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Review article

Changing parasite landscapes in captive primates: methodological advances and findings from the Wrocław Zoo

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ABSTRACT. Long-term parasitological studies of non-human primates (NHPs) kept in zoological gardens offer valuable insights into host–parasite relationships in controlled settings. Despite regular veterinary supervision and preventative measures, many surveys have shown that captive primates often harbour diverse intestinal parasites, including species of zoonotic importance. This work summarises the historical and current parasitological research conducted on primates at Wrocław Zoological Garden, Poland, and highlights changes in diagnostic techniques, parasite diversity, and infection patterns over time. Early studies, employing classical coproscopic methods such as direct smear, decantation, and flotation, reported an overall parasite prevalence of around 40%, mainly nematodes. Later investigations expanded sampling strategies, enabling assessment of anthelmintic efficacy and resistance in specific taxa. Environmental and managerial factors – including close contact with caretakers and visitors, limited enclosure space, and inadequate pest control – were identified as key contributors to transmission. Over the past twenty years, the use of molecular diagnostic tools has considerably improved detection sensitivity, particularly for intestinal protozoa that were often missed by traditional microscopy. A notable shift in the parasite community composition has been observed: helminth prevalence has decreased, while protozoan infections have become more frequent. Whether these changes are due to methodological advancements or actual alterations in parasite ecology remains uncertain. Overall, the findings indicate that enhancements in husbandry, enclosure hygiene, and veterinary care have effectively reduced helminth transmission, yet protozoan infections continue to be common. Ongoing monitoring with molecular methods, alongside comparative studies across European zoological institutions, is essential for a comprehensive understanding of the long-term dynamics of primate parasitism in captivity.

Introduction

For many decades, zoos have been a vital source of knowledge about various species of animals kept in controlled environments. These settings, where animals are confined to limited spaces and specific conditions, provide an excellent platform for scientific research across numerous biological and medical disciplines. Primates, in particular, have long attracted the interest of researchers, as they are the group of animals most closely related to humans in both evolutionary and behavioural terms. Historically, these species have been the focus of zoologists, anthropologists, biologists, veterinarians, and a wide range of other specialists, including parasitologists.

According to theoretical assumptions, animals kept in captivity, subject to continuous health monitoring and appropriate prophylactic measures, should not exhibit a high prevalence of parasites. However, numerous studies conducted over the years have demonstrated that primates in zoological gardens also host a wide range of parasites, including species with potential zoonotic importance [1–23].

In Wrocław, the tradition of studying the parasitic fauna of exotic animals has a long history, with local scientific institutions continuously collaborating with zoological gardens, especially the Wrocław Zoological Garden [8–10,14–16, 18,21,22].

Research on primates at Wrocław Zoo would not, however, have been possible without the primates themselves and the facility of the zoological garden, which in 2025 celebrated the 160th anniversary of its founding [24]. To better understand the external factors to which primates were historically exposed, as well as the conditions under which they lived, it is necessary to begin at the institution's inception, namely in 1863, when the initial concept and plans for opening a zoo in then-German Breslau were formulated [24–27].

The history of Wrocław ZOO

The history of the Wrocław Zoological Garden dates back to the second half of the 19th century. The formal opening of the facility, situated on the floodplain of the Oder River in then-Breslau, took place on 10 July 1865. In its early years, the zoo became popular among the local community; in 1870 alone, nearly 90,000 visitors were recorded. Interestingly, the earliest primate exhibits at the zoo did not include non-human animals but rather humans. In the 1870s, following the models of French and English "human zoos", ethnographic displays were organised in Wrocław, where entire groups of people from other continents were brought in to showcase aspects of their daily lives in staged settings. While today such exhibitions are unquestionably criticised, at the time they were among the main attractions of the zoo [24,26].

During the same period, the first non-human primates were introduced to the zoo, and in 1866, the primate house, designed by Karl Schmidt, was completed. In the following decades, the primate collection was expanded to include additional species, such as chimpanzees and orangutans, which were maintained in relatively good condition by the standards of the late 19th century. A particularly significant event was the arrival in 1897 of a gorilla named Pussi – the first gorilla not only in the history of this zoo but also in this part of Europe. Its presence marked a turning point in the perception of great apes; contrary to the prevailing notion of gorillas as "wild and brutal beasts", Pussi exhibited sociable and curious behaviour, maintaining close contact with keepers. Her 11-year lifespan in the zoo was exceptional for that period, as most gorillas brought to Europe did not survive beyond 1 year [24,26].

