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Research and Research Training in BIAZA Zoos and Aquariums: an analysis of the BIAZA research database

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Abstract

The BIAZA research database is a spreadsheet containing details that member collections submit about research (postgraduate and professional) and research training (up to undergraduate) projects being undertaken within their collection. The database contains information on 4816 projects since 1969, and these have been analysed to discern trends in numbers, taxa and subjects studied, academic institutions and collections involved. Thirty-eight collections contributed information to the database (31.4% of BIAZA membership). Both research and research training projects have increased substantially since 2000, which parallels a growth in animal care, welfare and behaviour courses in academic institutions. Projects in both categories are skewed heavily towards behavioural studies on mammals, with smaller numbers of projects on members of other taxa, or other topics. A small number of zoos and academic institutions are responsible for the majority of projects in both categories, although the number of academic institutions that have carried out projects in BIAZA zoos is very large (n=246 in 18 different countries). It is concluded that both research and research training are significant and widespread activities in BIAZA collections, but that more needs to be done to promote a wider diversity of topics and taxa studied.

Introduction

Research is an essential component of the mission statements of most accredited zoos. It is a licensing requirement for zoos in some areas, such as the UK and the European Union, and is an accreditation requirement for most zoo accrediting bodies (Hosey et al. 2013). Zoos are important for both basic and applied research (Kleiman 1992, Hosey 1997), much of which informs zoo practice in animal welfare and conservation, which is becoming more imperative in the light of current threats to biodiversity (MacDonald and Hofer 2011). Also, a central aspect of zoo-based research is research training, which involves giving students opportunities to practise and develop research skills using living animals. Such activities are important because of the skills they develop (Rumbaugh 1971), and also because student projects can provide useful information which can feed into and inform housing and husbandry decisions, even if most are unlikely to be published (Rose et al. 2014). It is useful to periodically monitor the research activities and output of zoos, not only to determine how well they are fulfilling these activities but also to provide data to help inform researchers about where future research efforts should be directed.

Zoos began to appear just over two hundred years ago, and some of the earliest collections, such as the Jardin des Plantes and London Zoo, included research among their guiding principles (Baratay and Hardouin-Fugier 2002). For the next century or so, zoo-based research was mostly concerned with anatomy and taxonomy (Hochadel 2011), with most observational studies using live animals being anecdotal rather than systematic. Even as late as the 1970s and 80s,

there were attempts to draw attention to the potential that zoos offered for both research and research training (Rumbaugh 1971, 1972; Moran and Sorensen 1984). In October 1973, the American Association of Zoological Parks and Aquariums (as it was then known, now the AZA: Association of Zoos and Aquaria) held its first-ever Research Symposium as part of its Annual Conference to promote cooperation between zoos and the biomedical and academic research communities (National Academy of Sciences 1975). Nevertheless, in a questionnaire survey of 65 zoos in the United States, Maroldo and Parker (1978) found that only 10 of the 32 who responded were involved in comparative psychology research projects in the zoo; in a follow-up survey of 122 zoos across 27 different countries worldwide (but not including the USA), few carried out any comparative psychology research, but indicated that they were willing to consider proposals (Maroldo 1978). Comparative psychology is only one aspect of the research carried out in zoos, but given the predominance of behavioural research in zoos now, they perhaps imply a generally low level of zoo-based research during the 1970s. However, since then, zoo-based research has increased substantially.

Most of the documenting of this growth in zoo research has been with North American collections. A 1986 survey of American zoos and aquariums, in which responses were gained from 120 out of 153 collections contacted (Finlay and Maple 1986) revealed that 70% of respondents were engaged in research. However, the lack of a definition of research in the questionnaire allowed some collections to apply this liberally ("Their research program consisted of the cross-breeding of a lion and a tiger" in one zoo). This survey was repeated 10 years later by Stoinski et al. (1998), who received replies from 123 of the 173 AZA institutions surveyed and found that 88% of responding collections were engaged in research. Although 65% of those who answered the relevant question said that they published in peer-reviewed journals, the zoos were not asked how many projects or how many publications came from their research efforts. Nevertheless, the survey demonstrated considerable growth in zoo-based research, both in terms of the number of collections and the number of individuals involved in research. Publications produced from research in AZA zoos have now been surveyed by Loh et al. (2018) using a literature search; between 1993 and 2013 a total of 5175 papers were produced by AZA member institutions, with an increase during that 10-year period from 114 publications in 1993 to 437 publications in 2013.

