

1 Zoos and Research

1.1 Introduction

Zoo research has been something of a Cinderella subject until relatively recently. Most of the work that has been published on zoos has been biological in nature but few academics would describe themselves as zoo biologists.

A major problem for zoo researchers is that very often their work must be conducted in an ad hoc manner, in conditions that are beyond their control. Data are often ‘snatched’ in an opportunistic manner for all sorts of practical reasons: because of the weather, animal management and husbandry routines, changes to group composition, movements and deaths (or births) of animals, time constraints and a whole host of other events. Many studies of animals living in zoos have few subjects because zoos rarely keep large numbers of the same species (Table 1.1). However, there has been a trend towards multi-institutional studies in recent years. For example, Meehan et al. (2016) studied the welfare of elephants (*Loxodonta* and *Elephas*) in 68 North American zoos and Cronin et al. (2020) studied intragroup conflict among Japanese macaques (*Macaca fuscata*) in 10 zoos.

The purpose of this chapter is to review the studies that have attempted to examine the nature of, and trends in, research conducted on zoos and aquariums and the animals living in them.

1.2 The Advent of Dedicated Journals for Zoo Research

The Zoological Society of London (ZSL) has been publishing research since 1830, initially in the *Proceedings of the Zoological Society of London* and the *Transactions of the Zoological Society of London*, now the *Journal of Zoology* (Fig. 1.1). Many of the early papers published by ZSL reported the discovery of new species and matters of general zoological interest that did not relate directly to the Society’s living collections. For example, Richard Owen published papers on the anatomy of the cheetah and giraffe, and the osteology of the orangutan (Owen, 1834; 1839a; 1839b) when he was Hunterian Professor in the Royal College of Surgeons, prior to his appointment as superintendent of the Natural History Department of the British Museum. Others papers, however, described animals received by the zoo from benefactors or collected by the zoo’s staff on their many expeditions. In 1928, Joan

Table 1.1 Examples of studies conducted in zoos using five or fewer animals.

Authors	Study title	No. subjects
Elzanowski and Sergiel (2006)	Stereotypic behavior of a female Asiatic elephant (<i>Elephas maximus</i>) in a zoo	1
Gresswell and Goodman (2011)	Case study: training a chimpanzee (<i>Pan troglodytes</i>) to use a nebulizer to aid the treatment of airsacculitis	1
Zapico (1999)	First documentation of flehmen in a common hippopotamus (<i>Hippopotamus amphibius</i>)	1
Law and Tatner (1998)	Behaviour of a captive pair of clouded leopards (<i>Neofelis nebulosa</i>): introduction without injury	2
Xian et al. (2012)	Suckling behavior and its development in two Yangtze finless porpoise calves in captivity	2
Asa (2011)	Affiliative and aggressive behavior in a group of female Somali wild ass (<i>Equus africanus somalicus</i>)	3
Fischbacher and Schmid (2000)	Feeding enrichment and stereotypic behavior in spectacled bears	3
Franks et al. (2010)	The influence of feeding, enrichment, and seasonal context on the behavior of Pacific walruses (<i>Odobenus rosmarus divergens</i>)	4
Powell and Svoke (2008)	Novel environmental enrichment may provide a tool for rapid assessment of animal personality: a case study with giant pandas (<i>Ailuropoda melanoleuca</i>)	4
Dembiec et al. (2004)	The effects of transport stress on tiger physiology and behavior	5
Leighty et al. (2009)	GPS assessment of the use of exhibit space and resources by African elephants (<i>Loxodonta africana</i>)	5
Penfold et al. (2007)	Effect of progestins on serum hormones, semen production, and agonistic behavior in the gerenuk (<i>Litocranius walleri walleri</i>)	5

Procter, the Curator of Reptiles at ZSL, presented a paper on a Komodo dragon exhibited at one of its scientific meetings:

Procter, J. B. (1928). On a living Komodo Dragon *Varanus komodoensis* Ouwens, exhibited at the Scientific Meeting, October 23, 1928. *Proceedings of the Zoological Society of London*, 98, 1017–1019.