At the turn of the 19th and 20th centuries, the Wrocław primate house experienced continuous expansion and modernisation. In 1887, a new pavilion was erected, and at the beginning of the 20th century, outdoor enclosures were added to address issues such as rickets in monkeys. Simultaneously, focus was given to veterinary care, exemplified by a successful cataract operation on a spider monkey in 1904, which received wide coverage in the contemporary press [24–27].

Despite its vigorous development, the zoo's operations were frequently interrupted by historical events. After World War I, the zoo closed in 1921, and its inhabitants were redistributed to other German zoos. It reopened in 1927, with the primate collection subsequently expanded once more. In the 1930s, public primate training demonstrations became a major attraction, drawing large crowds. During this period, great apes were exhibited performing tasks such as riding bicycles, wearing costumes, and being held by visitors, with direct and almost unrestricted contact with the public. While these practices were very popular at the time, they now clearly demonstrate a lack of awareness regarding animal welfare and the epidemiological risks associated with such close interactions [24–27].

World War II, however, marked a period of profound tragedy for the zoo. During the siege of Festung Breslau in 1945, although no explicit directive to destroy the animal collection has been documented, most of the large mammals and carnivores were nonetheless shot, while aerial bombardments caused severe damage to the zoo's facilities. Primates that had been evacuated or confined under improvised conditions largely failed to survive the winter. Postwar records indicate that only about 30 individuals representing various primate species remained, most of whom were subsequently transferred to other Polish zoological gardens. The zoo reopened successfully in 1948, marking the start of a new chapter under Polish administration. Karol Łukaszewicz became the first Polish director of the now officially Polish institution, initiating the systematic reconstruction of the primate collection [24,26,27].

The 1960s and 1970s marked a new phase in the history of Polish zoological gardens: a period of systematic scientific research on zoo animals, including primates [28,29]. A key milestone was the establishment in 1962 of a specialised parasitology laboratory in Łódź [29]. This centre did not limit its analyses to animals from its own zoo but initiated extensive studies covering zoological gardens throughout Poland. As a result, a network of systematic parasite observations in zoo animals was created, positioning Łódź as a natural centre for zoo parasitology [28–29].

In Wrocław, a significant moment occurred in 1966 when Antoni Gucwiński became the director after Karol Łukaszewicz's retirement. Under his leadership, many rare primate species were introduced to the zoo; between 1970 and 1974, thirteen gorillas were imported from Cameroon, which were hand-reared by Hanna Gucwińska in a private apartment. The need to provide suitable conditions for these animals led to the construction of a specialised pavilion for gorillas and orangutans (completed in 1976) and a summer enclosure for fossa (completed in 1980). Although home nursing of wild animals might seem controversial today, the gorillas became the symbol of Wrocław Zoo, and their reproductive success and longevity demonstrated the improving expertise of the institution in care and research [26,27].

During this period, Wrocław also gained international recognition. In June 1972, the XIV International Symposium on Diseases of Zoo Animals was held in the city, attended by 250 participants from 25 countries. This event promoted closer collaboration among veterinarians, directors, and scientists across Europe and underscored the growing role of Polish zoological gardens in research on the health of exotic animals [26,31–33].

The intensive organisational and scientific development rapidly translated into research outputs. By the mid-1970s, the first series of systematic parasitological studies on primates in Polish zoos, including Wrocław, began to emerge. Their analysis reflects both the state of knowledge at that time and the changes in the approach to caring for exotic animals in captivity [9,15,16,21,22].

The 1970s and the first series of parasitological research on Wroclaw's primates

The earliest scientific reports on primate parasites at Wrocław Zoo appeared in the 1970s, coinciding with a period of increased research into the health of exotic animals in Poland. Wrocław, owing to its academic traditions and close collaboration between the zoo, the University of Wrocław, and the Agricultural Academy (now the Wroclaw University of Environmental and Life Sciences), became one of the country's foremost centres of zoo parasitology. The analyses covered both great apes and a variety of lesser primates, aiming not only to characterise the parasitic fauna but also to identify potential risks to public health [9,15,16,21,22,28,34].

One of the earliest studies that guided subsequent research on primate parasitic fauna at Wrocław Zoo was Olga Paciepnik's master's thesis in 1974, supervised by Associate Professor Janina Złotorzycka. The study investigated intestinal parasites found in monkeys kept at Wrocław Zoo, using coproscopic methods. Although simple, the methodology employed provided the first systematic overview of the parasite species in captive primate populations [15].

The author references data from various zoological gardens, noting that in some cases, up to 35% of primate mortalities were associated with parasitic diseases [1]. Studies carried out at Brno Zoo revealed that all examined individuals were infected with *Trichocephalus* (now *Trichuris*) [35]. Likewise, high infection rates have been documented in other zoological gardens across Europe and worldwide [2,34,36]. However, the author emphasises that parasite identification and classification were often limited to the family level, which hampers accurate epidemiological assessments [15].