These surveys show the state of research in AZA zoos, and its growth over the past three decades, but similar surveys of research activities and outcomes have apparently not been undertaken for zoos and aquariums outside of North America. A brief survey of 57 European zoos revealed that 73% were engaged in research activity (Nogge 1997), but this was a relatively informal survey with little detail. In 1999, the British and Irish Association of Zoos and Aquariums (BIAZA) instituted an annual research conference. This has grown from a 1-day conference with 14 talks and six posters in 1999 to a three-day event with 39 talks and 43 posters in 2018, which suggests not only that British and Irish zoos are active in research, but also that this activity has grown substantially over the past 20 years (Hosey, unpubl. data). The data to test this assumption exist and are located in a database managed by Paignton Zoo on behalf of BIAZA. Until 2006, the information for this database was submitted voluntarily and informally by members, but from 2006 member institutions were formally asked to submit research details as part of annual monitoring by BIAZA. From 2013, collections were sent a separate research template to complete and return annually in an attempt to standardise this process. However, many collections do not use the template and often omit columns such as the 'Publication' column, as publications often come much later and not in the year the research project was carried out (A. Plowman, personal communication). Return rates of these data are quite low (less than 20% of BIAZA collections), but the data do include most of the larger zoos where the majority of zoo-based research projects are based. Therefore, the database probably represents a reasonable picture of most of the zoo-based research, which has been occurring in British and Irish zoos during the past few decades.

Here, this database is analysed to answer questions about the current state of zoo research within the BIAZA area, and to identify trends in research activity. This analysis distinguishes between research, which is regarded as the production of results that are potentially publishable in peer-reviewed journals, and which are therefore considered to be the projects undertaken by postgraduate and postdoctoral workers, academic staff of institutions of further and higher education, and zoo-based researchers; and research training, which are regarded as projects that are unlikely to be published in peer-reviewed journals, but that contribute to the development of research skills in students and often produce results that are of use to the host collection, and that we hence consider to be projects undertaken by students up to and including degree level or equivalent. The questions this study wanted to answer from the database were: i) how much research and research training is being undertaken in BIAZA member collections, has it been increasing, and is it continuing to increase; ii) how is this activity spread across different taxa within the host collections; iii) what are the main topics of research in BIAZA collections; and iv) is research and research training concentrated in a small number of collections and academic institutions, or spread more evenly? The database contains very little information on published outcomes, so it is not possible to assess how many of the projects in the database end up as published papers, but it is hoped to address this with other surveys in future.

Materials and methods

BIAZA database

The BIAZA Research Database is a Microsoft Excel file that, at the end of 2017, had details of 4816 research and research training projects. Since analysis started in 2018, the end of 2017 was used as the cut-off point in order to include complete years. The variables required to answer the questions were as follows:

Academic qualification: The database identifies the qualification to which a research project contributes, and also some explanation of non-qualification based projects. Using this information this study attempted to identify projects which were best considered as research training (in the UK educational system these would include projects up to and including degree level, which covered a range of qualifications, including A-level, HND, Foundation Degree and Honours Degree) and those that could be regarded as research (postgraduate or professional), which included Masters, Doctoral and post-doctoral projects, as well as those carried out by academic lecturers or zoo staff. The database does contain projects being undertaken in BIAZA zoos by individuals from non-UK or Irish educational institutions, and it is recognised that this categorisation may not hold true for all of these. However, as only 43 (n=2990) research training and 87 (n=1339) research projects are non-UK/Irish, any which have been inadvertently incorrectly categorised will be too few to affect the overall results of the survey. There were, however, 487 projects (10.1%) for which no qualification or academic or professional level was given. These have been categorised as 'unknown' and have not been analysed since it is not possible to determine if they are research or research training.