The first volume of the *International Zoo Yearbook* (IZYB) was published by the ZSL as a single bound volume in 1959 and thereafter more-or-less annually. This first volume contained, among other things, articles that focused on new developments in the keeping of great apes in captivity, along with accounts of new ape facilities at the zoos in Antwerp, Zurich, West Berlin, Tokyo and London. It also contained an eight-page ‘International List of Animal Dealers’. This included one L. Gaillard of Buenos Aires, who specialised in supplying

Pumas, Jaguars, Maned Wolves, Wild Cats, Nandus and Wildfowl
and Heini Demmer of Vienna, who specialised in



Fig.1.1 The Zoological Society of London has been at the forefront of the publishing of zoological research since 1830. (A black and white version of this figure will appear in some formats. For the colour version, please refer to the plate section.)

Gorillas, Okapis, Pigmy Hippos, & other African Fauna; Kiang, Kulan, Siberian Tigers, Snow Leopards and various ruminants from Asia.

It is, of course, unthinkable now that an academic publication associated with zoos would publish such a list, although, at the time, it was perfectly legitimate for animal dealers to sell livestock to zoos, provided they complied with the relevant legislation in force at the time.

The IZYG contains reference sections on international studbooks for rare species and a list of the major zoos and aquariums of the world. In more recent volumes the main articles have focused on a particular theme, for example, reintroductions (Vol. 51, 2017), education (Vol. 50, 2016), reptiles (Vol. 49, 2015), freshwater fishes (Vol. 47, 2013) and bears and canids (Vol. 44, 2010).

The *Journal of Zoo and Wildlife Medicine* was originally published as the *Journal of Zoo Animal Medicine*. The first issue was published in 1970 by the American Association of Zoo Veterinarians, and included the following papers:

- Krahwinkel, D. (1970). Primate anesthiology. *The Journal of Zoo Animal Medicine*, 1(1), 4–9.
- Fowler, M., and Gourley, I. (1970). Pyloric stenosis in a Bengal tiger (*Panthera tigris*). *The Journal of Zoo Animal Medicine*, 1(1), 12–16.
- Russell, W., Herman, K. and Russell, W. (1970). Colibacillosis in captive wild animals. *The Journal of Zoo Animal Medicine*, 1(1), 17–21.
- Fowler, M. and Mottram, W. (1970). Amputation of the tail in an Asian elephant. *The Journal of Zoo Animal Medicine*, 1(1), 22–25.

The first dedicated academic journal published as a periodical for general research on zoos and animals living in zoos was *Zoo Biology*. The first issue was published in 1982 and contained contributions from giants in their fields, including Frans de Waal, Hal Markowitz, Terry Maple (the founding editor) and Betsy Dresser. Along with colleagues, they reported on social behaviour in a chimpanzee (*Pan troglodytes*) colony, behavioural enrichment in Asian small-clawed river otters (*Aonyx cinereus*), computerised data collection and artificial insemination in Persian leopards (*Panthera pardus saxicolor*):

Maple, T. L. (1982). Toward a unified Zoo Biology. *Zoo Biology*, 1, 1–3.

Nieuwenhuijsen, K. and de Waal, F. B. M. (1982). Effects of spatial crowding on social behavior in a chimpanzee colony. *Zoo Biology*, 1, 5–28.

Foster-Turley, P. and Markowitz, H. (1982). A captive behavioral enrichment study with Asian small-clawed river otters (*Aonyx cinereus*). *Zoo Biology*, 1: 29–43.

Loskutoff, N. M., Ott, J. E. and Lasley, B. L. (1982). Urinary steroid evaluations to monitor ovarian function in exotic ungulates: I. Pregnanediol-3-glucuronide immunoreactivity in the okapi (*Okapia johnstoni*). *Zoo Biology*, 1, 45–53.

Dresser, B. L., Kramer, L., Reece, B. and Russell, P. T. (1982). Induction of ovulation and successful artificial insemination in a Persian leopard (*Panthera pardus saxicolor*). *Zoo Biology*, 1, 55–57.