The study also describes the housing conditions and the surrounding environment where the animals lived, with particular attention to daily hygiene routines and environmental factors influencing primate health. Enclosures were cleaned twice daily with water and detergents; however, thorough disinfection was not carried out, which could allow parasites to survive. Nonetheless, the author stresses the important role of staff in maintaining cleanliness and conducting regular animal observations, enabling early detection of health issues. Faecal samples were collected early in the morning before visitors arrived. In total, approximately 1,549 faecal samples were obtained from 42 primates representing 18 species: *Cercopithecus neglectus*, *Cercopithecus lhoesti*, *Colobus polykomos*, *Hylobates hoolock*, *Pan troglodytes*, *Papio cynocephalus*, *Hylobates lar*, *Erythrocebus patas*, *Cercopithecus mona*, *Presbytis obscurus*, *Cercocebus t. torquatus*, *Macaca irus*, *Cercocebus t. atus*, *Macaca mulatta*, *Cebus apella*, *Theropithecus gelada*, *Papio papio*, and *Gorilla g. gorilla*. Additionally, faecal samples from primate house staff were analysed [15].

The results indicated that 18 individuals (42.8%) were infected. The study detected one species of symbiotic protozoa, one species of trematode, and eight species of nematodes, including *Trichocephalus trichiurus*, *Strongyloides* sp., *Ancylostoma duodenale*, *Necator americanus*, Capillariinae, *Dicrocoelium dendriticum*, *Hepaticola hepatica*, *Gongylonema pulchrum*, *Ascaris lumbricoides*, and *Oesophagostomum apiostomum*. Analyses of personnel faeces were negative [15].

The prevalence of individual parasite species was as follows: *Trichocephalus* – 30.2%, *Strongyloides stercoralis* or *S. papillosus* – 11.9%, *Ancylostoma duodenale* or *Necator americanus* – 11.9%, Capillariinae – 9.1%, *Dicrocoelium dendriticum* – 2.3%, *Hepaticola hepatica* – 2.3%, *Gongylonema pulchrum* – 2.3%, *Ascaris lumbricoides* – 2.3%, *Oesophagostomum apiostomum* or Ancylostomatidae – 2.3%. No pathogenic protozoa or cysts were detected.

The author provides a detailed description of the methods used: samples were transported in prewashed and dried plastic containers, and faeces were collected every other day over several months. The analyses included direct faecal examination, decantation, the Fulleborn method, and the De Rivas method. In the direct smear technique, faeces were mixed with physiological saline, with the author noting that this method was only effective when egg concentration exceeded 500 eggs per gram of faeces. The decantation procedure employed a modification of the Telman method, as described by De Rivas, which involved ether, a reagent commonly used in laboratory studies of that period. Flotation was performed using the Kafoid and Barber method in the Bass-Fulleborn modification. Permanent slides prepared from decantation and De Rivas methods were used for parasite identification and for quantifying egg counts across entire faecal samples [15].

Compared to other European studies, the author concluded that primate health in Wrocław Zoo was relatively good, with lower infection rates than reported elsewhere [15,16]. According to the author, factors contributing to this included high hygiene standards, the addition of black currant to their feed - which is believed to have an antiparasitic effect – and vitamin supplements to enhance primate immunity [15,16]. The findings of this master's thesis also formed the basis for a scientific publication in *Wiadomości Parazytologiczne* [16] titled "Pasożyty jelitowe małp z ogrodu zoologicznego we Wrocławiu".

In the latter half of the 1970s, research on primate helminth fauna at the Wrocław Zoo continued through two master's theses supervised by Associate Professor Jadwiga Złotorzycka. Both were completed in 1978: one focusing on apes [21], and the other on Strepsirrhini, Tarsiiformes, Platyrrhini, and Cercopithecoidea primates [22]. Consequently, earlier research was expanded into a more detailed analysis of parasitic fauna across both systematic groups [15,16].

Rzeczkowska's study encompassed the entire ape population at Wrocław Zoo, consisting of 30 individuals representing gorillas, chimpanzees, orangutans, and gibbons. She provided a detailed account of animal husbandry conditions, routine coproscopic examinations, and preventative measures, including regular deworming and the administration of blackcurrant extract in feed to prevent enterobiasis. The study material comprised 660 faecal samples collected from March to December 1977. A variety of coproscopic methods was utilised, with decantation proving the most effective. Eggs from various parasites were identified, including *Dicrocoelium dendriticum*, *Ancylostoma duodenale*, *Trichuris trichiura*, *Strongyloides stercoralis*, *Enterobius vermicularis*, and *Ascaris* sp. Notably, *Dicrocoelium* eggs were found in a gorilla showing clear clinical signs. Infection levels ranged from low in gorillas to high *Trichuris* burdens in orangutans. Initial therapeutic trials indicated that helmintazol (active ingredient: tiabendazol) was ineffective against whipworms and pinworms; however, subsequent treatments with mintezol and pyrantel embonate successfully eradicated most parasites from the studied group [21].

