Florida Fish and Wildlife Conservation Commission, 2019).

Some zoos with limited off-exhibit space in their reptile and amphibian buildings employ front-opening exhibits as a space-saving measure, where the public viewing windows double as the exhibits' main access doors (Mendyk, 2015). Such a design may invite visitors to tamper with exhibit doors and locks, posing potential security and public safety risks and damage to locking mechanisms. Facilities with front-opening exhibits should ensure that the doors, frames and locks are of solid construction (i.e. heavy-duty metal framing versus wood or plastic) and tamper-proof. I personally recall several wooden-framed front-opening exhibits at the Long Island Reptile Museum that were regularly tampered with by visitors, which resulted in damage to the frames, exhibit breaches and occasionally thefts and/or escapes. Front-access, overlapping sliding glass doors, as seen on many commercially-available reptile enclosures, should be also avoided in public gallery areas; enclosures with large panes of sliding glass are especially vulnerable. For example, an adult *Sanzinia madagascariensis* was stolen from the Long Island Reptile Museum by flexing the two large sliding panes of glass (ca. 1.0 x 1.2 m each) just

Fig 4: Examples of double-paned exhibit viewing windows for added security as viewed from behind the scenes service areas; A) exhibit on rolling casters, B) exhibit mounted on swiveling 'lazy Susan'. Fig. 4a courtesy of Emily Fyfe.

enough to pop over the jewelry cabinet-type slide lock that secured the panes, thereby allowing the doors to be slid past one another.

Limiting tours and access to behind-the-scenes areas

Many zoo herpetologists take pride in touring friends, family, colleagues, and special visitors around behind-the-scenes areas of their reptile buildings to showcase unique or favorite specimens in the collection and special breeding and research projects. Some zoos also occasionally host 'open-house' events for their members or offer paid behind-the-scenes tour experiences that grant zoo visitors special access to off-exhibit areas. Although highlighting the important work that goes on behind the scenes in zoo herpetology departments is important for zoo visitors and the general public (see Murphy et al., 2020), zoos should also be cautious with who they grant access to, as such access could invite trouble or provide opportunities for thieves to scope out the locations of rare specimens and potential building vulnerabilities. I am aware of two unpublicized incidents that occurred in the United States and Europe where collection animals were stolen during behind-the-scenes tours of zoo reptile houses, and Murphy (2015) recalled the theft of a rare snake from a behind the scenes area of the Dallas Zoo reptile house by a professional colleague during an open-house wine and cheese event held in conjunction with an academic conference. Such behind-the-scenes access may be best limited to small numbers of individuals kept under watchful supervision.

Concluding remarks

With the many other pressing challenges associated with managing herpetological collections and departmental operations in zoological parks, guarding against animal thefts may not always be at the forefront of most zoo herpetologists' or administrators' minds. Nevertheless, as history has shown, theft has been a persistent threat to herpetological collections that should be taken seriously. It is hoped that this review of cases and discussion will inspire institutions to take additional steps towards safeguarding their collections.

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Zusammenfassung

Eine der Hauptaufgaben der Zoologischen Gärten besteht darin, die Tiere in ihrem Bestand vor einer Vielzahl von Gefahren und Bedrohungen zu schützen. In vielen Zoos und zugehörigen Einrichtungen kam es im letzten Jahrhundert zu Tierdiebstählen, wobei Reptilien und Amphibien am stärksten betroffen waren. Dieser Artikel befasst sich mit der allgemeinen Entwicklung von Reptilien- und Amphibiendiebstählen aus Zoos sowie ähnlichen Einrichtungen. Er gibt einen historischen Überblick über außergewöhnliche Diebstähle aus diesen Einrichtungen, die bis ins späte 19. Jahrhundert zurückreichen. Ein besonderer Schwerpunkt liegt dabei auf einigen sehr dreisten und seltsameren Vorfällen, die sich vor allem in englischsprachigen Ländern ereigneten. Ausgehend von diesen historischen Berichten schließe ich mit Ausführungen darüber, wie Zoologische Gärten ihren herpetologischen Bestand besser präsentieren und vor Diebstahl schützen können.

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Zool. Garten N.F. 88 (2020) 113-122

DER ZOOLOGISCHE GARTEN

Die korrekte Wortwahl in der Tiergartenbiologie

Correct wording in zoo biology

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Zusammenfassung

Es werden deutsche Wörter anstelle von Anglizismen in der Tiergartenbiologie vorgeschlagen und Alternativen für unglückliche tiergartenbiologische Begriffe aufgezeigt. Neue deutsche Tiernamen werden kommentiert.

Schlüsselwörter: Tiergartenbiologie; Anglizismen; unglückliche Begriffe; deutsche Tiernamen.

Einleitung

Schon mein Vorvorgänger als Frankfurter Zoodirektor Bernhard Grzimek (1971) legte großen Wert auf eine korrekte deutsche Sprache unter Vermeidung von Anglizismen. In diesem Zusammenhang sei Poley (2003) zitiert: „Überflüssig aber sind Fremdwörter, die nur wenige Fachleute verstehen oder die nur dazu dienen, Effekte zu erhaschen und Modernität vorzugaukeln.“ Lebendige Sprache verändert sich im Laufe der Zeit. Der Begründer der wissenschaftlichen Tiergartenbiologie, Heini Hediger (1942), brauchte in seinem weiterhin gültigen Standardwerk Ausdrücke wie „Käfig“, „Gefangenschaft“, „Ausbrecher“ und „Ausreißer“ – alles Begriffe, die er selber heute wohl nicht mehr verwenden würde. Wichtig ist aber vor allen Dingen, dass neu eingeführte Begriffe präzise das beschreiben, was ihnen entspricht und dass sie besser und trefflicher sind als herkömmliche Begriffe. Inzwischen haben sich nicht nur einige Anglizismen in unsere Sprache eingeschlichen, sondern es werden leider auch immer wieder einmal unglückliche Begriffe verwendet. Poley (1983; 2003) hat sich auch damit eingehend befasst, unter anderem mit dem prägnanten Satz „...die deutsche Wissenschaftssprache braucht um ihrer Existenz und ihres Niveaus willen ein Höchstmaß an Ausdrucksgenauigkeit und Differenzierungsvermögen.“

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Ergebnisse und Diskussion

Behavioural enrichment ist ein unnötiger Anglizismus: Mit Verhaltensanreicherung oder Lebensraumbereicherung stehen gleich zwei aussagekräftige deutsche Ausdrücke zur Verfügung. Hediger (1942) erwähnt schon den Mangel an Beschäftigung und deren Behebung.

Weitere Anglizismen: Das Tiertraining ist Dressur, Target ist die Zielscheibe (Betteridge, 1974), Show ganz einfach Schau, Keepers Talk ist ein Tierbetreuer-Gespräch und Masterplan eine Gesamtplanung. Die Anglizismen sind natürlich nicht auf die Tiergartenbiologie beschränkt, sondern wir sprechen fast täglich vom Event anstatt Veranstaltung, vom Meeting anstatt Zusammenkunft oder Treffen und vom Management anstatt Behandlung (Betteridge, 1974). Als wir 1985 die Europäischen Erhaltungszucht-Programme (EEP) gründeten (Schmidt, 1987), waren Deutsch und Englisch gleichberechtigte Sprachen; erst mit der Gründung der European Association of Zoos and Aquariums (EAZA) wurde Englisch die einzige offizielle Sprache. Das seither von der EAZA durchgeführte „Screening“ von Zoos entspricht nicht der offiziellen Übersetzung Abschirmung, Verschleierung (Betteridge, 1974), sondern kann eher mit Überprüfung oder Kontrolle übersetzt werden.

Gefährdung: Die klaren englischen Begriffe „vulnerable“, „endangered“, „critically endangered“ und „extinct in the wild“ (IUCN, 2020) werden teilweise auch in Deutsch verwendet oder unklar übersetzt. Auch die offiziellen deutschen Übersetzungen „verletzlich“ für „vulnerable“, „vom Aussterben bedroht“ für „critically endangered“ und „in der Natur ausgestorben“ für „extinct in the wild“ sind nicht sehr gut. Die nächstliegenden Übersetzungen dafür sind „gefährdet“, „stark gefährdet“, „von der Ausrottung bedroht“ (nicht „vom Aussterben bedroht“) und „in der Natur ausgerottet“ (nicht ausgestorben).

Aussterben – Ausrottung: Sehr häufig wird zwischen diesen beiden Ausdrücken nicht korrekt unterschieden. Meistens wird Aussterben für Ausrottung (nach Duden online sind Ausmerzung, Vernichtung oder Auslöschen Synonyme, aber nicht Aussterben) verwendet. Auch der große Tiergärtner Dathe (1989) hat die Ausdrücke ungenau verwendet: „Es gibt aber schon eine ganze Anzahl [Tierarten], die durch tiergärtnerische Einrichtungen vor dem Aussterben gerettet werden konnte,...“. Aussterben ist das natürliche biologische Phänomen im Verlaufe von Hunderttausenden bis Millionen Jahren der Evolution – also beispielsweise das Aussterben der Dinosaurier. Was wir heute erleben mit dem Verschwinden von täglich zwischen 24 und 150 Tierarten (Pearce, 2015), ist eine vom Menschen direkt oder indirekt – selbst durch die Klimaerwärmung – verursachte Ausrottung innerhalb kurzer Zeit. Poley (2003) geht genau auf die Unterscheidung der beiden Ausdrücke ein. Besonders unsinnig ist der von Tierrechtlern gebrauchte Ausdruck „lieber in Würde aussterben als in Gefangenschaft überleben“. Wer will schon freiwillig, aber „in Würde“, von dieser Erde verschwinden? Daneben gibt es ethische, ökologische und sogar wirtschaftliche Gründe, die gegen die Ausrottung von Tierarten sprechen.

Washingtoner Artenschutz-Übereinkommen ist in Wirklichkeit kein Artenschutz-Übereinkommen, sondern gemäß genauer Übersetzung von Convention on International Trade in Endangered Species of Fauna and Flora (CITES) das Abkommen über den Internationalen Handel mit gefährdeten Arten von Fauna und Flora.

Gefangenschaft: Wir Tiergärtner (unter anderen Poley, 1983; 2003) wehren uns zu Recht seit Langem gegen die Verwendung dieses Begriffes in Zusammenhang mit gut geführten Zoos. Zur Verfügung stehen stattdessen Begriffe wie „in menschlicher Obhut“, „in Menschenhand“, „in Gehegehaltung“ oder „in Zoohaltung“. Es gibt einen grundsätzlichen Unterschied zwischen der Gefangenschaft eines Menschen und der Zoohaltung eines Wildtiers: Der gefangene Mensch in einem Rechtsstaat ist nach einer Straftat rechtskräftig verurteilt und wird mit Gefängnis bestraft, das heißt in einen suboptimalen, kleinen Raum gesperrt, zumindest früher auch suboptimal ernährt und die meisten Sozialkontakte werden ihm verwehrt. Tiere hinter Gitter erwecken unterschwellig emotional den Eindruck von Gefangenen, was Tierrechtsorganisationen für ihre Zwecke nutzen. In gut geführten Zoos leben Tiere in möglichst gitterlosen und vor allem naturnah gestalteten Anlagen mit den für die Art wichtigen Fixpunkten, die auch dem Psychotop der Art (Hediger, 1961) entsprechen. In Bezug auf Anzahl und Gruppenzusammensetzung werden möglichst natürlich zusammengesetzte und züchtende Gruppen gehalten und es wird optimales Futter angeboten – leider häufig zu üppig und ohne saisonale Schwankungen. Zoogehege werden immer größer mit einer Fläche bis zu 80 Hektar (Schmidt, 1978) und auch Zoos werden immer größer mit dem Spitzenplatz von The Wilds in Cumberland/Ohio (USA) mit einer Fläche von mehr als 36 Quadratkilometern (Brown & Richardson, 2019). Nationalparks werden dagegen manchmal kleiner und werden immer häufiger eingezäunt wie beispielsweise der 100 Quadratkilometer große Nairobi-Nationalpark (Kenia) und viele weitere, vor allem südafrikanische Reservate. Das heißt auch, dass die manchmal in Bezug auf genetische Variabilität zu kleinen Populationen nicht ohne menschliche Eingriffe überleben können. Viele Fische, Amphibien, Reptilien, Vögel und Kleinsäuger in Ökosystemhallen (Burgers Bush in Arnheim, Niederlande, Masoalahalle in Zürich, Schweiz, Gondwanaland in Leipzig) leben demgegenüber mit weniger menschlichen Eingriffen. Zoos und Reservate gleichen sich also immer mehr an. Oft ersuchen Naturschutzorganisationen Zoos, eine Population einer stark gefährdeten oder von der Ausrottung bedrohten Tierart zu übernehmen und eine Erhaltungszucht aufzubauen. Der moderne, wissenschaftlich geleitete Zoo ist also heute Refugium und nicht Gefängnis!

Ausbrechen wird von Poley (1983) richtigerweise als Ausbrechen aus einem Gefängnis abgelehnt. Er schlägt dafür Entweichen oder Entkommen von Zootieren vor. Martel (2003) beschreibt in seinem Erfolgsroman „Schiffbruch mit Tiger“, dass Zootiere auch bei offener Gehegetür in ihrem Gehege bleiben oder dahin zurückkehren – ein Phänomen, das erfahrene Tiergärtner immer wieder erleben, aber kaum je publizieren.