Popp, J. W. (1982). Observations on the behavior of captive sitatunga (*Tragelaphus spekei*). *Zoo Biology*, 1, 59–63.

Gerth, J. M., Lewis, C. M., Stine, W. W. and Maple, T. L. (1982). Evaluation of two computerized data collection devices for research in zoos. *Zoo Biology*, 1, 65–70.

Recent interests in visitor studies, animal welfare and molecular biology as a conservation tool were reflected in the July/August 2017 issue of the journal, which carried articles about visitor engagement with a research demonstration on turtle cognition, the effects of visitors on ring-tailed lemur (*Lemur catta*) behaviour, measurement of stress in golden langurs (*Trachypithecus geei*) and the use of molecular tags in sexing birds of prey. The most recent issue of the journal (Vol. 41, March 2022) contains papers on the social organisation of Hamadryas baboons (*Papio hamadryas*), the attachment of zookeepers to the animals in their care, reproduction in giant pandas (*Ailuropoda melanoleuca*), population management in zoos and aquariums, nutrient analysis of ants used as food for pangolins (*Manis pentadactyla*), the dietary management of bears, coprophagy in gorillas (*Gorilla g. gorilla*) and the captive rearing of orphaned wild dogs (*Lycaon pictus*).

An attempt was made to establish a journal dedicated to aquarium research in 1997. Unfortunately, *Aquarium Sciences and Conservation* ceased publication in 2001 after just three volumes due to lack of contributors. Since 2013 two new open access journals dedicated to zoo research have been established. The first was an initiative of the European Association of Zoos and Aquaria (EAZA) – the *Journal of Zoo and Aquarium Research* – and its first issue was published in 2013. The second is the *Journal of Zoological and Botanical Gardens*, which was first published in

2020 and, to date, has published zoo-based studies almost exclusively, with very few papers of botanical interest.

1.3 What Do Zoo Researchers Research?

A number of papers have considered the nature of zoo research and how this has changed over time. Several of these have analysed the topics covered by articles in *Zoo Biology*. Care must be taken in interpreting these studies. It is undoubtedly the case that fewer zoo-based studies are published in *Zoo Biology* than are published elsewhere, and much of the emphasis of the journal is on work conducted in facilities accredited by the Association of Zoos and Aquariums (AZA). If dedicated zoo journals did not exist, zoo research would still be published in journals concerned with, for example, animal behaviour, reproduction and animal welfare, but analysing the topics studied by zoo researchers would be much more difficult. Furthermore, some zoo research is not about animals, and reports of this other work are dispersed among a very wide range of journals concerned with subjects such as visitor studies, cultural history, ethics and law. I am not aware of any review of zoo research that has attempted to gather together and analyse all of the outputs of those who have studied zoos in one form or another. What follows is a brief account of what we know about the nature of zoo research as seen through the eyes of zoo biologists.

1.3.1 Taxonomic Bias and Research Trends

In 1992 Devra Kleiman, working at the Department of Zoological Research at the Smithsonian's National Zoological Park in Washington, DC, reviewed the historical emphases on behavioural research in zoos and concluded that doing behavioural studies of excellence in zoos and aquariums had become more complicated than was previously the case (Kleiman, 1992). She attributed this to three factors. First, there had been significant changes in the aims and objectives of modern zoos, with an increasing focus on conservation. Second, there had been changes of focus in the science of animal behaviour. Third, there had been a tendency for trained animal behaviourists to take positions as curators and directors of zoos, leaving them no time to conduct research.

An analysis of the research subjects of 353 papers published in *Zoo Biology* between 1982 and 1992 found that 287 (81.3%) concerned non-human mammals (Hardy, 1996). Of these, 29.6% were studies of behaviour or behavioural ecology, a further 5.9% involved behavioural/environmental enrichment and 20.2% were studies of reproductive biology. Only 3.8% of all papers were concerned with genetics or population biology, and just 2.3% involved wildlife management. The remaining studies were concerned with nutrition and diet (3.5%), exhibit design and evaluation (1.2%), veterinary medicine (5.6%), captive management (24%) and morphology and development (5.6%).