Simultaneously, Semczuk studied a group of 29 primates from six species. Samples were collected throughout 1977 using coproscopic methods such as smear, modified Telman, and decantation, and the digestive tracts of deceased animals were also examined. A wide range of intestinal parasites was identified, including *Strongyloides stercoralis*, *S. papillosus*, *Ancylostoma duodenale*, *Trichuris trichiura*, Capillariinae, *Ascaris lumbricoides*, *Hymenolepis diminuta*, *Enterobius* (possibly *vermicularis*), and *Oesophagostomum apiostomum*. Nematodes, especially *Strongyloides* and *Ancylostoma*, showed high prevalence, while whipworms exhibited the highest infection intensity and notable resistance to treatments. The author notes differences between the *Enterobius* nematode found in primate faeces and those described in the literature, raising the possibility of a different species or subspecies. Environmental factors, such as outdated pavilion infrastructure, small enclosures with contaminated soil, the presence of rodents and synanthropic insects, and close contact with visitors, were recognised as key in maintaining parasite life cycles. Together with necropsy observations, these findings emphasise the complexity of parasitic infections in primate husbandry and the epidemiological risks linked to zoo conditions [22].

Both 1978 studies significantly expand previous research by showing that, despite prophylactic measures and regular deworming, parasitic infections continued to be widespread among both great and lesser primates. The studies also highlighted the impact of environmental conditions, parasite drug resistance, and risks of interspecies transmission, including potential human involvement as a source or intermediary in parasite life cycles. Additionally, an article in *Wiadomości Parazytologiczne* was published, summarising both studies [9,21,22].

New decade = new research in the 1980s

The 1980s brought significant changes both to the operation of the Wrocław Zoo and to the wider sociopolitical landscape of the country. This period was particularly difficult, marked by rapid development in some aspects of zoo management on one hand, and tensions stemming from domestic political issues on the other. The director, Antoni Gucwiński, who had led the zoo since 1966, became the centre of personnel and political disputes in the years before and during the martial law period. He was accused of mistreating staff, while he claimed that certain employees deliberately neglected the animals and even poisoned them. In 1982, Gucwiński made a drastic move, dismissing 20 staff members, including all active members of the "Solidarność" movement [26,27].

Despite these organisational and political tensions, the zoo continued to enhance its infrastructure. In 1987, the process of connecting all pavilions and buildings to the municipal power and heating network was completed, greatly improving the ability to maintain suitable living conditions for animals during winter. Previously, the zoo operated 22 independent boiler houses, which posed logistical challenges and incurred high costs. This modernisation coincided with record attendance, with 805,000 visitors in that year – the highest in the zoo's history. However, critical voices also emerged. In 1988, the director was accused of inadequate supervision of the facilities, citing disorganised, dilapidated infrastructure and "animal sadness", which allegedly damaged the zoo's image as a modern institution.

All these circumstances – personnel tensions, infrastructure modernisation, and increasing expectations regarding animal welfare – created a new context for scientific research conducted at the Wrocław Zoo. During this period, parasitological analyses of primates were continued and expanded. Those became increasingly systematic and based on refined methods, responding to the challenges of intensified husbandry and growing awareness of the importance of animal health [8,10].

After nearly a decade-long break, parasitological research on primates at Wrocław Zoo was resumed in the latter half of the 1980s. A new series of analyses was conducted as part of a master's thesis by Beata Kruczkowska, supervised by Dr Anna Okulewicz, in 1987, titled *Intestinal Parasites of Primates from the Wrocław Zoological Garden* (*based on coproscopic examinations*) (original title: *Pasożyty jelitowe małp wrocławskiego ogrodu zoologicznego /na podstawie badań koproskopowych*). These findings were subsequently published in *Wiadomości Parazytologiczne* in 1988 under the title *Intestinal Parasites of Primates from the Wrocław Zoo* (original title: *Pasożyty jelitowe małp wrocławskiego ZOO*) by Okulewicz and Kruczkowska. These studies continued the tradition of parasitology research on Wrocław primates, building on the methods employed by Paciepnik, Krynicka, and Rzeczkowska in the 1970s [9,15,16,21,22], while integrating changes related to animal diversity, pavilion modernisation, and insights gained from previous invasive and non-invasive coproscopic analyses [8,10].