Freiheit: Nur biologisch Unbedarfte schwärmen emotional von der „goldenen Freiheit“ mit Adlern, die am Himmel segeln. Dies ist eine anthropozentrische Wunschvorstellung, die gewisse Menschen auf Tiere projizieren. Im Jahre 2001 wurde mir das weitaus realitätsnähere Bild davon in einer eindrücklichen Tierdemonstration im Alice Springs Desert Park (Australien) vorgeführt: Ein zahmer Keilschwanzadler (*Aquila audax*) schraubte sich hoch hinauf in den Himmel, bis er vom residierenden, wilden Paar Keilschwanzadlern aus dessen Territorium angegriffen und vertrieben wurde. Martel (2003) beschreibt dies sehr schön: „Tiere der Wildnis sind weder in der Zeit noch im Raum frei ...“ Hediger (1942) hat dieses Phänomen als Raum-Zeit-System beschrieben. Hediger (1965) zeigte auch, dass gut eingewöhnte Tiere ihre Anlage als künstliches Territorium akzeptieren, was sich in dessen Markierung und Verteidigung zeigt. Der Zoo Hannover baute 1,95 Meter schmale Trockengräben für verschiedene Antilopenarten (Dittrich & Gleitz, 1967). Obwohl Gazellen über fünf Meter weit springen können, überquerten nur wenige Antilopen ausnahmsweise die schmalen Gräben (Dittrich, 1968). Einen besonders interessanten Fall schildert der Autor: „Das Huftiergehege … wird durch den gleichen Graben von 1,95 m Breite … von der benachbarten Stelzvogelwiese getrennt, die an einer Stelle mit einem beiderseits von dem Graben flankierten Winkel in das Huftiergehe hereinragt. … Als es zwischen zwei hier geborenen, 15 Monate alten Rotstirngazellenböcken (*Gazella rufifrons*) nach Wochen des Animponierens und Androhens zu einer kämpferischen Auseinandersetzung kam, jagte am Ende der Überlegene den Rivalen im Gehege umher. Allmählich wurde der Verfolgte immer näher an den Rand des Geheges gedrängt und raste schließlich direkt auf den in das Gehege ragenden Winkel der Vogelwiese zu. Er sprang mit einem Riesensatz von mehr als 5 m Weite über den ersten Graben, über die letzte Ecke der Vogelwiese, ohne dort aufzusetzen, und über den zweiten Graben wieder in das eigene Gehege zurück.“ Besser könnte nicht gezeigt werden, dass der symbolische Graben die akzeptierte Grenze des künstlichen Territoriums ist, das auch bei Aggression nicht verlassen wird. Dies wird bestärkt durch die Beobachtung „Einige Antilopenböcke sind ihnen bekannten Personen gegenüber außerordentlich aggressiv und ernsthaft gefährlich. … Sie greifen sofort an, setzen diese nur ihren Fuß durch die Gehegetür … . Niemals sprangen sie aber über den Graben, wenn diese Personen, vor allem ihre Tierpfleger, sich unmittelbar davor aufhalten." (Dittrich, 1968) Auch diese Beobachtung zeigt eindrücklich, dass die Antilopenböcke ihr künstliches Territorium gegen ihre vertierlichten Rivalen verteidigen. Ein artgerechtes Gehege, also ein künstliches Territorium, kann viel kleiner sein als das Territorium im Freiland, weil der Tierbetreuer regelmäßig Nahrung bringt. Im Freiland müssen im Territorium genügend „überschüssige" Beutetiere für Raubtiere vorhanden sein, respektive genügend Pflanzen/Früchte über das ganze Jahr zur Verfügung stehen. Ganz wichtig für die Tiergartenbiologie ist Hedigers (1942) inzwischen bei vielen nachkommenden Kollegen vergessen gegangene Erkenntnis, dass in der Zoohaltung Raumqualität wichtiger ist als Raumquantität. Anstatt Freiheit sollten wir Wildnis, Natur oder Freiland verwenden, Begriffe, die auch Martel (2003) benutzt.

Freie Wildbahn: Viele, auch bedeutende Tiergartenbiologen verwenden anstatt Freiheit den Begriff freie Wildbahn. Dieser letztere Begriff hat allerdings ursprünglich eine andere Bedeutung: Wildbahn ist ein jagdlicher Terminus, freie Wildbahn ist eine Schneise im Wald (Grimm & Grimm, 1960). Im Barock haben Fürsten Schneisen in den Wald schlagen lassen, um bei der Jagd freie Sicht zum Schuss auf das Wild zu haben (Abb. 1). Also verbleiben Wildnis, Natur oder Freiland als geeignete Begriffe.

Habitat als lateinischer Ausdruck für Lebensraum wird heute – wie im Englischen – meistens gebraucht. Früher wurde der griechische Ausdruck Biotop (Hediger, 1942) bevorzugt. Mit Lebensraum steht auch hier ein deutscher Ausdruck zur Verfügung.

Abb. 1: Freie Wildbahn im Schlossgarten Schwetzingen: Eine von Menschen geschlagene Schneise im Wald zur besseren Sicht auf Tiere bei der Jagd.

Moderne Tieranlage ist ein unsinniger, menschlicher Begriff. Ein Musterbeispiel einer „modernen" Anlage ist sicher die 1934 gebaute Pinguinanlage von Architekt Berthold Lubetkin im Zoo London (Großbritannien) (Abb. 2), in der bis 2004 Pinguine gehalten wurden, die aber auch sehr schnell veraltet ist. Die Anlage steht unter Denkmalschutz und wurde typischerweise von Architekturseite gepriesen (Vevers, 1976). Lubetkin beschreibt die beiden Methoden „… to reproduce the natural habitat of each animal; the second approach, which, for want of a better word, we may call the geometric, consists of designing architectural settings for the animals in such a way as to present them dramatically to the public, in an atmosphere comparable to that of a circus" (Allen, 2017). Tiere brauchen keine modernen Anlagen, sondern Anlagen, die möglichst artgerecht und naturnah auch im Sinne eines Psychotops (Hediger, 1961) sind – also auch die psychologischen Bedürfnisse der Bewohner abdecken. Hier muss betont werden, dass noch so natürlich gestaltete Felsen nicht dem Psychotop von beispielsweise Regenwaldbewohnern entsprechen. Schon das Berliner Aquarium unter den Linden war im 19. Jahrhundert als Felsgrotte gestaltet (Klös, 1988). Je naturnaher eine Tieranlage ist, desto weniger veraltet sie. Nachkommende Tiergärtner meinen fälschlicherweise oft, dass erst die jetzige Generation entsprechende Anlagen baut. Jede Generation strebte zu ihrer Zeit anhand der dannzumal vorliegenden Daten und Möglichkeiten das Beste an. Aquarien und Terrarien sind seit vielen Jahrzehnten naturnah gestaltet worden (außer oft die abiotischen Faktoren Licht, Temperatur und Luftfeuchtigkeit), gefolgt von Volieren. Viele Säugetiere allerdings, vor allem größere, erhalten erst in den letzten Jahrzehnten naturnah gestaltete Anlagen.

Zoo- und Aquarium-Industrie wird vor allem in Nordamerika verwendet. Der Terminus ist gefährlich, denn eine Industrie ist grundsätzlich gewinnorientiert. Poley (2003) schreibt dazu: „Mit einer kaufmännisch oder politisch geprägten Sprache geht ja auch eine andere Geisteshaltung einher,...". Wissenschaftlich geführte Zoos sind kulturelle Institutionen mit Aufgaben

Abb. 2: Eine „moderne" Tieranlage im Zoo London, die 1934 von Architekt Berthold Lubetkin gebaute Pinguinanlage, in der bis 2004 Pinguine lebten.

in Bildung, Forschung, Arten- und Naturschutz. Die meisten guten Zoos sind gemeinnützig. Beides ist erforderlich für den Import von CITES-I-Wildfängen. Ein besserer Ausdruck ist Gemeinschaft der Zoos und Aquarien.

Einweihung und Taufe sind religiöse Begriffe, die in Zoos meistens fehl am Platz sind. Im Natur- und Tierpark Goldau (Schweiz) weihte zwar ein Pfarrer die neue Fischotteranlage und das neue Mehrzweckgebäude (Abb. 3) ein. Andernorts sollte man besser die korrekten neutralen Begriffe Eröffnung und Namensgebung verwenden.

Abb. 3: Der katholische Pfarrer weiht das Mehrzweckgebäude im Natur- und Tierpark Goldau ein.

Tierpfleger oder Tierwärter haben sich seit Langem eingebürgert. Poley (1983) plädiert für den Gebrauch von Tierpfleger anstatt Tierwärter. Leider erinnert Tierpfleger an einen Krankenpfleger und Tierwärter an einen Gefängniswärter. Zum Glück sind unsere Zootiere meistens nicht krank und vor allem keine Gefangene, so dass sich Tierbetreuer anbieten würde. Die offizielle Bezeichnung des deutschen Lehrberufes lautet „Tierpfleger – Fachrichtung Zoo". In Aquarien und Terrarien nennt man die Betreuer schon lange Aquarianer und Terrarianer (pers. Mitt. F. Schmidt).

Spaß an der Arbeit hat sich zu meinem Bedauern nicht nur im Zoobereich, sondern quer durch alle Berufe als Zeichen der allgemeinen Spaßkultur festgesetzt. Ich habe nichts gegen Spaß, aber Arbeit sollte mehr als das, nämlich Freude und Befriedigung, bereiten.

Rindenmulch und Holzhäcksel/Holzschnipsel werden häufig verwechselt. Der Rindenmulch stammt aus Baumrinde und kompostiert langsam zu einem humusartigen Bodengrund, der sich seit den 90er Jahren des letzten Jahrhunderts zuerst im Walter-Zoo in

Gossau (Schweiz) für Schimpansen, seit 1994 im Zoo Zürich (Schweiz) für Gorillas und in immer mehr Zoos bewährt. Wenn die Schicht mindestens 20 bis 40 Zentimeter dick ist und feucht gehalten wird, muss das Substrat nur etwa alle 20 Jahre gesamthaft ausgewechselt werden. Holzschnipsel dagegen sind gehäckseltes Holz, das zur Kompostierung viel länger braucht.

Geschlechtsbestimmung wird vor allem von Veterinären immer wieder falsch benutzt. Bei Säugetieren und Vögeln wird das Geschlecht durch das Geschlechtschromosom, bei vielen Reptilien durch die Inkubationstemperatur bestimmt. Was wir Tiergärtner machen, ist vielmehr eine Geschlechtsdiagnose, Geschlechtserkennung oder eine Feststellung des Geschlechts.

Haustier, Heimtier und Nutztier: Auch diese drei Ausdrücke werden immer wieder falsch angewendet. Ein Haustier – als Gegensatz zum Wildtier – ist ein Vertreter einer domestizierten Rasse. Domestikation ist eine genetische Zuchtwahl durch den Menschen, in der Regel auf ein bestimmtes Zuchtziel hin. So wurde das Rind auf Fleisch- und Milchproduktion, das Schaf auf Wollproduktion, der Hund je nach Rasse zum Beispiel als Jagdhelfer oder Herdenhütehund gezüchtet.

Ein Heimtier wird vom Menschen zu seiner Freude im Haus oder Garten gehalten; es kann sowohl ein Haus- wie ein Wildtier sein. Als Beispiele seien nur das Hausmeerschweinchen oder die Griechische Landschildkröte (*Testudo hermanni*) genannt.

Das Nutztier wird vom Menschen in der Regel zur Gewinnerzielung gehalten. Beispiele sind die Landwirtschaftsrassen von Pferd, Schwein, Rind, Ziege, Schaf und Huhn. Aber auch Pelztiere wie Marderhund (*Nyctereutes procyonoides*), Nerz (*Mustela lutreola*) oder Chinchilla (*Chinchilla lanigera*) gehören dazu. Letztere waren ursprünglich Wildtiere, die aber einem Domestikationsprozess – beispielsweise auf Farbmutanten – ausgesetzt sind.

Domestizierte Elefanten: Leider gibt es selbst Tiergärtner, die nicht wissen, dass weder der Afrikanische Elefant (*Loxodonta africana*) noch der Asiatische Elefant (*Elephas maximus*) je domestiziert wurden. Auch der Asiatische Elefant ist nie domestiziert, sondern gezähmt, in seiner Heimat zum Arbeitstier oder im Zirkus auf Kunststücke dressiert und damit in diesen Fällen als Nutztier eingesetzt worden. Ein Zoologe sollte die Unterschiede zwischen Domestikation, Zähmung und Dressur kennen.

Tiernamen

Raubkatze ist eigentlich ein Pleonasmus, denn jede Katze ist ein Raubtier. Man kann systematisch zwischen Schleich-, Klein-, Groß- und Hauskatze sowie wilden Katzenarten unterscheiden.

Afrikanischer Wildhund wurde von Grzimek 1969 eingeführt. Leider ist dies ein ungenauer neuer Name, da es exakt ein Dutzend Arten afrikanischer Wildhunde gibt. Diese sind Hyänenhund (*Lycaon pictus*), Streifenschakal (*Canis adustus*), Goldschakal (*Canis aureus*), Schabrackenschakal (*Canis mesomelas*), Äthiopischer Fuchs oder Semienwolf (*Canis simensis*), Rotfuchs (*Vulpes vulpes*), Canafuchs (*Vulpes cana*), Kap- oder Kamafuchs (*Vulpes chama*), Blassfuchs (*Vulpes pallida*), Sand- oder Rüppellfuchs (*Vulpes rueppelli*), Fennek (*Fennecus zerda*) und Löffelhund (*Otocyon megalotis*) (Grzimek, 1989; Kingdon, 1997). Bei der Erwähnung des neuen Namens müsste man deshalb immer nachfragen, welcher afrikanische Wildhund gemeint sei. Noch 1959 brauchten Grzimek & Grzimek den Namen Hyänenhund. Der Kopf des Hyänenhundes gleicht tatsächlich ein wenig einem Hyänenkopf, wie auch Grzimek (1972) erwähnt. Weiter schreibt Grzimek (1972): „Wir wollen diese Bezeichnung [Hyänenhund] aber vermeiden, da es sich um einen echten Wildhund handelt, der verwandtschaftlich mit Hyänen nichts zu tun hat.“ Dieses Argument ist aber nicht relevant. Aus dieser

Logik heraus müssten wir viele weitere Tiernamen ändern. Schnabeligel, Beutelratte, Beutelmaus, Beutelwolf, Rattenkänguru, Hasenkänguru, Antilopenkänguru, Fledermaus, Flughund, Katzenmaki, Wieselmaki, Löwenäffchen, Bärenpavian, Bärenmakak, Ameisenbär, Meerschweinchen, Wasserschwein, Marderhund, Tigeriltis, Erdwolf, Zebramanguste, Fuchsmanguste, Seebär, Seelöwe, Walross, See-Elefant, Seeleopard, Seehund, Schweinswal, Erdferkel, Seekuh, Flusspferd, Hirscheber, Schweinshirsch, Pferdehirsch, Zebraducker, Steinböckchen, Kuhantilope, Pferdeantilope, Rehantilope, Hirschziegenantilope und Giraffengazelle sind nur einige der Säugetierarten, die mit dem gleichen Argument umbenannt werden müssten – und das Chaos wäre komplett. Ich verzichte aus Platzgründen auf Beispiele aus anderen Tiergruppen wie bei den Fischen von Adlerrochen über Seepferdchen bis Zebrabuntbarsch. Schon 1973 argumentierte Dathe genau gleich: „Die mancherseits gebrauchte Artbezeichnung „Afrikanischer Wildhund" möchten wir nicht verwenden, einerseits deswegen, weil es in Afrika eine Vielzahl von Wildhundarten gibt, und zum anderen, weil der Kopf des Hyänenhundes in der Tat im Habitus sehr dem Kopf einer Fleckenhyäne, *Crocuta crocuta* (Erxl.), ähnelt und der Hyänenhund somit trefflich charakterisiert wird. Man wird wegen des Namens ebenso wenig auf eine Verwandtschaft zu den Hyänen schließen, wie man es ja auch nicht etwa bei der Zebramanguste, *Mungos mungo* (Gm.), oder beim Affenadler, *Pithecophaga jefferyi* Ogilvie-Grant, tut." Im Englischen heißt der Hyänenhund Cape Hunting Dog. Dieser Name wird immer häufiger durch den treffenden Namen Painted Dog ersetzt. Im Deutschen gibt es inzwischen auch Bunthund, Picassohund (Brandstätter, 2011); als direkte Übersetzung aus dem Kiswahili (Mbwa mwitu) käme Buschhund in Frage. Leider kam keiner dieser Namen gegen die Autorität von Bernhard Grzimek an, so dass wir am sinnvollsten beim korrekten deutschen Namen Hyänenhund bleiben.