An examination of 349 papers published in the same journal between 1996 and mid-2004 suggested a significant change in the direction of research carried out in zoos (Rees, 2005b). Reproductive studies replaced behaviour as the largest category (34%). This was followed by studies of nutrition, growth and development (19%) and behaviour and enrichment (17%). Only 2% of studies were concerned with ecology, field biology, conservation and reintroduction, but there was an increase in papers on taxonomy, genetics and population biology (10%).

An analysis of trends in the 395 research articles published in *Zoo Biology* in its first 15 years indicated a taxonomic bias towards mammals (73% of articles), with only 10% of articles on birds, 7% on reptiles and 7% on invertebrates (Wemmer et al., 1997). The predominant research areas were behaviour and reproduction, with, surprisingly, only a small number of papers on demography and genetics. Most papers were multi-authored and arose from institutions in the United States, with 26% of papers resulting from collaborative efforts between zoos and universities. The authors noted that almost one-third of papers were produced by the academic community and did not involve collaborations with zoos or aquariums. They concluded that there was a shortage of research-oriented staff in zoos and that the taxonomic bias discovered was in part the result of many authors publishing in taxon-specific journals.

Information from 991 articles published in *Zoo Biology* in its first 25 years (1982–2006) was evaluated by Anderson et al. (2008). They found that most articles were descriptive accounts that included inferential statistics and/or biological analyses, most concerned captive animals and they concentrated on mammalian behaviour and reproduction, especially in primates (35.5%). Carnivora were the second most popular subjects (23.4% of articles), followed by Artiodactyla (13.9%), Proboscidea (8.8%) and Perissodactyla (6.0%) (Fig. 1.2). The majority of first authors were affiliated with zoos or universities in the United States. Trends during this 25-year period indicated a significant increase in papers that were experimental and dealt with applied science, diet and nutrition, and a significant decrease in descriptive



Fig.1.2 A researcher studying white rhinoceros (*Ceratotherium simum*) in a British safari park.

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papers, work concerning basic science, behaviour and population biology. The number of collaborative articles also increased with time.

A highly skewed distribution across 15 research subject categories was found in an analysis of 904 projects conducted in British and Irish zoos (Semple, 2002). Behavioural studies represented the largest category (40%), followed by studies of environmental enrichment (18%) and reproduction (8%). Studies of the genetics, ecology or conservation of a species were poorly represented, comprising just 5% of all projects.

The popularity of particular research areas is not necessarily reflected in the number of published studies, and discrepancies occur between the number of studies undertaken and the number published (Hardy, 1996). For example, behavioural and behavioural ecology studies made up 22.8% of 302 research projects carried out on mammals by zoo staff in 40 American zoos, but only 5.3% of studies published in the same period (Wiese et al., 1992). Only 19.5% of studies undertaken were concerned with reproductive physiology, but they accounted for almost 31% of all published studies. Natural history or fieldwork studies represented 23.1% of all published studies but only 16.6% of studies conducted.

Some taxa are very poorly represented in zoo research programmes. A survey of the research activity and conservation programmes of 52 North American zoo reptile and amphibian departments found that, of 164 technical papers produced between 1987 and 1997 by the 22 respondent institutions, 79% were conducted by just three institutions and only 16 field studies were reported (Card et al., 1998). Funding specifically for research was received by just one institution. The authors of the study concluded that zoo herpetology departments were not realising their potential for formalised research and conservation projects.

Lankard (2001) listed and categorised 957 publications produced in 1999–2000 by the member institutions of the AZA. Ecology/field conservation/reintroduction was the largest research category by far (27%). The second largest category was veterinary medicine/physiology (15%), followed by behaviour/ethology (9%). Studies of reproductive physiology/technology amounted to only 7% of the total, and nutrition accounted for just 3%. However, with regard to research output this is misleading because the documents examined encompassed a wide range of publications from status reports on individual taxa and recovery plans to papers on how to use a compass and how to make weather recordings. Publications ranged in quality from papers in peer-reviewed journals to technical handbooks, studbooks and items in newsletters.