Kruczkowska's master's thesis examined changes in animal species composition and noted the lack of updated data since studies from the 1970s. In the literature, she referenced earlier European reports indicating primate deaths caused by protozoan infections [3,4] and emphasised the effect of stress on weakened immunity in primates, particularly concerning their contact with visitors [37]. At the XIII International Symposium on Diseases of Non-Domesticated Animals in Helsinki in 1971, the main causes of primate mortality in zoos were identified as protozoan diseases (30.6%), parasitic infections (28%), and tuberculosis (25%) [28,31].

Research material was collected from July 1986 to April 1987 from 35 primates, including 15 apes and 20 primates from other groups, housed in two pavilions. Animals were kept in pairs within their enclosures. During winter, all individuals remained indoors, whereas in summer, chimpanzees had access to an island surrounded by a dry moat and additional fencing. In one of the pavilions, animals could interact through metal bars but were separated from humans by glass. Enclosures and furnishings were cleaned twice daily with water and detergents, whereas cockroach disinfection was carried out sporadically. All primates were prophylactically dewormed once per year, with medications administered via feed [8,10].

Faecal samples were collected roughly every 2 days during morning cleaning at 7:15 a.m., with particular attention paid to examining fresh material to detect protozoan trophozoites. Nine primate species were studied: *Pan troglodytes*, *Hylobates lar*, *Pongo pygmaeus*, *Cercopithecus neglectus*, *Cercopithecus mona*, *Ateles belzebuth*, *Conopithecus niger*, *Colobus abissynicus*, and *Erythrocebus patas* [8,10].

Three methods were used together: direct smear, decantation, and Fulleborn flotation. Parasite treatment involved fenbendazole. Six nematode species were identified: *Trichocephalus trichiurus* (25.7%), *Capillaria* sp. (51.4%), *Strongyloides stercoralis* (17.1%), *Nematodirus weinbergi* (single case), *Ascaris lumbricoides* (17.1%), and *Enterobius vermicularis* (28.6%), with pinworms notably common in young chimpanzees and recorded for the first time in lesser primates. The overall infection rate was 80%. Flotation was the least effective method, while the direct smear demonstrated the highest sensitivity [8,10].

Follow-up examinations were conducted at 4-day and 8-day intervals, with deworming repeated three times. After the initial treatment, *Strongyloides* and *Ascaris* were eradicated, but *Trichocephalus*, *Enterobius*, and *Capillaria* persisted. Following a second dose given three weeks later, the presence of parasites gradually decreased, with complete removal only after the third application. *Nematodirus* was recorded for the first time in the history of the Wrocław Zoo. No protozoan cysts were detected [8,10].

The author emphasised the significance of primate-human contact and the potential risk of parasite transmission through unwashed vegetables or objects brought into enclosures by children, despite regulations forbidding feeding. Environmental conditions within pavilions – high temperature and humidity – may have further promoted parasite spread [8, 10].

The turn of the 20th and 21st centuries

At the junction of the 20th and 21st centuries, the Wrocław Zoo underwent significant infrastructural and ecological changes. In 1997, the city faced the so-called "millennium flood", which raised water levels in ponds and flooded the basements of several pavilions. Fortunately, there were no direct animal losses; the only casualty was a zebra, which panicked upon seeing a landing helicopter. Poland's accession to the European Union in 2004 compelled the zoo to modify its operations to comply with new EU regulations and directives, particularly those related to animal welfare, hygiene standards, and veterinary oversight.

More than a decade after the studies conducted in the 1980s, research on the intestinal parasites of primates at the Wrocław Zoological Garden was resumed. The results of these investigations were published in 2000 in the German journal *Der Zoologische Garten* by Okulewicz, Barańska, and Filla, representing a continuation of earlier observations and analyses [14]. The study, carried out in 1997, involved 12 apes (two gibbons, one orangutan, and nine chimpanzees), 50 monkeys from the families Cebidae (including *Ateles belzebuth* and *Cebus apella*) and Cercopithecidae (such as *Cercocebus aterrimus*, *C. torquatus*, *Cercopithecus aethiops*, *C. mona*, *Cynopithecus niger*, *Erythrocebus patas*, *Macaca irus*, *M. mulatta*, *and M. nemestrina*), as well as 80 individuals of *Papio cynocephalus*. In total, 920 faecal samples were analysed. The diagnostic methods employed included direct smears, flotation, and sedimentation techniques. It should also be noted that during the summer months, the animals were routinely dewormed with Fenbesan (substance: fenbendazole) paste, which may have affected the observed parasite load. Parasitological examinations revealed the presence of one protozoan species (*Isospora* sp.) and several nematodes, including *Trichuris trichura*, *Oesophagostomum apiostomum*, *Ascaris lumbricoides*, *Enterobius vermicularis*, and members of the subfamily Capillariinae. The overall prevalence of intestinal parasites was 66.2%, with *T. trichura* being the most common, found in 32.4% of the examined samples [14].