Finkenschnabelstar: Direkt entgegengesetzt zu Grzimeks Intentionen hat der Kölner Zoo (Pagel, 2020) den gut eingeführten Namen Schmalschnabelstar (*Scissirostrum dubium*) nach Hoyo et al. (1992) und Barthel et al. (2020) in Finkenschnabelstar umbenannt. Mit Grzimek (1972) könnte man hier sagen: Der Finkenschnabelstar ist kein Fink. Mit solchen Umbenennungen wird große Verwirrung gestiftet. Treffende neue Tiernamen sind zum Beispiel Graureiher anstatt Fischreiher (*Ardea cinerea*), Schwarzschwan anstatt Trauerschwan (*Cygnus atratus*), Bartgeier anstatt Lämmergeier (*Gypaetus barbatus*) oder Mähnenspringer anstatt Mähnenschaf (*Ammotragus lervia*).

Verdeutschte englische Tiernamen kommen immer wieder bei zoologisch unbedarften Übersetzern vor, wie Tasmanischer Teufel für Beutelteufel (Tasmanian Devil, *Sarcophilus harrisii*) oder Grüne Schildkröte für Suppenschildkröte (Green Turtle, *Chelonia mydas*). Kwet (2020) kreierte für die Suppenschildkröte mit Grüner Meeresschildkröte einen ungeeigneten deutschen Namen. Suppenschildkröten sind wie alle Meerschildkröten grundsätzlich braun gefärbt, aber häufig veralgt: Korrekter wäre demzufolge Begrünte Meeresschildkröte. Kwet (2020) versucht den Namenszusatz „Grüne" zu rechtfertigen mit der grünlichen Färbung des Schildkrötenfetts. Eine direkte Übersetzung kann auch zu einem falschen deutschen Tiernamen führen: Die Sable Antelope ist nicht die Säbelantilope (*Oryx dammah*) aus der Sahara, sondern die süd- und ostafrikanische Rappenantilope (*Hippotragus niger*).

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Widmung

Ich widme diesen Beitrag dem großen Tiergartenbiologen und Zoodirektor i. R. Prof. Dr. Lothar Dittrich, mit dem ich seit Jahrzehnten freundschaftlich verbunden bin.

Summary

A critical review of anglicisms and not acceptable German terms in zoo biology. German names of some animal species have been changed to questionable new names.

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DER ZOOLOGISCHE GARTEN

Keeping and breeding of threatened endemic Malagasy freshwater fishes at Cologne Zoo (Germany): a contribution towards the advancement of a conservation breeding network

Haltung und Nachzucht bedrohter endemischer Süßwasserfische aus Madagaskar im Kölner Zoo: ein Beitrag zur Weiterentwicklung eines Erhaltungszuchtnetzwerks

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Abstract

Madagascar, one of the largest islands worldwide, is a global biodiversity conservation hotspot, characterized by its biota's high degree of endemism. More than two thirds of the 169 Malagasy freshwater fish species that so far have been scientifically named are endemic and many also micro-endemic, i.e. only known from restricted regions or even a single drainage. They probably represent the most threatened group of vertebrates on Madagascar. Habitat conservation measures are urgently required to prevent extinctions from deforestation, overfishing, and exotic species introductions, but for many species *ex situ* captive breeding was already recommended in 2003 as representing the only reliable means to save them from extinction. This article reports on the successful husbandry and breeding of five threatened freshwater fishes from Madagascar at the Aquarium of the Cologne Zoo, Germany: the aplocheilid killifish *Pachypanchax sakaramyi*, the bedotiid rainbowfishes *Bedotia madagascariensis* and *Rheocles vatosoa* (all Endangered), and the rare cichlids *Ptychochromis insolitus* (Critically Endangered) and *P. loisellei* (Endangered). Our report summarizes initial data from our ongoing efforts in

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DNA barcoding and survey of captive stocks of Malagasy freshwater fishes. Because a correct identification is crucial in conservation breeding programs, in particular when repatriation or restocking in the natural habitat is an option, we sequenced a segment of the mitochondrial gene for 16S rRNA from the currently nine endemic Malagasy freshwater fish species held at Cologne Zoo to confirm their identity. We also give recommendations regarding the IUCN Red List of Threatened Species (IUCN 2020) conservation status of the endemic Malagasy freshwater fish species treated in this article together with those ones scientifically named since 2003, which may serve as input for future formal reassessments of these species. For *Pachypanchax sakaramyi*, *Bedotia madagascariensis*, *Rheocles vatosoa*, *Ptychochromis insolitus* and *P. loisellei* we further provide an overview of diagnostic characters, distribution range, population size/threats and conservation status. We also have analyzed the zoo data base ZIMS (Zoological Information Management Software, Species360) in concert with the European database Zootierliste to provide topical information on zoos and institutions holding aforementioned species. *Rheocles vatosoa*, *Ptychochromis insolitus* and *P. loisellei* were sent from Toronto Zoo (Canada) to Cologne Zoo (Germany) in 2019. None of these species was previously represented in any German zoo, and *P. loisellei* was not represented yet in any European institutional collection nor held by private breeders. The transfer of these species from Toronto Zoo thus seeded the husbandry and conservation breeding of these species in Germany and, on behalf of the Madagascar Fauna and Flora Group, kickstarted the establishment of a conservation breeding network for these and other Malagasy freshwater fishes in Europe. With the breeding at Cologne Zoo's Aquarium of the three threatened Malagasy freshwater fish species received from the Toronto Zoo and the subsequent transfer of their progeny to so far nine other zoos, an important step towards optimized conservation breeding and the establishment of a viable network of institutional breeders in Europe has been taken: So far 215 *Ptychochromis insolitus* fry and in addition 90 *P. loisellei* have been distributed from Cologne Zoo to other zoos or aquariums within Europe. At present, also Citizen Conservation programs for endangered Malagasy freshwater fish species are jointly being established, initially in Germany, to extend the conservation breeding network.

Keywords: Atheriniformes, Cichliformes, Cyprinodontiformes, *Bedotia*, *Pachypanchax*, *Ptychochromis*, *Rheocles*, conservation breeding, husbandry network, molecular identification

Introduction

Madagascar, one of the largest islands worldwide, is a global biodiversity conservation hotspot, characterized by its biota's high degree of endemism (Myers et al., 2000; Goodman & Benstead, 2003). Madagascar was isolated from other major landmasses for more than 65 million years, making it a prime model region to explore mechanisms of evolutionary diversification (Vences et al., 2009). This also applies to the organisms dwelling in Madagascar's aquatic habitats (Groombridge & Jenkins, 1998).

The composition and richness of Malagasy freshwater fishes differ in many respects from those of the African mainland, and their origins are disputed. Early researchers characterized this faunal assemblage as depauperate in species (Kiener & Richard-Vindard, 1972), but more recently, Sparks & Stiassny (2003) listed 143 native Malagasy freshwater fish species, and 26 new species have been scientifically named in the 17 years since this assessment. Despite a species richness comparable to other landmasses of similar size (Sparks & Stiassny, 2003), it remains true that the higher-level diversity of these fishes is limited and the majority of species is referrable to three families: Cichlidae (cichlids), Bedotiidae (Madagascar rainbowfishes) and

Aplocheilidae (Old World killifishes). Two of these families contain at least some species tolerant of brackish or salt water, and this is even more true for groups such as gobiids or eleotrids which also have representatives in Malagasy streams and lagoons. In contrast, the rich primary freshwater clades common in Africa are lacking (Briggs, 2003). In the absence of Cenozoic fossils, cladistic placement of the Malagasy clades provides arguments for favoring an ancient, Gondwanan origin (Sparks & Smith, 2005; Chakrabarty et al., 2012) whereas molecular clock analyses, and Bayesian analysis of fossil occurrences, suggest much younger origins of basically all Malagasy lineages and thus favor an origin by Cenozoic overseas dispersal (Vences et al., 2001; Crottini et al., 2012; Near et al., 2012; Friedman et al., 2013; Matschiner et al., 2017).

Independent of the conundrum of the biogeographic origins of these fishes, they are undoubtedly a unique assemblage. Of the 143 species listed by Sparks & Stiassny (2003) all those that complete their entire life cycle in fresh water – over 65% – are endemic and many of them also micro-endemic, viz. only known from restricted regions or even a single drainage. Most importantly, freshwater fishes are probably the most threatened group of vertebrates on Madagascar. According to Benstead et al. (2003), 34% of them were Endangered, 22% Critical, 17% Vulnerable, 5% Near Threatened and 4% already Extinct, using criteria established by the International Union for Conservation of Nature and Natural Resources. Of the 26 species scientifically named since 2003, one is already Extinct, four Critically Endangered, eleven Endangered, one Vulnerable and one Near Threatened (Table 1). The three principal threats to the freshwater biodiversity of Madagascar are deforestation, overfishing, and exotic species introductions (Benstead et al., 2003). Habitat conservation measures are urgently required to prevent extinctions, but for many species, *ex situ* captive breeding at this time represents the only reliable means to save them from extinction (Benstead et al., 2003; Loiselle, 2003).

Being aware of the need for more conservation breeding efforts for Madagascar's threatened freshwater fishes, the Aquarium of Cologne Zoo 15 years ago started implementing a targeted husbandry setup for threatened, poorly known and rarely bred freshwater fish species from the island, including a program of environmental education (Ziegler, 2005). This modest initial effort focused on exhibiting and breeding a scientifically still unnamed Madagascar Rainbow fish, *Bedotia* sp. „Ankavia" (Mailliet, 2005). However, after an initial period of successful reproduction this lineage became extinct at Cologne Zoo because of limited availability of reproducing individuals, viz. fitting sexual partners. In 2007, the focus on threatened Madagascar freshwater fish was reactivated and the endangered aplocheilid killifish *Pachypanchax sakaramyi* added to Cologne Zoo's fish collection. In 2013, another *Bedotia* species was acquired, at the time considered to be the endangered *B. geayi*. However, Loiselle & Rodriguez (2007: 7) critically noted that in 1953 live *Bedotia* collected from the town of Ambila-Lemaitso, located on the shore of Lake Anjanaborona, which lies immediately south of Lake Rasoabe, were shipped to France and then introduced to the aquarium hobby community under the name *Bedotia geayi*, notwithstanding the fact that the type series of *B. geayi* originated from the Mananjary basin, several hundred kilometers to the south of Lake Rasoabe. Based upon this fact as well as significant morphometric and color pattern differences, these authors recognized the two taxa as specifically distinct and suggested that *B. madagascariensis* is the correct name for the species long sold as *B. geayi* in the aquarium trade. In 2018, the first Malagasy cichlid reached Cologne Zoo's Aquarium: the critically endangered pinstripe damba (*Paretroplus menarambo*).

In 2019, Cologne Zoo hosted the annual meeting of the Madagascar Fauna and Flora Group (MFG). As one outcome of the meeting, it was decided to evaluate the perspectives of zoo keeping of threatened Malagasy freshwater fishes and to build and optimize conservation breeding networks for these animals. As a first urgent measure offspring of the two rare cichlids, *Ptychochromis insolitus* (Critically Endangered) and *P. loisellei* (Endangered) and of the poorly known rainbowfish *Rheocles vatosoa* (Endangered) were sent from Toronto Zoo (Canada) to Cologne Zoo (Germany) in 2019. None of these species was previously represented in any German zoo, and *P. loisellei* was not represented yet in any European institutional collection nor held by private breeders. The transfer of these species from Toronto Zoo thus seeded the husbandry and conservation breeding of these species in Germany and, on behalf of the MFG, kickstarted the establishment of a conservation breeding network for these and other Malagasy freshwater fishes in Europe.

The present study reports on the experiences and achievements with keeping and breeding of Malagasy freshwater fishes at Cologne Zoo to date and provides a first overview of and perspectives for the planned conservation breeding network. Our report summarizes initial data from our ongoing, more comprehensive efforts in DNA barcoding and survey of captive stocks of Malagasy freshwater fishes, which we hope will help improving the conservation of these fascinating and highly threatened animals.

Tab. 1: Endemic Malagasy freshwater fish species scientifically named since 2003 and their conservation status based on the IUCN Red List of Threatened Species (IUCN, 2020) (EX = Extinct; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient).

Family	Species	Conservation Status
Anchariidae	*Ancharius griseus* Ng & Sparks, 2005	EN
	Gogo arcuatus Ng & Sparks, 2005	DD
	G. atratus Ng & Sparks, 2005	DD
	G. ornatus Ng & Sparks, 2005	EN
Aplocheilidae	*Pachypanchax arnoulti* Loiselle, 2006	VU
	P. patriciae Loiselle, 2006	EN
	P. sparksorum Loiselle, 2006	EN
	P. varatraza Loiselle, 2006	EN
Bedotiidae	*Bedotia albomarginata* Sparks & Rush, 2005	EN
	B. alveyi Jones, Smith & Sparks, 2010	NT
	B. leucopteron Loiselle & Rodriguez, 2007	EN
Cichlidae	*Paretroplus gymnopreopercularis* Sparks, 2008	CR
	P. lamenabe Sparks, 2008	EN
	P. loisellei Sparks & Schelly, 2011	EN
	Ptychochromis curvidens Stiassny & Sparks, 2006	DD
	P. ernestmagnusi Sparks & Stiassny, 2010	DD
	P. insolitus Stiassny & Sparks, 2006	CR
	P. loisellei Stiassny & Sparks, 2006	EN
	P. mainty Martinez, Arroyave & Sparks, 2015	DD
	P. makira Stiassny & Sparks, 2006	DD
	P. onilahy Stiassny & Sparks, 2006	EX
	Ptychochromoides itasy Sparks, 2004	CR
Clupeidae	*Sauvagella robusta* Stiassny, 2002	EN
Milyeringidae	*Typhleotris mararybe* Sparks & Chakrabarty, 2012	CR
Gobiidae	*Sicyopterus punctissimus* Sparks & Nelson, 2004	DD
	Sicyopus lord Keith, Marquet & Taillebois, 2011	Not yet evaluated

Materials and methods

For the species kept at Cologne Zoo for which novel data are presented herein, we assembled information on the institutions keeping and breeding them globally. For this purpose, we examined the Zoological Information Management Software (ZIMS, Species360), an international record keeping database for zoological institutions (data retrieval carried out from early to mid-2020). Many zoos subscribe to this system and enter their collection data into it, however, as a cautionary note, the completeness of ZIMS data cannot be guaranteed, as some data may be obsolete or have not (yet) been entered, and some zoos do not participate in this system. In addition, we summarized species holdings from further institutions in Germany and Europe using the website "Zootierliste" (http://www.zootierliste.de/), which includes additional data, also from private zoos and animal rescue organizations.