In an investigation into the gaps in our knowledge of zoo animal management and welfare, Melfi (2009) identified three areas. First, research tended to focus on indicators of poor rather than good welfare. Second, animal husbandry and housing have been historically based on tradition rather than science. Third, a lack of species-specific baseline biological data for many species inhibits zoo research. Melfi noted that, at the time her work was published, studies of animal welfare in zoos had focused mostly on mammals, especially primates, large felids, bears and elephants.

The research contributions of institutions belonging to Canada's Accredited Zoos and Aquariums (CAZA) with respect to biodiversity conservation were analysed for

the first time by Pyott and Schulte-Hostedde (2020). They found that CAZA members published most in the area of veterinary science, but there were publications in biodiversity conservation. The institution's age, research-oriented mission statements and financial assets were significant predictors of research productivity, but overall CAZA institutions published significantly less than members of the AZA based in the United States. This is not surprising as several AZA members have research institutes devoted to conservation.

Research output conducted between 2009 and 2018 has been systematically analysed by Rose et al. (2019). They examined 1,434 papers and the species holdings of zoos recorded in the IZYG (2009–2018). The authors concluded that zoo-themed research has been slowly filling research gaps for an increasing number of species. However, their data set confirmed the bias towards research on mammals, with Carnivora (154 papers) and Primates (294 papers) being represented in more papers than all those covering birds, reptiles, amphibians and fishes put together (204 papers). Rose et al. (2019) found just 17 papers published on zoo-applicable invertebrate research from 2011 to 2018, most of which were concerned broadly with welfare. During the time period examined, a steady increase in publications was detected only for birds. Rose et al. concluded that most publications lead to a specific advancement of knowledge, including the validation of research methodologies, and that zoo-themed research made a meaningful contribution to science. However, they noted that trends in species holdings were not reflected in publication trends.

Bajomi et al. (2010) examined 3,826 publications concerned with animal reintroductions and found that the literature was biased in favour of vertebrates (especially mammals and birds). They concluded that managers working with invertebrates and amphibians are less willing and/or less able to publish their work than those working with mammals and birds.

1.4 The Rise of Research as a Core Activity of Zoos

In Europe systematic scholarly work in menageries began in the mid-1600s and expanded during the Enlightenment (Baratay and Hardouin-Fugier, 2002). Early zoo research was focused on studies of anatomy, physiology and systematics.

By the end of the twentieth century there was evidence of an increased emphasis on research in American zoos. Stoinski et al. (1998) surveyed 173 North American zoos and aquariums and identified an increase in the role of research in AZA institutions in the previous decade, and a doubling of the number of researchers per institution since 1986. However, they found that the most common reasons for American zoos not conducting research were lack of funds, time and qualified personnel. More recently, the factors facilitating research in AZA-accredited zoos have been examined by analysing a questionnaire completed by 231 zoo professionals (Anderson et al., 2010). The majority of respondents conducted behavioural research on animals in a captive setting, held a curatorial position and had their salaries supported by the operating budget of their institution. Approximately 30% held doctorates, 19% held

master's degrees, 34% held bachelor's degrees and 2% held other types of degree. The majority of respondents considered that they were part of a successful scientific programme and they judged that the two most important factors that contributed to this success were support from the chief executive officer and personnel dedicated to conducting scientific programmes.

A survey conducted by EAZA in 2005 found that only 25 (8.3%) of its 301 members had a research department and only about 33% had a research policy. Many EAZA members did not have a research budget and did not disseminate research findings in a publicly accessible format (Reid, 2007). EAZA subsequently launched a research strategy and action plan entitled *Developing the Research Potential of Zoos and Aquariums*.