Start Year: the year in which the project commenced was used to assess changes in the number of projects over time. Projects, of

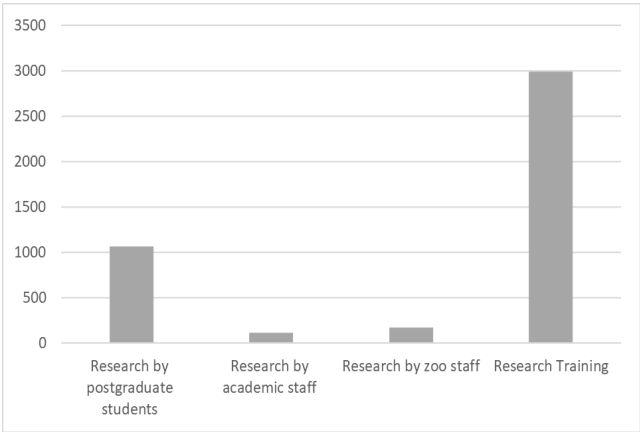

Figure 1. The number of research and research training projects in the BIAZA database, 1969-2017.

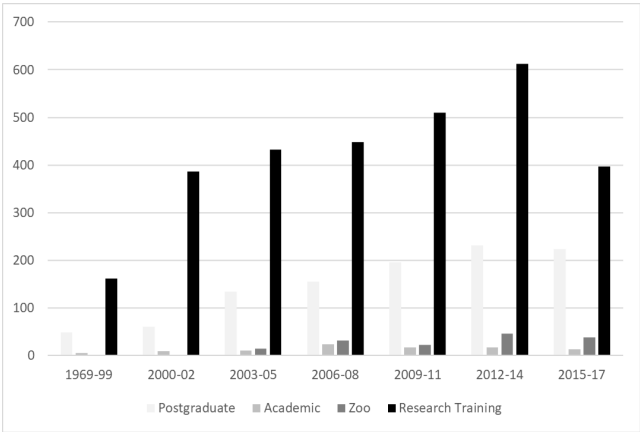

Figure 2. The number of research and research training projects according to their start year. All pre-1999 projects are shown in one category, projects since 2000 are shown in 3-year blocks.

course, run for different lengths of time, so start year was thought to be a better measure than trying to assess the number running in any one year, which could give undue prominence to long-running projects. The earliest projects in the database are from 1969, but because of low annual numbers prior to 2000, projects before this date have been allocated to a single category. From 2000 to 2017, project numbers are presented in 3-year blocks.

Taxon: The database lists the species and its taxonomic order for each project. This study has thus categorised taxa by order in the initial analysis of the database, but for clarity, in presenting the results, these have been condensed into larger categories: invertebrates, fish, amphibians, reptiles, birds and mammals. While two of these are strictly speaking not taxa, they accord with a convenient categorization of the sheer diversity of the animals studied in these projects, and for convenience, they are termed 'taxa' for the purpose of this paper. Projects which study more than one species are labelled 'multi-species'.

Research Subject: The database uses 38 different categories of research subject, ranging from Anatomy to Welfare. For convenience, these have been condensed down into 18 categories, with a further one, 'other', for projects where a research category has not been identified or cannot be allocated to these major categories.

Collection: The database includes the name of the zoo or aquarium in which the project took place. Projects which take place over more than one collection are referred to as 'multi-zoo', and those which occur outside of the zoo are referred to as 'elsewhere'.