Our ongoing DNA barcoding project on Malagasy freshwater fishes is a continuation of previous efforts on amphibians and reptiles (Vieites et al., 2009; Nagy et al., 2012; Perl et al., 2014), with the goal of providing a molecular means of identifying species based on sequences of the mitochondrial genes for cytochrome oxidase subunit 1 (COI or cox1), the standard DNA barcoding gene for animals, and 16S rRNA (16S). In the present study, we focused on confirming the identification of the different groups held at Cologne Zoo (Tab. 2) based on mitochondrial DNA sequences. We opted to amplify and sequence a ca. 500 bp 16S segment (with standard primers and methods; see e.g. Vences et al., 2001), given that comparative reference sequences of reliably identified individuals of the majority of rainbowfish and cichlid species are available for this gene, mostly from the work of John S. Sparks and colleagues (see references for the respective taxa in the species accounts below). Although the divergence in this rather conserved gene is low for many species of Malagasy freshwater fishes, there are at least single mutational steps separating the majority of species and thus allowing a reliable identification. All newly determined sequences were deposited in GenBank (accession numbers MW217516-MW217526).

Tab. 2: Tissue samples taken from the Malagasy freshwater fish collection at Cologne Zoo for DNA barcoding, including IUCN Red List of Threatened Species Status (CR = Critically Endangered; EN = Endangered; VU = Vulnerable).

ID	Sample	Species	IUCN status
TZTIS 27	tissue fry	*Rheocles vatosoa*	EN
TZTIS 28	tissue fry	*Ptychochromis loisellei*	EN
TZTIS 29	tissue fry	*Bedotia madagascariensis*	EN
TZTIS 30	tissue new group	*Pachypanchax sakaramyi*	EN
TZTIS 31	tissue old group	*P. sakaramyi*	EN
TZTIS 32	tissue fry	*Ptychochromis insolitus*	CR
TZTIS 33	tissue adult	*P. oligacanthus*	EN
TZTIS 34	tissue adult	*Ptychochromis grandidieri*	LC
TZTIS 35	tissue adult	*Paratilapia* cf. *polleni*	VU
TZTIS 36	tissue adult (from Berlin Zoo)	*Paretroplus menarambo*	EN
TZTIS 37	tissue medium-sized (from Pisciculture)	*P. menarambo*	EN
TZTIS 38	tissue small-sized (from Pisciculture)	*P. menarambo*	EN

Molecular identification of Cologne Zoo breeding stocks

Pachypanchax sakaramyi: Two 16S sequences from the older and from the more recently obtained groups in Cologne Zoo (TZTIS 30-31) were identical to each other and to reference sequences collected close to the type locality (reference sequence with GenBank accession number KJ844812, corresponding to the voucher specimen FGZC 1245).

Bedotia madagascariensis: Tiergarten Bernburg (Germany), from which the *Bedotia* fry founding the Cologne Zoo colony was obtained, sustained them under the name *Bedotia geayi*, which according to Loiselle & Rodriguez (2007) is a common misidentification in the aquarium trade. The color pattern of our specimens fully matches with *B. madagascariensis*, and a 16S sequence from one sample (TZTIS 29) differed by only 0.2% uncorrected distance from a *B. madagascariensis* reference sequence (AY266060). Interestingly, sequences of complete mitochondrial genomes in GenBank (e.g., AP017440) are 100% identical to the sequence of our specimen, but are also mislabelled as *B. geayi*. Apparently, no reference sequence of a genuine *B. geayi* specimen is currently available.

Rheocles vatosoa: A 16S sequence of one specimen from our breeding stock (TZTIS 27) was 100% identical to the reference sequence of *R. vatosoa* (AY266073) from Sparks & Smith (2004), thereby confirming its identification.

Paratilapia cf. *polleni*: One sample (TZTIS 35) was sequenced for a segment of the 16S gene but yielded only a short, poor quality sequence of 214 bp. Yet, the sequence obtained did not match with any previously published sequence, reflecting the lack of a comprehensive revision of the genus *Paratilapia* and of a comprehensive genetic sampling of the genus.

Paretroplus menarambo: We sequenced a segment of the 16S gene for three specimens, corresponding to the three groups separately obtained by Cologne Zoo (TZTIS 36-38), which all were identical to each other and to the reference sequence (AY263823), thus validating their identity and confirming that they can be combined for conservation breeding purposes.

Ptychochromis grandidieri: A 16S sequence of one of Cologne Zoo's specimens (TZTIS34) turned out to be identical to the reference sequence of *P. grandidieri* (MH767428), thus confirming its identification.

Ptychochromis insolitus: One 16S sequence of one of our specimens (TZTIS 32) differed by only a single mutation (uncorrected distance 0.2%) from the reference sequence AY662725, labelled in GenBank as *Ptychochromis* sp. Sofia and thus almost certainly corresponding to *P. insolitus* and confirming the identification of the Cologne Zoo breeding stock.

Ptychochromis loisellei: A sample taken from Cologne Zoo's specimens (TZTIS 28) yielded only a very short 16S sequence due to sequencing failure. In this short stretch, the sample was 100% identical to various *Ptychochromis*, including AY662723, which corresponds to *P. loisellei* (in GenBank as *Ptychochromis* sp. "Garaka").

Ptychochromis oligacanthus: We obtained one 16S sequence from the specimens of the group kept at Cologne Zoo (TZTIS 33), which proved to be identical to the reference sequence MH767430, thus confirming the identification of our specimens.

Species accounts of Malagasy fish bred in Cologne Zoo

Aplocheilidae

Pachypanchax sakaramyi (Holly, 1928)

Sakaramy killifish (Malagasy name: Zoto)

Diagnosis: *Pachypanchax sakaramyi* differs from *P. playfairi*, type species of the genus, in lacking raised dorsolateral squamation as well as rows of discrete red dots on the flanks, red edging to the dorsal and anal fins and a black caudal-fin margin. This species has the shortest dorsal fin base of all described Malagasy congeners and further differs in having chest scales smaller than those of the flanks and a row of scales at the base of the dorsal and anal fins. The similar species *P. omalonotus*, which occurs in close proximity to *P. sakaramyi* (e.g. in the Sambirano region) has the shortest and deepest caudal peduncle of any Malagasy *Pachypanchax* and further differs from *P. sakaramyi* in having the scales of the chest the same size as those of the flanks and in its marked color polymorphism. Loiselle (2006) presented diagnostic color pattern features, which set *P. sakaramyi* apart from all congeners. Males of this species grow up to 9 cm in total length (Froese & Pauly, 2018).

Fig. 1: Sakaramy Killifish (*Pachypanchax sakaramyi*), Cologne Zoo. Photo: M. Vences.

Distribution: The species was originally described from the Sakaramy River, at the village of the same name, approx. 30 km south of the city of Antsiranana (Diego Suarez), 500 m above sea level. It is endemic to streams draining the northern and eastern versants of the Ambohitra Massif (Montagne d'Ambre), a Plio-Pleistocene volcanic formation that dominates the northern tip of Madagascar.

Population size/threats: The subpopulations are very fragmented. According to Sparks (2016), several streams crossed by the national road from Antsakoabe village to Antsiranana were sampled and *Pachypanchax* were not found. As reported by Loiselle (2006), this species was formerly sufficiently abundant to be harvested for domestic consumption using wicker-fishing baskets but has been extirpated from most of its original range. Local residents ascribe its disappearance to predation by introduced *Poecilia reticulata* and *Gambusia holbrooki* upon *P. sakaramyi* fry. A factor of equal importance is ongoing deforestation of the Ambohitra Massif, which changes the hydrological regime of small streams from permanent to intermittent, resulting in the extirpation of their subpopulations of *P. sakaramyi*. The most recent loss of habitat resulted from the diversion of the source of the Sakaramy River in 2000 to provide drinking water for several private residences and the guesthouse of the Benedictine monastery located on the outskirts of the town of Joffreville (Sparks, 2016).

Fig. 2: Sakaramy Killifish (*Pachypanchax sakaramyi*), wild breeding male. Photo: P. Loiselle.

Conservation Status: A managed population has been established in North America and Europe, but barring the immediate implementation of habitat protection and restoration programs, according to Loiselle (2006) the extirpation of the remaining riverine populations appears inevitable. During surveys of Foret d'Ambre in March 2007, *P. sakaramyi* still was abundant in the streams in the forest (Frank Glaw in litt.). With an estimated extent of occurrence of 550 km^2, a single location and an ongoing decline in habitat, the IUCN Red List Status is Endangered, with population trend decreasing (Sparks, 2016).

Natural history: According to Loiselle (2006), *Pachypanchax sakaramyi* inhabits high-gradient streams flowing under both degraded and intact forest cover and the peripheral waters of low-altitude crater lakes. Individuals of all sizes occur in both areas of strong current and tranquil pools, but are most abundant in the latter. Water temperatures between 20.5-22.2 °C were measured in partially shaded segments of the Sakaramy River in October. The water of the Sakaramy River and other streams draining the Ambohitra Massif was free of suspended matter, unstained by tannins, moderately soft (total and carbonate hardness 36.0-72.0 ppm), slightly alkaline (pH 7.2-7.5) and deficient in dissolved substances (conductivity 58.0-75.0 µS/cm).

Stream bottoms consist of bare bedrock or rounded basaltic cobble, interspersed with boulders up to 60 cm in diameter. Waterlogged branches are common along the margins of larger pools. No submerged aquatic plants were observed growing in the upper Sakaramy River. The Madagascar lace plant (*Aponogeton madagascariensis*), an unidentified epilithic Podostemonaceae and the exotic water hyacinth *Eichhornia crassipes* were observed growing in *P. sakaramyi* habitat in the Antsahalalina River.

P. sakaramyi has been observed feeding upon both stranded terrestrial insects at the surface of the water and upon small aquatic invertebrates taken from the bottom. As the upper Sakaramy River is devoid of other fish, its only enemies therein appear to be the Malagasy malachite kingfisher and predatory invertebrates such as dragonfly nymphs and large prawns of the genus *Macrobrachium*.

Juvenile *P. sakaramyi* live in loose associations in the shallows. Adults frequent deeper water away from the banks. Large individuals of both sexes are solitary. Females tend to swim slowly in a stop-go manner, while males are in constant, active motion throughout their habitat. Loiselle (2006) observed a consort-type mating system, in which males contend for access to ripe females rather than for control of spawning sites. Pairs were observed spawning upon waterlogged branches and among the cobbles of the stream bottom. Spawning was observed in the habitat in October. The species is suspected to either have a completely aseasonal reproductive pattern or a very protracted breeding season extending from early spring through the austral summer and into the autumn.

Husbandry: Cologne Zoo's Aquarium keeps two groups of adults behind the scenes. One, only received recently, is held in an aquarium 80 cm L (length) x 50 cm W (width) x 50 cm H (height) in size, with an actual capacity of 200 l. The aquarium is furnished with roots and aquatic plants (*Anubias*, *Cryptocoryne*, *Microsorum*). The second group lives in an aquarium L120 x W50 x H50 cm in size under similar conditions. A third adult group is housed harmoniously with *Bedotia madagascariensis* in a tank of 1200 l capacity and a front panel of W100 x H110 cm in size (the aquarium broadens to the rear) exhibited in the public area. The background consists of stones and the substrate consists of sand, while aquatic plants of the genera *Aponogeton*, *Cryptocoryne*, *Hygrophila*, *Microsorum*, *Pogostemon*, and *Rotala* serve as interior decoration. Fry are reared backstage in planted (*Anubias*, *Microsorum*) 112 l aquariums (L80 x W40 x H35). Depending on size, fish are fed-flake and frozen food (white, black or red mosquito larvae, freshwater shrimp) as well as living food (*Artemia*, *Chaoborus* (glassworm larvae) from time to time. The tanks have a water temperature of 24.6 °C, carbonate hardness is 3 °KH, total hardness 5 °dGH, conductivity 230 µS/cm and pH value 7.5.

Reproduction: Both in the public display tank and in the backstage tanks females deposit eggs on leaves and stems of aquatic plants. Reproduction is continuous and requires no special triggers. Adults do not prey upon fry, but older fry will predate upon newly hatched siblings. However, groups should not include too many males, as according to our observations this also appears to have a negative impact on fry survivorship.

Zoo husbandry network: According to ZIMS, the species is held in two zoos in the USA, viz. the Jenkinson's Aquarium and in the New York Aquarium, and in 14 zoos in Europe, including four German zoos (Aquazoo Düsseldorf, Cologne Zoo, Tiergarten Bernburg, Wuppertal Zoo). Furthermore, the species is kept in Europe in Ostrava Zoo, Plzen Zoo (Czech Republic), Rotterdam Zoo (Netherlands), Silesian Zoological Garden, Wroclaw Zoo (Poland), Tropikariet Helsingborg (Sweden), Zurich Zoo (Switzerland), North of England Zoological Society Chester, Reaseheath College Animal Centre, ZSL London Zoo (UK). In addition, according to Zootierliste, the species is held in Darmstadt Vivarium and in Leipzig Zoo (Germany), in Tiergarten Schönbrunn, Vienna (Austria), in Prague Zoo (Czech Republic) and in the Bolton Museum (UK). In addition to the group we received from Leipzig Zoo in April 2007 and the offspring we already provided to a number of institutions both in Germany (e.g. Tiergarten Bernburg, Wuppertal Zoo) and in Europe (e.g. Wroclaw Zoo, Poland) we have been keeping another group at Cologne Zoo's Aquarium since 2019.