In spite of this, most of the research conducted in EAZA zoos is produced by a small number of zoos. In the period 1998–2018 the 393 EAZA members contributed a total of 3,345 peer-reviewed papers to the scientific literature (Welden et al., 2020). During this time period more than two-thirds of EAZA members published, with the last decade of the period experiencing a three-fold increase. However, only seven institutions produced more than 100 papers each (representing 37% of the total). The top 10 publishing EAZA institutions produced a total of 1,458 papers: 43.6% of the total. The publication of this research led to an immediate response from staff at the ZSL, who claimed that their research had been under-represented by Welden et al. (2020) as much of the Society's work is published under the auspices of the Institute of Zoology, and individual staff are not associated with either of the ZSL's two zoos (Koldewey et al., 2020).

At least some of the recent interest in zoo research has been driven by changes to international and European Union law. Article 9 of the Convention on Biological Diversity 1992 requires parties – almost all of the countries in the world – to adopt measures for the *ex-situ* conservation of biodiversity. Regrettably the United States has chosen to remain outside the Convention.

Within the European Union, Article 9 has been implemented by the Zoos Directive (Council Directive 1999/22/EC of 29 March 1999), which requires zoos and aquariums to adopt a conservation role. One of the ways in which Member States may comply with the Directive is by undertaking research from which conservation benefits accrue. When I examined the nature of zoo research some five years after the adoption of the Directive in 1999 I concluded that most zoo research at that time had been concerned with animal behaviour, environmental enrichment, nutrition and reproduction, and was therefore largely irrelevant to *ex-situ* conservation (Rees, 2005b). I suggested that it was unlikely that zoos would increase their output of conservation-relevant research because most do not have adequate human or financial resources. The Directive did not make research a mandatory activity for zoos, it is merely one of the ways in which zoos may comply. They may also comply by engaging in training, information exchange or captive breeding. As most, if not all, zoos already engaged in at least one of these activities before the Directive was adopted, I argued that they could effectively comply by doing nothing new.

The leaders of modern progressive zoos want to engage with research. Many keepers are now well qualified at least in part because of the expansion of higher education courses aimed specifically at training them (see Section 3.14.1). In the United Kingdom, as the number of dedicated courses in universities has expanded there has, of necessity, been a concomitant expansion in specialist academic staff. More university staff interested in zoos has led to more postgraduate research, more collaboration with zoos, more publications and more dedicated journals.

1.5 The Grey Literature

Zoo professionals are in a unique position to gather data on many aspects of the husbandry of their animals. In many, if not most, cases their efforts result in the collection of data that are unsuitable for publication in academic journals because they are not collected in a systematic manner, the sample size is too small to yield statistically significant results, the information collected is anecdotal in nature, or for some other reason. This does not mean, however, that the information has no value, and many interesting articles have been published in the ‘grey literature’: documents published outside the normal academic channels. This may be within husbandry manuals or zoo reports, or in publications such as *International Zoo News*, *Ratel* (the journal of the Association of British and Irish Wild Animal Keepers (ABWAK)), *Connect* (the magazine of AZA) and *The Shape of Enrichment*. Articles in publications of this type are not peer-reviewed, but many are written by experienced keepers, zoo curators and directors, and others with knowledge of zoos and animals living in zoos, including academics.

The knowledge and expertise of zoo professionals should not be underestimated. It is not uncommon for those of us who study the behaviour of animals living in zoos to inform keepers of the results of our scientific studies only to be met with the response, ‘Yes ... we know.’ Indeed, if our scientific findings differed markedly from what experienced keepers know about their animals, we should perhaps question our methodology.

1.6 Zoo Research Is Not Just About Animals

Zoos have attracted interest from academics across a very wide range of disciplines and to the best of my knowledge there has been no attempt at a comprehensive survey of all of the zoo-related peer-reviewed work that has been published. This would be difficult because, although a small number of dedicated journals exist, most of which are affiliated to zoological organisations – *Zoo Biology* (AZA), *Journal of Zoo and Wildlife Medicine*, *Journal of Zoo and Aquarium Research* (EAZA), *International Zoo Yearbook* (ZSL) and *Journal of Zoological and Botanical Gardens* – a great deal of zoo research is published in journals that have a wider remit. My own work on zoos and animals living in zoos has appeared in *Zoo Biology*, the *Journal of Applied Animal*