Another significant change occurred in 2007 when Radosław Ratajszczak became the director. That same year, a powerful cyclone struck Wrocław, bringing down trees and causing substantial damage to infrastructure; fortunately, no animals were reported injured. The administration began modernising and optimising zoo areas, including selling surplus fences, decorative items, and scrap metal, which generated about half a million Polish złoty. In October 2007, the renovated primate house was opened to visitors, and in 2008, the new Gibbon Pagoda, a gibbon island, was inaugurated [24,26,27].

The most significant investment in the early 21st century was the Afrykarium, a unique complex dedicated to African fauna and flora, whose construction took several years and was opened to the public in 2014. During this period, the zoo also expanded other pavilions, including the Madagascar Pavilion in 2010, showcasing endemic island fauna, as well as enclosures for snow and clouded leopards, lynxes, and otters. Simultaneously, educational and recreational programmes for visitors were developed. These enhancements allowed the Wrocław Zoo to sustain its status as one of Europe's oldest and most species-rich zoological gardens, attracting approximately 2 million visitors annually and reinforcing its national and international prominence [24].

2023–2025 and a new series of parasitological research in Wrocław Zoo

This decade marks the beginning of a new phase in parasitological research. The studies are being carried out at Zoo Wrocław and other Polish zoological gardens by a team from Wrocław University of Environmental and Life Sciences.

Discussion

Parasitological studies of primates at the Wrocław Zoological Garden, conducted since the 1970s, show a clear evolution in analytical scope, although the methods used up to the year 2000 remained largely unchanged. The first systematic observations by Paciepnik [15,16] relied on classical coproscopic techniques, such as direct smear, decantation, and Fulleborn flotation. These studies established the basic composition of intestinal parasites, including nematodes, trematodes, and symbiotic protozoa, with an overall prevalence of approximately 42.8% in the primate population. Despite the relatively simple methodology, the results aligned with contemporary European observations and supported the implementation of the first prophylactic procedures at the zoo [1,2,4,35,36,38].

In subsequent decades, studies by Rzeczkowska and Semczuk in 1978 [21,22] involved larger sample sizes, greater diversity of primate species, and more systematic sample collection [9,21,22]. Repeated faecal analyses and post-treatment control examinations enabled assessment of anthelmintic efficacy and detection of resistance in certain nematode species, including *Trichocephalus trichiurus* and *Enterobius vermicularis*. These findings emphasised the impact of environmental factors, such as close contact with caregivers and visitors, limited enclosure space, and the presence of insects and rodents, as well as the importance of regular disinfection and health monitoring.

Research conducted in the 1980s, notably by Kruczkowska [8], revealed a similar parasitic fauna structure but employed more precise methods for sample collection and preparation, enabling detection of protozoan trophozoites and more accurate assessment of nematode infection levels. These findings suggest that, despite the implementation of prophylactic measures and repeated deworming, intestinal parasites remained a prevalent issue among primates, and animal-human interactions may have facilitated interspecies transmission.

Currently, although classical coproscopic methods are still used, research in Europe and at our institution increasingly focuses on molecular techniques. Such approaches enable more sensitive detection of protozoa, including zoonotic species that may have previously gone unnoticed. At the same time, a notable shift in the dynamics of parasitic fauna has been observed: helminths are detected less often, while protozoan prevalence has risen significantly. Whether this trend results from advances in methodology or actual changes in intestinal parasite composition remains an open question, requiring further systematic investigation using molecular approaches and long-term monitoring.

The decline in helminth prevalence may also be due to improvements in animal care practices within zoological institutions. While the methods used in parasitological research stayed largely the same throughout the 20th century, the environments where animals were kept underwent significant changes. Archival records from 1930 to 1940 show that animals were mainly viewed as visitor attractions, which often led to direct contact with humans and, consequently, increased exposure to zoonotic agents. The life expectancy of primates in the first half of the 20th century was notably short, often measured in months rather than years, highlighting the poor welfare standards of the time. Chronic stress, worsened by inadequate housing conditions, likely contributed to weakened immune systems. Additionally, animal facilities lacked basic infrastructure such as electrical power and central heating, leaving primates particularly susceptible to extreme weather conditions, including harsh winters. Veterinary care in zoological gardens was also quite basic throughout this period.