We received this second group from H. Brünner (Karlsruhe, in litt.), which derives from upstream of the type locality. It is currently kept backstage only and separate from the long-term held group.

Bedotiidae

Bedotia madagascariensis Regan, 1903

Madagascar rainbowfish (Malagasy name: Zono)

Diagnosis: *Bedotia madagascariensis* belongs to the group of species whose color pattern in life is based upon two dark lateral stripes clearly expressed in both sexes. This feature unambiguously distinguishes it from congeners in which the lateral stripes are either replaced by a pattern of dark spots or are altogether lacking in one or both sexes. It distinguishes from its laterally striped congeners by its caudal fin coloration, which consists of an extensive hyaline to iridescent yellow-white basal zone, a crescent-shaped black median band and broad red or white tips. Low second dorsal (10–12) and anal (14–17) fin ray counts are diagnostic for preserved specimens (Loiselle & Rodriguez, 2007).

Fig. 3: Madagascar rainbowfish (*Bedotia madagascariensis*), Cologne Zoo. Photo: M. Vences.

Distribution: The present range of *B. madagascariensis* extends from the lower reaches of the Ivoloina River, the effective northern terminus of the Lakendrano Mpangalana (Pangalanes Canal), as far south as Manambolo Creek, which drains into this waterway 10 km south of the town of Vatomandry. The recent capture of juvenile *B. madagascariensis* in the rapids of the Ikopa River near the village of Antanimbary and of adult fish in Lanefitra Creek at Ankadibe Village, several hundred kilometers to the west, suggests that these probably translocated populations are now well established in the Betsiboka basin (Loiselle & Rodriguez, 2007).

Population size/threats: The species is abundant in the lakes of the Pangalanes Canal and in lower reaches of many streams flowing into it (Ravelomanana & Sparks, 2016c). The main threats it faces are habitat loss and degradation through siltation caused by deforestation and predation by the introduced spotted snakehead (*Channa maculata*). According to Loiselle & Rodriguez (2007), prior to snakehead introduction in the early 1970's, the only fish large enough to prey upon *B. madagascariensis* were cichlids of the genus *Paratilapia*, flagtails of the genus *Kuhlia*, the endemic grunter *Mesopristes elongatus*, *Glossogobius giuris*, and eels of the genus *Anguilla*. This species is also potential prey of piscivorous wading birds and the Malagasy malachite kingfisher (*Corythornis vintsioides)*. Despite its relatively small size, there is an active artisanal fishery for *B. madagascariensis* over most of its range. Predation pressure in all probability precludes longevity in nature, which is up to ten years in captivity (Ravelomanana & Sparks, 2016c).

Conservation Status: The IUCN Red List Status is Endangered, with population trend decreasing (Ravelomanana & Sparks, 2016c).

Natural History: According to Loiselle & Rodriguez (2007), *B. madagascariensis* inhabits clear streams flowing under partial or complete forest cover at altitudes up to 30 meters above sea level. As long as the stream is shaded, this species appears indifferent to the composition of the riparian vegetation, prospering even when it is comprised entirely of exotic species. Although capable of breasting a fairly strong current, *B. madagascariensis* prefers the quieter sections of well-shaded streams. Rivers draining the eastern versant of Madagascar are characterised by extremely soft water (General hardness [GH] < 17.1 ppm, electrical conductivity 17.0–27.0 µS/cm). It is thus not unusual to find this species inhabiting classic black water habitats such as *Dracaena/Pandanus* swamps, where pH values can be as low as 4.8. Although therapeutic salinity levels up to 5.0 parts per thousand are tolerated in captivity, this species is never found in brackish waters in nature. Water temperatures measured during the month of October in the habitats it frequents ranged from 23-32 °C.

B. madagascariensis is typically observed in loose, size-graded associations of up to several dozen individuals. Juveniles are usually found in the shallows, while adults frequent deeper water away from the banks. Pairs of *B. madagascariensis* have been observed depositing eggs in coarse gravel in nature (Loiselle, unpublished data). This species reproduces in the rainy season and probably has a protracted breeding season in nature (according to literature data compiled by Glaw & Vences, 1994). It lays about 15-20 eggs per day continuously over an extended period in captivity. Young hatch after 5-8 days and grow rapidly becoming sexually mature at the age of 5-6 months (Brunel, 1968; Staeck, 1990).

Husbandry: Backstage at Cologne Zoo's Aquarium a group of adults is maintained in an aquarium L80 x W40 x H36 cm in size with an actual capacity of 112 l. The aquarium is fur-

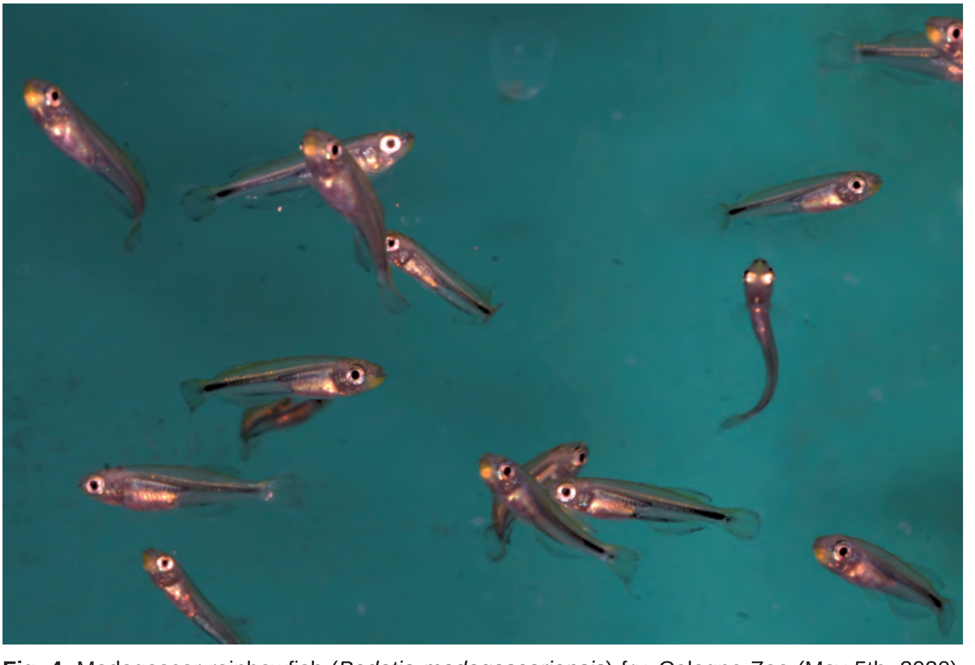

Fig. 4: Madagascar rainbowfish (*Bedotia madagascariensis*) fry, Cologne Zoo (May 5th, 2020). Photo: T. Ziegler.

nished with roots and mops made of nylon yarn for spawning. A second adult group is kept together with *Pachypanchax sakaramyi* in a show tank in the public area, in an aquarium of 1,200 l capacity. Fry are reared backstage in an aquarium L80 x W40 x H35 cm in size of 112 l capacity, filled with several nylon yarn mops. Depending on size, fish receive the same diet as *P. sakaramyi*. The tanks have a water temperature of 24.6 °C, carbonate hardness is 3 °KH, total hardness 5 °dGH, conductivity 230 µS/cm and pH value 7.5. Their husbandry, like that of *P. sakaramyi*, poses few difficulties.

Reproduction: Both in the 1,200 l public exhibition tank and in the backstage tank females deposit eggs on both aquatic plants and nylon mops. Reproduction continues uninterrupted, without need of special triggers. However, breeding groups should not be too large for optimal reproductive output. Groups consisting of 2 males and 3 females are most successful. From late 2019 through June 2020 our backstage group alone produced around 500 fry.

Zoo husbandry network: According to ZIMS, 8 zoos in Europe keep this species, including four German zoos (Aquazoo Düsseldorf, Cologne Zoo, Tiergarten Bernburg, Wilhelma Stuttgart). Furthermore, the species is kept in Europe at Tiergarten Schönbrunn, Vienna (Austria), Fota Wildifepark (Ireland), Tropikariet Helsingborg, (Sweden), Tilgate Nature Center (UK). In addition, according to Zootierliste, the species is likewise held in Den Bla Planet Aquarium (Denmark), Zaragoza Fluvial Aquarium (Spain). According to ZIMS, *B. geayi* is kept in Leipzig Zoo (Germany), Aquario di Genova (Italy), Parc Merveilleux (Luxemburg), Wroclaw Zoo (Poland), Perm Zoo (Russia), Malmö Aquarium and Tropicarium (Sweden), Zürich (Switzerland). According to Zootierliste, *B. geayi* is held in seven zoos in Germany and in ten zoos in the remaining EAZA region. However, as *B. geayi* has never been exported from Madagascar, all putative holdings of this species in fact should represent misnamed *B. madagascariensis* as we have demonstrated from Cologne Zoo's captive population. Our offspring have already been provided to several zoos, the last recipients Duisburg Zoo and Nürnberg Zoo (Germany) and the Plzen Zoo (Czech Republic). It is finally worth noting that *B. madagascariensis* is a mass-market aquarium fish produced on an industrial scale in North America and the Far East. The currently managed population is probably several orders of magnitude larger than the current wild population.

Rheocles vatosoa Stiassny, Rodriguez & Loiselle, 2002

Crystal Rheocles (Malagasy name: Zonobe)

Diagnosis: *Rheocles vatosoa* most easily distinguishes from congeners by a shorter upper jaw, by a fully scaled dorsum, nape, and venter and by absence of black pigmentation of the genital papilla (Stiassny et al., 2002). *R. vatosoa* displays marked sexual dimorphism in color pattern. Males also grow larger than females, are deeper-bodied and have longer dorsal and anal fins (Stiassny et al., 2002). Males grow up to 7.9 cm in total length (Froese & Pauly, 2018).

Distribution: The species is endemic to the upper and middle reaches of the Lokoho River in the general vicinity of the town of Andapa. *Rheocles vatosoa* has the broadest altitudinal range so far recorded for any species of the genus, with specimens collected from as low as 157 m asl up to 940 m asl (Stiassny et al., 2002).

Population size/threats: In forested streams within portions of its range, this species is still abundant. However, within much of the Andapa basin and in Andrakata River, this species is now very rare. Numbers have declined substantially over the past half-century (Ravelomanana & Sparks, 2016c).

Conservation Status: Populations of *R. vatosoa* have been catastrophically impacted by the misuse of mosquito nets as fishing gear. Even though the catchment of the streams in the Lo-

Fig. 5: Crystal Rheocles (*Rheocles vatosoa*), Cologne Zoo. Photo: T. Ziegler.

koho basin is protected by Marojejy and Anjanaharibe Sud National Parks, due to the restricted range (less than 5,000 km²), the threat from invasive alien species and a continued decline in habitat extent and quality outside the National Park mainly due to deforestation and rice farming, the IUCN Red List Status is Endangered, with population trend decreasing (Ravelomanana & Sparks, 2016c).

Natural History: Throughout its range, *Rheocles vatosoa* is found in clear streams over gravel or coarse sand bottoms. Such streams are characterized by soft, slightly acidic to moderately alkaline water, total and carbonate hardness value < 1 °dGH, electrical conductivity between 23 and 30 µS/cm and pH values between 6.8 and 7.5 (Stiassny et al., 2002, Ravelomanana & Sparks, 2016c). It occurs both in large, rapidly flowing rivers and small brooks. In the Andapa region, inhabited biotopes were characterized by a shrubby riparian zone. *Rheocles vatosoa* feeds on terrestrial and aquatic insects and larvae. The species begins spawning in late October and early November. The breeding season appears to be protracted. In nature, this species deposits demersal eggs in patches of coarse gravel (Stiassny et al., 2002; Loiselle, unpublished data).

Husbandry: Backstage at Cologne Zoo's Aquarium two groups of adults are maintained in two aquariums with a surface area of L80 x W40 cm and an actual capacity of 112 l. The aquariums are furnished with nylon yarn mops for spawning. Later another adult group was transferred into a semi-oval exhibition aquarium in the public area, of 800 l capacity and with a front panel measuring W100 x H110 cm. The background consists of stones and the substrate consists of sand, while various aquatic plants serve as interior decoration. Fry are reared backstage in planted aquariums of L80 x W40 x H35 cm in size of 112 l capacity. The tanks have a water temperature of 24.6 °C, carbonate hardness is 3 °KH, total hardness 5 °dGH, conductivity 230 µS/cm and pH value 7.5. Depending on their size, fish receive the same diet as *Pachypanchax sakaramyi*.

Fig. 6: Crystal Rheocles (*Rheocles vatosoa*) offspring, Cologne Zoo (April 30th, 2020). Photo: T. Ziegler.

Reproduction: For spawning, aquaria for adults are filled with mops made of nylon yarn. Females sporadically deposit eggs therein, usually several per day. Egg size is ca. 1.5 to 2 mm in diameter. Initial food for fry is powder food and *Artemia* larvae nourished with vitamins.

Zoo husbandry network: According to ZIMS, the species is kept only at Toronto Zoo (Canada), Cologne Zoo (Germany), and the Zoological Society London, ZSL (UK). According to Zootierliste, Cologne Zoo is the only zoo in the EAZA region, which keeps the species. Initially we have received 30 surplus individuals from Toronto Zoo. Currently we keep around 40 fry (August 2020). Several zoos already have shown interest in obtaining surplus, among them Plzen Zoo (Czech Republic), Museo di Storia Naturale, Università di Pisa (Italy), and Rotterdam Zoo (Netherlands).

Cichlidae

Ptychochromis insolitus Stiassny & Sparks, 2006

Mangarahara Cichlid (Malagasy name: Joba Mena)

Diagnosis: A *Ptychochromis* exhibiting the western-type palatine morphology *sensu* Stiassny & Sparks (2006) and most readily distinguished from congeners by the presence (most obvious in preservation) of a faint midlateral stripe, beginning just posterior to the dorsocaudal margin of the opercle and extending to caudal-fin origin. *Ptychochromis insolitus* can be easily distinguished from its closest relative *P. inornatus* by pigmentation pattern (Stiassny & Sparks, 2006), notably the red coloration in the unpaired fins of adult males. Males grow up to 15.0 cm standard length (de Rham & Nourissat, 2004).

Fig. 7: Mangarahara Cichlid (*Ptychochromis insolitus*) male, Cologne Zoo. Photo: T. Ziegler.

Distribution: The species is endemic to the tributaries of the Sofia River, notably the Amboaboa river near the town of Marotandrano, in northeastern Madagascar. Previously it was also found in the Mangarahara river (Stiassny & Sparks, 2006) but recent surveys in 2013 have found this river to be almost completely dried out by the end of the dry season (September/November) and the fish is no longer present (Ravelomanana et al., 2016).

Population size/threats: *Ptychochromis insolitus* is extremely rare throughout its limited range, and few specimens have been collected despite sizeable collections of other species having been made in this region, including other cichlids, notably *Paretroplus nourissati* (Stiassny & Sparks, 2006). No additional specimens were found in 2011 at the type locality, the Amboaboa River near the town of Mandritsara. Some representatives were found in the Amboaboa upstream near Marotandrano in 2013, but this population is not strong (Ravelomanana et al., 2016). The species is threatened mainly by habitat loss and lack of water at certain times of year, largely due to inappropriate stream flow management by an upstream dam. The local fishery also has an important impact on the population decline. Artisanal fishery activity employing seine nets with small mesh size or poisoning using a local rotenone analog is common in Marotandrano although such methods are illegal (Ravelomanana et al., 2016).

Conservation Status: This species appears to be extremely rare within its known and very restricted range, viz. a small portion of the Sofia River drainage. The extent of occurrence is estimated at much less than 100 km². Despite targeted efforts, the species is rarely collected. Given the high rate of deforestation in the region, construction of dams and introduction of exotic competitors and predators, this species faces a very high risk of extinction (Ravelomanana et al., 2016). Thus, the IUCN Red List Status is Critically Endangered, with population trend decreasing.

Natural History: The substrate at the type locality is mostly sand and rock, with deeper pools present in sheltered areas. The water is clear, shallow with swift current (Stiassny & Sparks, 2006). In upstream reaches of the Amboaboa River this species has shown remarkable survival skills and has managed to find one of the very last remaining persistant water sources to live in, However, this population is small and standing water represents a suboptimal habitat (Ravelomanana et al., 2016).

Husbandry: *Ptychochromus insolitus* is a moderately shy species that is rather aggressive towards conspecifics. Setting up an isolated pair in an effort to breed this species led to the loss of the female. In light of this failure, adult individuals are now maintained in two groups consisting of 11 and 18 fish, respectively backstage at Cologne Zoo's Aquarium. The aquariums have a surface area of L100-120 x W60 cm and a maximal capacity of 270 l. Fry are reared backstage in four aquariums with a surface area of L80-150 x W60 cm. All aquariums are furnished with several large stones for surface structure and in the adult aquariums, to provide egg deposition sites. Depending upon their size, fish receive flake and frozen foods (white, black or red mosquito larva, freshwater shrimp) as well as living food (*Artemia*, *Chaoborus* larvae) from time to time. The tanks have a water temperature of 24.6 °C, carbonate hardness is 3 °KH, total hardness 5 °dGH, conductivity 230 µS/cm and pH value 7.5. In summer 2020 a group of 40 fry was moved into an aquascaped 20,000 l exhibition tank together with *P. loisellei* and a school of *Bedotia madagascariensis* in order to highlight Madagascar's endangered freshwater fish diversity.

Fig. 8: Mangarahara Cichlid (*Ptychochromis insolitus*), Cologne Zoo: egg deposition (upper left, 24th November 2019); female guarding eggs on stone (upper right, February 24th, 2020); larva (lower left, November 29th, 2019); larvae after feeding with *Artemia* (lower right, December 16th, 2019). Photos: T. Ziegler.

Fig. 9: Mangarahara Cichlid (*Ptychochromis insolitus*) offspring, Cologne Zoo: upper left, February 1st, 2020; upper right, April 22nd, 2020; lower left, July 2nd, 2020; lower right, July 2nd, 2020. Photos: T. Ziegler.

Reproduction: *Ptychochromis insolitus* is a biparentally custodial open brooder. Clutches were deposited on stones or on the bottom of their aquarium. Clutch sizes to date range from 100 to 250 eggs. Hygienic behavior and close-in defense of the clutch were undertaken exclusively by the smaller female. During spawning, the females are strikingly bright golden in color with the eye region being deep black. Males defend the borders of the pair's territory but have nothing to do with the proximate defense of the eggs. The smaller adult group was revealed to be reproductively most active. Several females in this group were observed that they laid eggs. Two clutches left together with the adults in the aquarium did not develop, due to fungal infestation or because they were eaten by the adults. Also because adult behavior has been characterized by elevated levels of aggression, it was decided to remove most of the clutches for separate rearing. Largest fry measured around 4.5 cm (at the age of six months, in May 2020). However, this may not represent maximum size of half-year old individuals because the largest offspring individuals already were selected and captured before to be provided to other zoos for extending the conservation breeding network.

Zoo husbandry network: According to Ravelomanana et al. (2016), captive breeding has been successfully undertaken by an aquaculture facility in Andapa in northeastern Madagascar. According to ZIMS the species is held at Toronto Zoo (Canada) and in six zoos in Europe: Tiergarten Schönbrunn, Vienna (Austria), Den Bla Planet Aquarium (Denmark), Cologne Zoo, and Wilhelma Stuttgart (Germany), Zoological Society London, and ZSL Whipsnade Zoo (UK). According to Zootierliste, the species is further held in the EAZA region in Rotterdam Zoo (Netherlands). Originally, in November 2019 we received 30 individuals bred at Toronto Zoo.

Cologne Zoo was the first institution at that time, which received the species after it was formerly kept at Berlin Zoo. To extend the breeding network in Europe, where no breeding happened in the past years, the first group of offspring from Cologne Zoo was sent to Tiergarten Schönbrunn in Vienna (Austria) in January 2020 (n = 30). Further, groups of our offspring were sent to Berlin Zoo (Germany) (n = 15) and to Wilhelma, Stuttgart (Germany) (n = 30) in March 2020, to Ostrava Zoo (Czech Republic) (n = 15) in June 2020, to Leipzig Zoo (Germany) (n = 15), Nürnberg Zoo (Germany) (n = 15), Duisburg Zoo (Germany) (n = 20), and Tiergarten Bernburg (n = 30) in July 2020 and to Malmö Museer (Sweden) (n = 25) in September 2020. In March 2020, another group of our offspring was sent to private breeders in Poland associated with the DCG, the German Cichlid Society (n = 20). In addition to these 215 surplus young bred at Cologne Zoo and so far distributed to other institutions/breeders we still have more than 400 surplus individuals of *P. insolitus* from more than ten clutches available to be provided to other institutions, such as Rotterdam Zoo and ZieZoo (Netherlands), as well as Plock Zoo (Poland). Both have already shown interest in maintaining this species.

Ptychochromis loisellei Stiassny & Sparks, 2006

Loiselle's Ptycho (Malagasy name: Garaka)

Diagnosis: A *Ptychochromis* exhibiting the eastern-type palatine morphology sensu Stiassny & Sparks (2006) and which is distinguished from all congeners by a unique pigmentation

Fig. 10: Loiselle's Ptycho (*Ptychochromis loisellei*), breeding couple (left female, right male), Cologne Zoo. Photo: T. Ziegler.

pattern and coloration comprising an expansive (generally vertically oriented) black band or blotched region of black pigment below the lateral midline and just anterior to origin of (and often extending over) the anal fin, and by an overall dark grayish-green body coloration, which becomes intense golden yellow in sexually active individuals. Males grow up to 20.0 cm standard length (Loiselle, unpublished data).

Distribution: The type locality of *P. loisellei* is the Mahanara River at the town of Antsirabe-Nord (Stiassny & Sparks, 2006). It has also been collected in the lower reaches of the Bemarivo River and Farihy Mahatsara (Lac Vert), a coastal lake situated immediately to the south of the town of Ihanara (Vohemar). According to local fishermen, *P. loisellei* also occurs in the middle and upper reaches of the Fanambana River, which lies roughly midway between the Mahanara and Farihy Mahatsara. (Ravelomanana & Sparks, 2016b; Loiselle, unpublished data).

Population size/threats: In the original description, Stiassny & Sparks (2006) stated that according to local fishermen, a decade and a half ago *P. loisellei* was still relatively common throughout the Mahanara River basin. According to Ravelomanana & Sparks (2016b) the main impacts thought to have caused the decline of this species are deforestation leading to loss of habitat through increased sedimentation, competition from introduced tilapias and overfishing. In Farihy (Lake) Mahatsara, a few hook and line fishermen operate but only one specimen was caught during a morning of observation. At Nosiarina Lake, where there is an important artisanal fishery, the population is also not as abundant as formerly.

Fig. 11: Loiselle's Ptycho (*Ptychochromis loisellei*), Cologne Zoo: couple (with male in front) guarding eggs on upper stone surface (upper left); larvae on ground (upper right); male above larvae group on ground attacking front panel (lower left); fry from first well-developing clutch (lower right, May 4th, 2020). Photos: T. Ziegler.

Fig. 12: Male Loiselle's Ptycho (*Ptychochromis loisellei*) inmidst fry from second well-developing clutch, Cologne Zoo (April 30th, 2020). Photo: T. Ziegler.

Fig. 13: Loiselle's Ptycho (*Ptychochromis loisellei*) couple guarding larvae from second well-developing clutch, Cologne Zoo (May 4th, 2020). Photo: T. Ziegler.

Conservation Status: As the estimated extent of occurrence is significantly less than 5,000 km² and because the population is targeted by an active fishery and threatened by alien invasive species and ongoing deforestation at three separate locations (Ravelomanana & Sparks, 2016b), its IUCN Red List Status is Endangered, with population trend decreasing.

Natural History: There is little published information about the habitat of *P. loisellei*. The species lives in clear and swift flowing rivers, and clear or turbid lakes (Ravelomanana & Sparks, 2016b). It is a demersal freshwater species (Stiassny & Sparks, 2006; Froese & Pauly, 2018).

Husbandry: *Ptychochromis loisellei* is a moderately shy species. Two groups consisting of 8 and 2 adult fish, respectively, are maintained backstage at Cologne Zoo's Aquarium. The aquariums have a surface area of L80 x W60 cm and a capacity of 200 l each. These aquariums are furnished with several large stones, roots and aquatic plants (*Vallisneria*), with a substrate of sand. Fry are reared backstage in two aquariums with a surface area of L80 x W60 cm. Depending on their size, fish receive the same diet as *P. insolitus*. The tanks have a water temperature of 24.6 °C, carbonate hardness is 3 °KH, total hardness 5 °dGH, conductivity 230 µS/cm and pH value 7.5. In summer 2020, a group of 15 fry was introduced to a 20,000 l aquascaped exhibition tank housing *P. insolitus* and a school of *Bedotia madagascariensis* established to highlight Madagascar's endangered freshwater fish diversity.

Fig. 14: Loiselle's Ptycho (*Ptychochromis loisellei*) female guarding eggs, Cologne Zoo. Photo: M. Vences.

Fig. 15: Loiselle's Ptycho (*Ptychochromis loisellei*) female performing brood care, Cologne Zoo. Photo: M. Vences.

Reproduction: *Ptychochromis loisellei* is a biparentally custodial open brooder. To date, only the isolated pair held in the backstage tank has bred successfully. The oval to rectangular clutches were deposited on smooth surfaces of stones. The pair has produced clutches of up to 400 eggs. The first clutch was guarded and defended only by the male, who even defended it against the female. The pair's second deposited clutch was cared for by both parents together. However, no larvae developed from these two first clutches due to fungal infestation of the eggs. Brood care in the third deposited clutch was first performed by the male and later by the female. Subsequently, after a temporary power interruption, the male began to attack the female. Due to this increasingly aggressive behavior it was decided to separate the clutch from the adult pair. This third clutch of about 100 eggs was the first from which larvae hatched. On 6 April, four days after hatching, the larvae began to swim freely. The next clutch also produced larvae. In this clutch, both parents performed brood care together. When a keeper approached the front panel of the aquarium for too long, the breeding couple did not hesitate to attack in turn the supposed invader.

It was also interesting to note that instead of selectively removing mold-infected eggs, unaffected developing eggs/young larvae from the clutch were moved by the parents to another site

Fig. 16: Loiselle's Ptycho (*Ptychochromis loisellei*), fry-tending pair. Photo: P. Loiselle.

in the rear of the aquarium. This parental relocation was observed in the first well developing clutch on the second day after larval hatching. In the second well-developing clutch, this relocation happened at the third day after larval hatching. However, the second well-developing clutch was not deposited in the morning hours as was the first one, but rather in the afternoon.

A third clutch from which larvae hatched was deposited on May 28. However, this happened during brood care for the previous one, whose fry measured ca. 0.5 to 1 cm. To avoid aggressive behavior of the breeding couple towards the older fry the couple was separated along with the new clutch. However, after photographing the parents with the new clutch some days later, the larvae of this clutch disappeared the following day. During the photo session one root was cautiously moved for few centimeters, which took only a few seconds. It seems either the translocation of the breeding couple, the photo session or most probably, the short-term manual intrusion into the aquarium must have interrupted the breeding couple from brood care and caused the loss of the clutch. Thus, during rearing, in particular of the young larvae, parents seem to be very sensitive towards disturbance, which is also affirmed by the negative impact of the power breakdown mentioned before. In particular during early larval development parents thus should not be disturbed during parental care to avoid offspring losses.

Zoo husbandry network: Captive breeding has been successfully undertaken by an aquaculture facility in Andapa in northeastern Madagascar and by aquariums abroad (Ravelomanana & Sparks 2016b). According to ZIMS the species is only held at Toronto Zoo (Canada) and Cologne Zoo (Germany). According to Zootierliste, Cologne Zoo is the only zoo in the EAZA region that keeps the species. Initially we received ten individuals bred at Toronto Zoo (Canada). As of June 2020 fry from the first well-developing clutch from our breeding couple at Cologne Zoo have grown to around 60 young fish of 2 cm length. The second well-developing clutch of the same breeding couple included about 400 1.0 to 1.5 cm long fry. The first offspring was sent to Ostrava Zoo (Czech Republic) (n = 15) in June 2020, to Leipzig Zoo (Germany) (n = 10), Duisburg Zoo (Germany) (n = 10) and Tiergarten Bernburg (n = 10) in July 2020, to

Fig. 17: Loiselle's Ptycho (*Ptychochromis loisellei*) fry, Cologne Zoo (July 2nd, 2020). Photo: T. Ziegler.

Fig. 18: Loiselle's Ptycho (*Ptychochromis loisellei*). Photo: P. Loiselle.