Major changes took place in the second half of the century, many driven by post-war reconstruction efforts. Increased cooperation with other European institutions encouraged the Wrocław Zoo leadership to adopt progressive standards in line with contemporary European practices. By the 1970s, Gucwiński [32] described inappropriate human–animal interactions and direct handling of animals by tourists as problematic and in need of regulation - a stark contrast to the widespread acceptance of such practices just a few decades earlier. Later, efforts to reduce human contact with animals were intensified, including the introduction of glass barriers and double-walled enclosures. These innovations not only enhanced hygiene standards but also decreased infestations by rodents and other potential intermediate hosts, issues rarely mentioned in modern reports.

Although the overall prevalence of parasites in non-human primates has remained fairly stable across studies, notable shifts in parasite composition have been observed. Nematodes such as *Trichuris trichiura* (formerly *Trichocephalus trichiuris*) continue to be detected in some primates in Poland and other European countries [8–10, 15, 16, 21, 22], whereas earlier reports from the first half of the 20th century described additional taxa, including trematodes like *Dicrocoelium dendriticum* and cestodes such as *Hymenolepis diminuta*, which have not been commonly recorded in surveys published after the 1980s [8, 10, 14, 18]. As mentioned above, the reduction in intermediate hosts (particularly rodents and other pests) likely disrupted parasite transmission cycles. Improvements in both veterinary care and general animal management practices further contributed to these changes. It is also worth noting that, up to the 1970s, many primates were introduced into captivity directly from their natural habitats, exemplified by the gorillas acquired by Wrocław Zoo in 1974. Consequently, some parasitic infections can be presumed to have been carried with very young animals possessing underdeveloped immune systems – parasites that might not normally persist or spread within established captive populations [26,27].

An important question arising from comparing historical and modern studies concerns the apparent underrepresentation of protozoan parasites in earlier research [8–10,15,16,21,22,39]. Although protozoan infections were already recognised as a significant concern in European zoological gardens in the 1970s [17, 23, 31], studies published before 2000 rarely documented protozoan species that are now frequently reported [5-7, 11-13, 19, 20]. The only protozoa identified in historical investigations were *Troglotydella* [15,16] and *Isospora* [14], whereas current studies often report organisms from these and related genera [5–7,11–13]. This discrepancy may mainly reflect differences in detection methods. Protozoans are now often identified using molecular techniques, while earlier methods were limited to microscopic examination of smears or flotation assays, which are less sensitive [5–7,12,13,39]. Another possible explanation is that protozoans and helminths may compete for the same ecological niche within the host. Consequently, when one group shows a high prevalence, the other tends to be less common. Evidence supporting this idea can be found in studies on humans in Mozambique, where molecular diagnostic methods were used to detect small intestinal protozoa, reducing detection bias. In that population, helminth infections had prevalence rates between 40% and 98%, depending on the species, while protozoan infections ranged only from 2% for *Cryptosporidium* spp. to 37% for *Giardia* spp. [40]. Similar findings were reported by Rondón et al. [41] in free-living non-human primates in Colombia, where individuals with a high burden of helminth infection showed lower protozoan prevalence. These observations imply that interspecific interactions and competition for host resources may significantly influence parasite community composition within the host.

Nevertheless, it remains uncertain whether the apparent scarcity of protozoan records in older studies reflects a genuine absence of infection or is instead due to diagnostic limitations. Considering

Table 1. Summary of parasitological studies on non-human primates at the Wrocław zoo