Malmö Museer (Sweden) (n = 25) in September 2020 and to Tiergarten Schönbrunn, Vienna (Austria) (n = 20) in October 2020 to extend the conservation breeding network. Other interested holdings are Münster Zoo (Germany), Rotterdam Zoo and ZieZoo (Netherlands) as well as Plock Zoo (Poland).

Additional species held at Cologne Zoo's Aquarium

Nine freshwater fish species from Madagascar are currently held at Cologne Zoo's Aquarium, eight of them threatened to some degree (Fig. 19, Table 2). Besides the five species treated in detail in this work and already successfully bred, the Critically Endangered Pinstripe Damba (*Paretroplus menarambo*) is also held. The Aquarium received three adult individuals in 2018 from Berlin Zoo (Germany) and a second group of juveniles of different sizes in February 2020 from Pisciciulture Estalens (France). Our molecular results showed that both groups are genetically homogeneous at least from a mitochondrial perspective, and thus can be used for conservation breeding purposes.

Another species received from Pisciculture Estalens in 2020 is *Paratilapia* cf. *polleni*. The specimens were provided under the name *Paratilapia* sp. "Andapa", probably descending from 200 juveniles provided to Pisciculture Estalens in 2014 (Patrick de Rham in litt.). The molecular data did not help to allocate the specimens to a specific lineage given the unclarified species-level taxonomy of the genus and the lack of reference sequences. If the specimens indeed originated from Andapa in northern Madagascar, it is possible that they are to be assigned to *P.*

Fig. 19: *Ptychochromis oligacanthus* (upper left), *P. grandidieri* (upper right), *Paratilapia* cf. *polleni* (lower left), *Paretroplus menarambo* (lower right), Cologne Zoo. Photos: T. Ziegler, M. Vences (lower right).

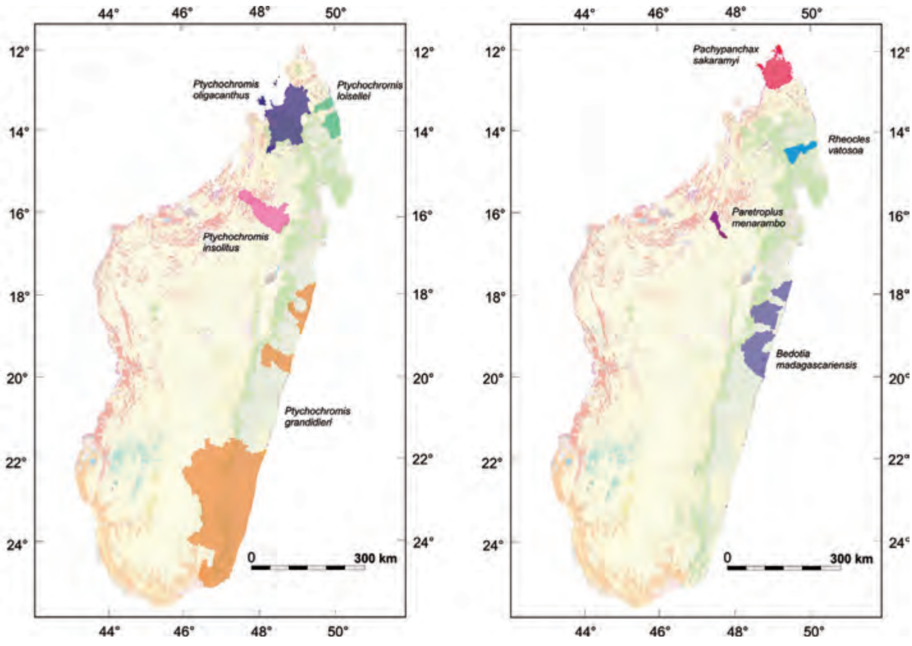

Fig. 20: Maps of Madagascar showing the distribution (after IUCN 2020) of seven focal species held in Cologne Zoo and discussed in this study (the distribution of *Paratilapia* is not shown due to uncertain taxonomy). Background colors in maps show remaining primary vegetation following the Madagascar Zoo Vegetation Mapping Project carried out from 2003–2006 (Moat & Smith 2007); green is humid forest (rainforest), reddish tones are deciduous forest and spiny forest-thicket.

polleni which was described from Ambassuana (= Ambazoana) river in north-western Madagascar; indeed, according to the distribution map in De Rham & Nourissat (2002), all northern populations of *Paratilapia* would belong to this taxon. It may also be possible that *Paratilapia* sp. “Andapa” corresponds to a separate species occurring in the Lokoho River drainage; however, according to the molecular data of Rakotomamonjy & Oliarinony (2018), samples from Andapa and north-western Madagascar (e.g., Nosy Be) are extremely similar in their COI sequences as visible from the branch lengths in the respective tree. We therefore refrain from assigning our specimens with confidence to any species at this time.

Since March 2020 Cologne Zoo has also been maintaining *Ptychochromis oligacanthus* and *P. grandidieri* received as offspring from a private breeder recommended by the DCG. In addition to 800, 1,200 and 2,700 l show tanks the Cologne Zoo has devoted a 20,000 l tank to threatened freshwater fishes from Madagascar (Fig. 20). It currently houses a shoal of about 300 *Bedotia madagascariensis*, which already have started to reproduce in this tank, 40 *Ptychochromis insolitus* and 15 *P. loisellei*. Inclusion of further cichlid species is planned in the near future.

Discussion

As shown by Loiselle & Rodriguez (2007), the genetically identified *Bedotia* in the Aquarium of Cologne Zoo proved not to be *B. geayi* as previously assumed, but actually represent

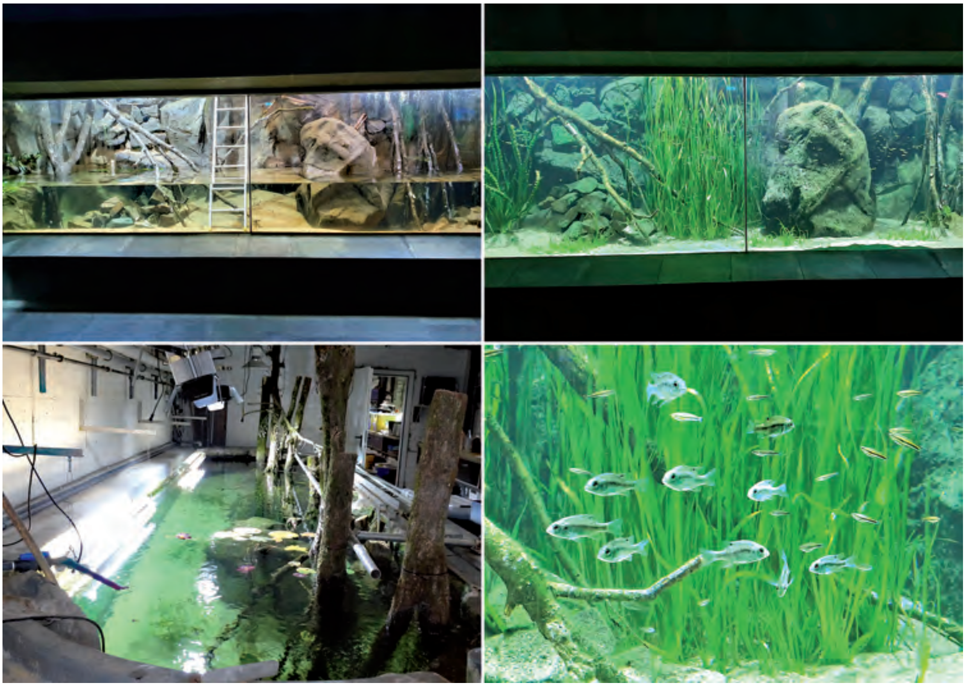

Fig. 21: 20,000 l tank previously showing Lake Tanganyika fish community now showing imperilled freshwater fish species from Madagascar: tank restructuring (upper left); filled tank with Madagascar Rainbow Fish shoal; view from keepers passage (lower left); Mangarahara cichlid shoal (lower right). Photos: T. Ziegler.

B. madagascariensis. A correct identification is crucial in conservation breeding programs, in particular when repatriation or restocking in the natural habitat is an option. By doing so, release of erroneously identified species or even hybrids can be prevented, and thereby the genetic integrity of the species in the wild ensured. At best, molecular identification can also help distinguish between geographic lineages and thus find suitable populations and sites for restocking. These are optimal species conservation measures in terms of a comprehensive approach, viz. the combination of different expertise bringing together best *ex situ* and *in situ* measures.

Analysis of records from the archive of Cologne Zoo's Aquarium revealed that *Bedotia* considered as *B. geayi* has been held by Cologne Zoo since 1972. In 1999, after 27 years, this group was eventually retired from the collection. Although these fish cannot be longer identified by molecular means, they probably were likewise representatives of *B. madagascariensis sensu* Loiselle & Rodriguez (2007). From the archive of Cologne Zoo's Aquarium it was clear that this *Bedotia* stock had regularly successfully reproduced. However, according to the files the offspring were not shared with other zoos but rather dispersed to pet shops and thus passed into private hands. Certainly in those days exhibition was the main focus of Cologne Zoo's Aquarium, contrasting to the current conservation and ark philosophy of this and many other zoos. This new emphasis on conservation breeding requires careful selection of taxa, validation of their taxonomic identity, assuring the genetic integrity of the breeding group, and ultimately the integration of the group into a well-managed conservation breeding network. Only with a sufficient number of participating zoos, it can be guaranteed that a species can be preserved in the long-term *ex situ* despite unexpected events, such as disease outbreaks or accidents in some of the facilities.

Because space and facilities in zoos are limited, Citizen Conservation programs offer an interesting additional option, in particular for smaller animals appreciated by hobbyists such as many fishes. Engaged private persons or specialist hobbyist associations like the German Cichlid Association (DCG) have the chance to contribute to maintaining captive populations of threatened species, by providing expertise and breeding facilities. At present, Citizen Conservation programs for endangered Malagasy freshwater fish species are jointly being established, initially in Germany. However, they can be extended to other countries.

Regarding the IUCN Red List of Threatened Species (IUCN 2020) conservation status of the endemic Malagasy freshwater fish species scientifically named since 2003 (see Table 1), changes may be necessary according to our knowledge (Loiselle, unpublished data). This article cannot provide a formal reassessment reviewing IUCN Red List criteria in depth, but we take this opportunity to summarize observations that may be taken into account in such future formal reassessments. It should be considered to change the conservation status of *Gogo atratus* and *Ptychochromis ernstmagnusi* from DD to VU. The Mananara River, where these two species occur, enjoys a remarkable degree of limnological integrity due to the fact that its almost entirely forested watershed lies within an extensive and very sparsely populated protected area. Despite their apparently restricted range both species are characterized by robust populations that are not yet intensively fished, which argues against a status as EN, but nevertheless a threatened status (VU) rather than NT or LC appears warranted due to overall increasing pressures on the remaining forested habitat in lowland eastern Madagascar. The conservation status of *Pachypanchax patriciae* probably could be changed from EN to VU. This species enjoys an extensive range that comprises two very different floristic regions. Populations are robust and much of its range is free of snakeheads and is likely to remain so for socioeconomic regions. The conservation status of *Bedotia leucopteron* may be changed as well from EN to VU. The Rianila-Iroko-Vohitra system enjoys a considerable degree of limnological integrity due to the fact that a significant portion of its headwaters watershed lies within well-forested protected areas, notably Analamazaotra-Mantadia National Park. Populations inhabiting the main channel of these rivers are not exposed to artisanal fishing and remain robust. The conservation status of *Sauvagella robusta* may move from EN to LC. The range of this species extends from the Sofia River at least as far south as the Tsiribihina River. The species is sufficiently abundant to support a sustained targeted fishery in Lake Tseny.

Concerning the species treated in this article, the conservation status of *Bedotia madagascariensis* may be changed from EN to VU. This species enjoys an extensive range and displays the ability to sustain robust populations in the face of an exotic predator, an active artisanal fishery and the replacement of primary forest cover by a much simplified successor assemblage of plants (Loiselle, unpublished data). The conservation status of *Ptychochromis oligacanthus* may be changed from from EN to VU. The species enjoys an extensive distribution. On the mainland of Madagascar, *P. oligacanthus* ranges from the Mananjeba River southwards to the Sambirano. It is also present in the Mount Passot crater lakes on the island of Nosy Be. These populations are robust and are neither subject to fishing pressure nor at risk from *Channa maculata*, which has not to date become established in extreme north-western Madagascar (Loiselle, 2005). As the increased seasonality in precipitation caused by climate change will adversely impact its habitat, this species, while not immediately threatened, can be accurately classified as Vulnerable (Loiselle, unpublished data). If *Paratilapia* sp. “Andapa” turns out to be a separate taxon, then it may be more appropriately classified as CR than the current VU. This form has to date only been found in the Lokoho River drainage. Wild populations probably no longer exist within the Andapa basin and it has become extremely rare within the remainder of the Lokoho system. If the experimental use of *Paratilapia* sp.

"Andapa" as an aquaculture subject, which began two decades ago, had not been proven successful, this form would have been known only from museum specimens. However, we reiterate the importance of a taxonomic revision of the genus *Paratilapia*, and herein have classified our samples cautiously as *P.* cf. *polleni* as neither their geographical origin nor the distinctness of the Andapa populations is fully clarified. *Paretroplus menarambo* is also highly threatened and its status should be changed from from EN to CR. Endemic to the Sofia River basin and formerly sufficiently abundant to support a commercial fishery, this species now apparently persists only in Lake Tseny. Adults of this relict population are at risk from the lake's active gill net fishery while juveniles are vulnerable to predation by the introduced *Channa maculata.* As a species that has undergone catastrophic decline and whose single surviving population remains seriously threatened, *P. menarambo* certainly qualifies as Critically Endangered (Loiselle, unpublished data). Similarly, the conservation status of *Pachypanchax sakaramyi* should be changed from from EN to CR. The upper reaches of the Sakaramy River supported the largest known population of this species. This population has collapsed following the diversion of the headwaters of the Sakaramy for human use and would have been extirpated had leaks in the piping carrying its water not resulted in the persistence of a few small puddles. Efforts to locate additional populations of *P. sakaramyi* elsewhere within its formerly extensive range have failed, although the species was still abundant in forest streams at Foret d'Ambre in March 2007 (Frank Glaw in litt). In light of these facts, also this species seems to qualify as Critically Endangered (Loiselle, unpublished data).

Cichlids from Madagascar, although not particularly colorful, are of high conservation priority because of their unique phylogenetic position as sister group to remaining cichlids. Studying these poorly known relict taxa – also in captivity – holds the potential to better understand the evolution of reproductive strategies, behavior, or genomes of cichlids, one of the most important model groups for speciation research. In general, the island's freshwater fish fauna is characterized by a number of archaic, basal taxa (Stiassny, 1992), and the behavior of most species is very incompletely studied. In this context, it is worth mentioning that Cologne Zoo's experiences in keeping and breeding of *Ptychochromis insolitus*, *P. loisellei* and *Rheocles vatosoa* so far have all taken place in behind the scenes facilities rather than in large, more naturally furnished tanks, where perhaps more systematic behavioral observations could be made in the future.

Loiselle (2003) already noted that captive breeding efforts undertaken by public aquariums, zoos, and individuals in North America and Europe had at that point resulted in the establishment of managed populations of 33 Malagasy fish species. Although constituting a strong beginning, it was recommended that a formally recognized species survival program should be implemented for the endemic freshwater fishes of Madagascar (Benstead et al., 2003). Such a program failed to come into being in North America (Loiselle, unpublished data). With the breeding at the Cologne Zoo's Aquarium of the three threatened Malagasy freshwater fish species received from the Toronto Zoo and the subsequent transfer of their progeny to so far nine other zoos, an important step towards optimized conservation breeding and the establishment of a viable network of institutional breeders in Europe has been taken. So far 215 *Ptychochromis insolitus* fry have been distributed by Cologne Zoo within Europe and 90 *P. loisellei*. A number of further transfers is planned in the near future, as unfortunately the Covid-19 pandemic has precluded several planned transfers for the moment. As basis for establishing an improved conservation breeding network research leading to a Masters of Education degree currently is underway at Cologne University analyzing zoo holdings of threatened Malagasy freshwater fish worldwide. The results of this work will be made publicly available soon (Leiss et al., in prep.). The results then can be used for optimized conservation breeding and network development measures.

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Zusammenfassung

Als eine der größten Inseln weltweit ist Madagaskar mit seinem hohen Grad an endemischer Biodiversität ein globaler Hotspot des Artenschutzes. Mehr als zwei Drittel der 169 madagassischen Süßwasserfische, die bisher wissenschaftlich benannt worden sind, sind für Madagaskar endemisch und viele davon dazu noch mikroendemisch, d. h. sie sind nur aus sehr kleinen Arealen oder einem einzelnen Gewässereinzugsgebiet bekannt. Es spricht vieles dafür, dass Fische die am stärksten bedrohte Wirbeltiergruppe auf Madagaskar darstellen. Maßnahmen zur Lebensraumerhaltung sind dringend erforderlich, um durch Entwaldung, Überfischung und das Einbringen invasiver Arten verursachten Aussterbeereignissen entgegenzuwirken. Für viele Arten wurden bereits im Jahr 2003, d. h. vor knapp zwei Jahrzehnten, *ex situ*-Erhaltungszuchten als einzige derzeit greifende Bewahrungsmaßnahmen eingefordert, um drohende Aussterbeereignisse abzuwenden. Hier berichten wir über die erfolgreiche Haltung und Nachzucht des aplocheiliden Ährenfischverwandten *Pachypanchax sakaramyi*, der bedotiiden Ährenfischverwandten *Bedotia madagascariensis* und *Rheocles vatosoa* (alle stark bedroht) und den seltenen Buntbarschen *Ptychochromis insolitus* (vom Aussterben bedroht) und *P. loisellei* (stark bedroht), alles gefährdete endemische Süßwasserfische aus Madagaskar, die im Aquarium des Kölner Zoos in Deutschland gehalten werden. Unser Bericht ist kombiniert mit ersten Ergebnissen unserer fortwährenden DNA-Barcoding-Analysen von *ex situ*-Beständen madagassischer Süßwasserfische. Da eine korrekte Identifizierung für Erhaltungszuchtprogramme ausschlaggebend ist, insbesondere wenn Rückführungen bzw. Populationsaufstockungen im natürlichen Lebensraum anstehen, sequenzierten wir zur exakten spezifischen Identifizierung ein Segment des mitochondrialen 16S rRNA Gens von den derzeit neun endemischen, im Kölner Zoo gehaltenen Süßwasserfischarten aus Madagaskar. Weiterhin geben wir Empfehlungen hinsichtlich des Schutzstatus der auf der Roten Liste der Weltnaturschutzunion (IUCN 2020) aufgeführten endemischen madagassischen Süßwasserfische, die in dieser Studie abgehandelt werden, gemeinsam mit den nach 2003 wissenschaftlich benannten Arten. Damit möchten wir eine Vorleistung für künftige formale Neubewertungen des Status dieser Arten erbringen. Für *Pachypanchax sakaramyi*, *Bedotia madagascariensis*, *Rheocles vatosoa*, *Ptychochromis insolitus* und *P. loisellei* tragen wir in den jeweiligen Artkapiteln Informationen zu den diagnostischen Merkmalen, zur Verbreitung, Populationsgröße, Bedrohung und zum Schutzstatus zusammen. Darüber hinaus haben wir die Zoo-Datenbank ZIMS (Zoologische Informations-Management Software von Species360) zusammen mit der Europäischen Datenbank Zootierliste ausgewertet, um aktuelle Information über die institutionelle bzw. Zoohaltung zuvor genannter Arten zu erhalten. Der Kölner Zoo erhielt *Rheocles vatosoa*, *Ptychochromis insolitus* und *P. loisellei* 2019 vom Toronto Zoo in Kanada. Keine der Arten war zu diesem Zeitpunkt in einem deutschen

Zoo vertreten. *P. loisellei* wurde darüber hinaus in Europa weder institutionell noch privat gehalten. Der von der internationalen Madagaskar Fauna und Flora-Gruppe mit initiierte Transfer besagter Arten vom Toronto Zoo zum Kölner Zoo war demnach die Gründung sowohl der Haltung dieser Arten in Deutschland als auch der Aufbau einer Erhaltungszucht für diese und andere madagassische Süßwasserfische in Europa. Aufgrund der erfolgreichen Nachzucht von drei der aus Toronto erhaltenen bedrohten madagassischen Fischarten im Aquarium des Kölner Zoos und der nachfolgenden Verteilung des Nachwuchses in derzeit neun andere Zoos, konnte ein erster wichtiger Beitrag zum Aufbau eines Erhaltungszuchtnetzwerks bedrohter madagassischer Süßwasserfische in Europa geleistet werden: Bislang wurden bereits 215 *Ptychochromis insolitus* und zusätzlich 90 *P. loisellei* von Köln aus an europäische Zoos verteilt. Derzeit werden weiterhin gemeinschaftlich Citizen Conservation Programme – zunächst in Deutschland – für bedrohte madagassische Süßwasserfischarten etabliert, um das Erhaltungszuchtnetzwerk mit engagierten Privathaltern zu erweitern.

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Zool. Garten N.F. 88 (2020) 157-158

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Buchbesprechungen

Sabine Begall, Hynek Burda, Radim Sumbera (2018). Graumulle. *Cryptomys* und *Fukomys*. Die Neue Brehm-Bücherei 679. VerlagsKG Wolf. Magdeburg. 460 Seiten, 108 Farbfotos, 73 Grafiken, 10 Tabellen. ISBN 978-3-89432-253-3. 39,95 €.

Eine lange Geschichte von der Ankündigung bis zum Erscheinen der Monografie über Graumulle ging letztlich erfolgreich zu Ende – gemäß des lateinischen „habent sua fata libelli". Den siebenjährigen Werdegang haben die Autoren im Vorwort beschrieben: Frau Prof. Dr. Sabine Begall (Lehrstuhlinhaberin für Allgemeine Biologie an der Universität Duisburg-Essen), Prof. Dr. Hynek Burda (Lehrstuhlinhaber für Allgemeine Biologie an der Universität Duisburg-Essen und Gastprofessor an der Südböhmischen Universität Budweis) sowie Prof. Dr. Radim Sumbera (Professor an der Südböhmischen Universität Budweis, seiner ursprünglichen Alma Mater). In sieben ausführlichen Kapiteln behandeln die Autoren die Familie der Sandgräber (Bathyergidae), wobei das erste die Systematik behandelt. Hierbei werden neben den beiden Gattungen der Graumulle auch Nacktmull, Silbermull, Strandgräber und Blessmull in Wort und Bild vorgestellt. Ein besonderer biologischer Blick wird bei der Diskussion systematischer Feinheiten spürbar, beispielsweise bei der Frage, ob die Nacktmulle nicht in eine eigenständige Familie zu stellen seien. Hierzu die Autoren: „Letztendlich ist es egal, ob wir denken, dass Nacktmulle so besonders sind, dass sie den Status einer eigenen Familie verdienen, oder eben nicht. Wir sollten im Hinterkopf behalten, dass es sich bei der höheren taxonomischen Klassifikation stets um unsere subjektive Meinung handelt." Der zweite Abschnitt „Wo leben Sandgräber? Habitat und Gangsysteme" behandelt Habitate, Nahrungsangebote, Gangsysteme inklusive Futterkammern, Schlafnestern, Latrinen, Ventilation, Feuchtigkeit und Temperatur. Im dritten Kapitel „Ökomorphologie und Ökophysiologie der Sandgräber" geht es um Graben und Grabtechniken, Thermoregulation und Stoffwechsel, Ernährung und Verdauung. Kapitel vier ist „Sinneswahrnehmung und Kommunikation" gewidmet. Was und wie sehen, hören, tasten, riechen Graumulle? Wie kommunizieren Graumulle (akustisch und seismisch)? Wie finden sie ihre Nahrung? „Orientierung in Raum und Zeit" heißt Abschnitt fünf. Neben der räumlichen Orientierung im Labyrinth ist die Orientierung am Erdmagnetfeld besonders spannend. Es folgt die „Lebensgeschichte" in Kapitel sechs. Tragzeit, Neugeborene, Kindheit, Fortpflanzung, Alterung, Sexualverhalten und die wichtige Frage der Eusozialität, die für Nacktmulle und Graumulle festgestellt werden konnte, sind Thema. Nur ein (oder wenige Weibchen, „Königin") sind gebärfähig und werden von den wenigen Männchen begattet. Der große Teil der anderen Koloniemitglieder ist asexuell und fungiert als Helfer der Gemeinde, also ein Sozialbild, wie wir es von Staaten bildenden Insekten kennen. Schon 1957 hat der deutsche Zoologe Professor Dietrich Starck in der „Zeitschrift für Säugetierkunde" über die Soziologie von Nacktmullen berichtet. Das letzte Kapitel „Graumulle und Mensch" beschäftigt sich mit der Haltung und Zucht in Menschenhand, der Bewertung der Mulle in Afrika als Schädlinge und Bereicherung des Kochtopfs. Abgeschlossen wird das

Buch mit einem überaus umfangreichen Literaturverzeichnis und einem Register. Für jeden Säugetierkundler und jede Zoobibliothek ist der NBB-Band „Graumulle“ ein Muss!

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Wolf-Rüdiger Große (2020), Der Fadenmolch, *Lissotriton helveticus*. Die Neue Brehm-Bücherei 503, 1. Auflage, VerlagsKG Wolf, Magdeburg. 140 Seiten, 105 Abbildungen, 5 Tafeln, 7 Tabellen. ISBN 978-3-89432-285.4. 19,95 €.

Privatdozent Dr. Wolf-Rüdiger Große, Dozent i. R. der Martin-Luther-Universität Halle-Wittenberg, ist seit früher Jugend begeisterter Terrarianer und Feldherpetologe, dessen Publikationsliste über 400 Titel umfasst. In NBB erschienen von ihm die Bände 615 „Der Laubfrosch“ und 117 „Der Teichmolch“ (1954 mit gleicher Bandnummer von Günther E. Freytag). Nun legt Wolf-Rüdiger Große „Der Fadenmolch“ vor, erstmalig für die NBB, abgesehen von einer kurzen Behandlung (S. 32-33) im Bd. 49 „Einheimische Lurche und Kriechtiere“ von Erhard Frommhold (1952). Das Buch umfasst 16 Abschnitte. Nach Einleitung und Beschreibung folgt das Kapitel Anatomie und Physiologie, das u. a. Haut, Sinnesorgane, Urogenitalsystem und Entwicklungsbiologie behandelt. Erstbeschreibung (1789), taxonomischer Status, Namen, Unterarten und Phylogenie sind Gegenstand des Abschnitts Systematik und Phylogenie. Die folgenden Kapitel geben über Verbreitung, Lebensräume und Nahrung Auskunft, im Weiteren werden jahreszeitliche sowie Tag- und Nachtaktivität beschrieben. Beim Thema Populationsbiologie geht es um Geschlechterverhältnis, Altersstruktur und Höchstalter (8-12 Jahre). Im neunten Kapitel dreht es sich um Fortpflanzung und Entwicklung: Paarung, Eiablage, Entwicklung und Metamorphose. Gefährdung und Schutz – hier sind regionale Unterschiede zu beachten, wenn auch die Art insgesamt noch in vielen Gebieten nicht bedroht erscheint. Klimatische und umweltbelastende Faktoren sind jedoch zu berücksichtigen. Forschungsziele sind Nachweise von Fadenmolchen im Gelände, Fotografie und genetische Untersuchungen. Kapitel 12 ist Haltung und Pflege inklusive Fortpflanzung im Terrarium gewidmet. Die abschließenden Kapitel 13 bis 15 umfassen englische und französische Zusammenfassungen, Danksagung und eine überaus umfangreiche Bibliografie. Beschlossen wird „Der Fadenmolch“ mit dem Register. Die reichhaltige Ausstattung mit Abbildungen ergänzt den Text trefflich. Jedem an Zoologie, Herpetologie und Tierhaltung Interessierten sowie Bibliotheken – ob privat oder in Tiergärten – sei „Der Fadenmolch“ uneingeschränkt empfohlen.

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DER ZOOLOGISCHE GARTEN ist eine internationale, wissenschaftliche Zeitschrift, die allen die Tiergärtnerei (im weitesten Sinne) betreffenden Originalarbeiten offensteht. Neben größeren Abhandlungen werden Kurzmitteilungen und Nachrichten aus Zoologischen Gärten aufgenommen.

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Aims and Scope

DER ZOOLOGISCHE GARTEN covers all aspects of zoological gardens, as for example

- experiences in breeding and keeping zoo animals
- management of zoological gardens
- behavioral science
- research on animals in the wild
- conservation of rare and threatened species
- reintroduction projects
- planning, building and designing at zoological gardens including horticulture
- veterinary medicine
- zoological pedagogic
- history of zoological gardens
- news from zoological gardens
- book reviews

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