Title	Authors	Year of publication	Nº of individuals	Names of primate species	Nº of samples	Methodology	General prevalence	Parasitofauna present	Other
Pasożyty jelitowe małp z ogrodu zoologicznego we Wrocławiu na podstawie badań koproskopowych (Intestinal parasites of monkeys from the Wrocław Zoological Garden based on coproscopic examinations)	Olga Paciepnik (Master's thesis prepared under the supervision of Prof. J. Złotorzycka)	1974	42	*Cercopithecus neglectus* *Cercopithecus lhoesti* *Colobus polykomos* *Hylobates hoolock* *Pan troglodytes* *Papio cynocephalus* *Hylobates lar* *Erythrocebus patas* *Cercopithecus mona* *Presbytis obscurus* *Cercocebus t. torquatus* *Macaca irus* *Cercocebus t. atys* *Macaca mulatta* *Cebus apella* *Theropithecus gelada* *Papio papio* *Gorilla g. gorilla*	1549	the Telman method as modified by De Rivas; direct stool examination and decantation; the Kafoid and Barber method as modified by Bass and Fülleborn	42.8%	*Troglotydella abasarti* *Dicrocoelium dendriticum* *Strongyloides* sp. *Hepaticola hepatica* *Trichocephalus trichiurus* *Ancylostoma duodenale* *Necator americanus* *Oesophagostomum apiostomum* *Ascaris lumbricoides* *Gongylonema pulchrum* Capillariinae	In addition, stool samples from zoo staff working with primates were examined
Zarobaczenie małp człekokształtnych Wrocławskiego ogrodu zoologicznego przed i po leczeniu (Parasitic infestation of great apes in the Wrocław Zoological Garden before and after treatment)	Maria Rzeczkowska (Master's thesis written under the supervision of Prof. J. Złotorzycka)	1978	30	*Pongo* sp. *Gorilla gorilla* *Pan troglodytes* *Hylobatidae*	660 samples (333 before antiparasitic treatment and 327 after it)	Direct smear methods and concentration techniques (sedimentation and flotation)	51.33% before treatment	*Trichocephalus trichiurus* *Strongyloides* (*stercoralis* or *papillosus*) *Ancylostoma duodenale* *Enterobius vermicularis* *Dicrocoelium dendriticum*	Included the effects of antiparasitic treatment

Table 1. Summary of parasitological studies on non-human primates at the Wrocław zoo (continued)

Title	Authors	Year of publication	Nº of individuals	Names of primate species	Nº of samples	Methodology	General prevalence	Parasitofauna present	Other
Robaczyce jelitowe małp zwierzokształtnych we Wrocławskim Ogrodzie Zoologicznym (Intestinal helminth infections of simian primates in the Wrocław Zoological Garden)	Irena Semczuk (Master's thesis written under the supervision Prof. J. Złotorzycka)	1978	29	*Ateles paniscus,* *Theropithecus gelada* *Cercopithecus mona* *Cercopithecus neglectus* *Erythrocebus patas* *Colobus abissynicus*	171	Thin smear, Telemann method modified according to De Rivas, decantation (sedimentation), and necropsy examinations	89.65%	*Strongyloides stercoralis* *Strongyloides papillosus* *Ancylostoma duodenale* *Trichocephalus trichiurus* Capillariinae *Ascaris lumbricoides* *Hymenolepis diminuta* *Enterobius vermicularis* (?) *Oesophagostomum apiostomum*	Included the effects of antiparasitic treatment, with an additional three *post-mortem* examinations
Pasożyty jelitowe małp wrocławskiego ogrodu zoologicznego /na podstawie badań koproskopowych (Intestinal parasites of primates in the Wrocław Zoological Garden based on coproscopic examinations)	Beata Kruczkowska (Master's thesis under the supervision of Dr A. Okulewicz)	1987	35	*Pan troglodytes* *Hylobates lar* *Pongo pygmeus* *Cercopithecus neglectus* *Cercopithecus mona* *Ateles bezlebuth* *Conopithecus niger* *Colobus abissynicus* *Erythrocebus patas*	760 samples (422 samples before antiparasitic treatment and 338 after it)	Direct smear method, decantation method, Fulleborn flotation method	80%	*Trichocephalus trichuris* *Capillaria* sp. *Strongyloides stercoralis* *Nematodirus weinbergi* *Ascaris lumbricoides* *Enterobius vermicularis*	Included the effects of antiparasitic treatment
Intestinal parasites in primates at the Wrocław Zoo	Anna Okulewicz, Małgorzata Barańska, Izabela Fill	2000	142	*Hylobates lar* *Pan troglodytes* *Pongo pygmaeus* *Papio cynocephalus* *Cercocebus aterrimus* *C. torquatus* *Cercopithecus aethiops* *C. mona* *Cynopithecus niger* *Erythrocebus patas* *Macaca irus* *M. mulatta* *M. nemestrina* *Ateles belzebuth* *Cebus apella*	920	Direct smear, flotation, and sedimentation	66.2%	*Isospora* sp. *Trichuris trichura* *Oesophagostomum apiostomum* *Ascaris lumbricoides* *Enterobius vermicularis* Capilariinae	

that several European studies from the 20th century [17,23,31] did report protozoan infections, under-detection caused by less sensitive or non-specific methods is the most likely explanation.

Conclusions

In summary, the evolution of parasitological research at the Wrocław Zoo – from classical coproscopic analyses to contemporary molecular methods – shows not only increasing diagnostic accuracy and sensitivity but also shifting biological and environmental contexts. The history of the zoo, including infrastructural changes, animal-human interactions, and enclosure modifications, offers an important interpretive backdrop, affecting both animal health and the risk of parasite transmission.

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