Academic Institution: 'Academic institution' means an institution of research or learning, so included here are the schools, colleges, universities and research organisations from which researchers or students come in order to carry out projects in zoos. More than 200 different academic institutions are represented in the database. A number of these changed their status and their name over the period covered by the database, for example by a higher education college attaining university status, and in these cases, the totals under each name have been summed. In some cases, the relevant information is missing from the database, presumably because the person in the collection filling in the form was unsure or unaware of the academic institution involved in the research. These cases have been listed as 'unknown.' Projects undertaken by zoo-based staff (n=169) were excluded from this analysis.

Table 1. Numbers of research and research training projects in the BIAZA database categorised by taxonomic category.

	plant	invert	fish	amphibian	reptile	bird	mammal	several	total
Research by postgraduate students	4	17	11	26	22	51	724	80	935
Research by academic staff	0	1	1	1	2	4	72	13	94
Research by zoo staff	0	4	3	5	5	23	105	12	157
Research training	6	30	44	13	55	267	2210	169	2794

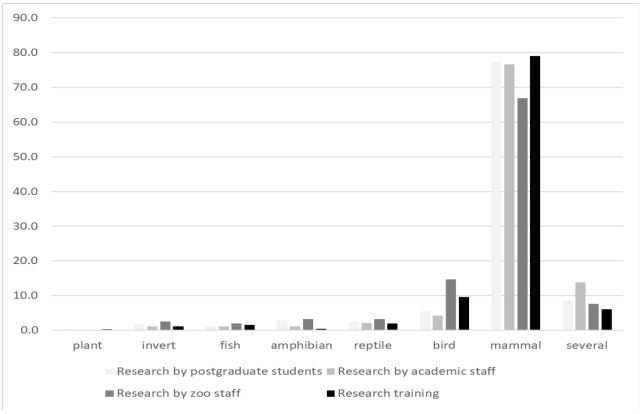

Figure 3. Percentage of research and research training projects in each major taxonomic category in the BIAZA database.

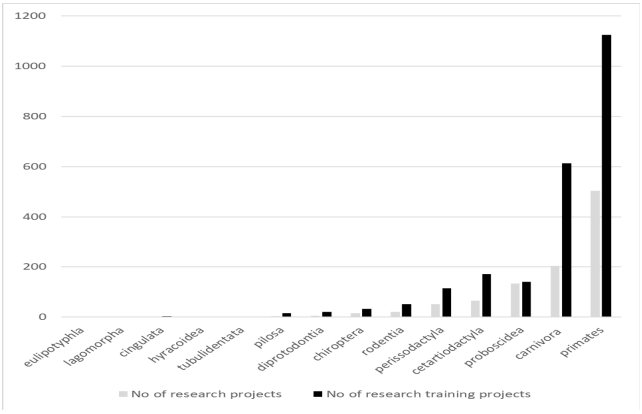

Figure 4. Representation of different mammalian orders in research and research training projects in the BIAZA database, showing a pronounced skew towards Primates and Carnivores.

Results

Academic level

A total of 4329 projects (89.9%) could be identified as either research or research training. There were far more research training (n=2990) than research (n=1339) projects, and most research projects (as opposed to research training projects) were undertaken by postgraduate students (Figure 1).

Start date

Start dates were identified in 1297 research projects and 2948 research training projects. They show a marked increase in the number of all projects up to 2012–14, with a slight reduction in all but postgraduate projects during 2015–17 (Figure 2).

Taxon

A total of 1186 research projects and 2794 research training projects could be classified by the taxonomic grouping of their subject, and covered 81 different animal and plant orders. Thus, both research and research training projects covered a wide array of taxa, which are shown categorised by major grouping in Table 1 (numbers of projects) and Figure 3 (percentages of projects). By far the greatest number of projects across all research categories concern mammals, with much smaller numbers on invertebrates or the other vertebrate groups. Within mammals, there is a marked taxonomic skew towards projects on Primates and Carnivora, with substantial numbers also on Proboscidea, Cetartiodactyla and Perissodactyla, and much lower numbers on the other orders (Figure 4). There was also a taxonomic skew among bird projects,

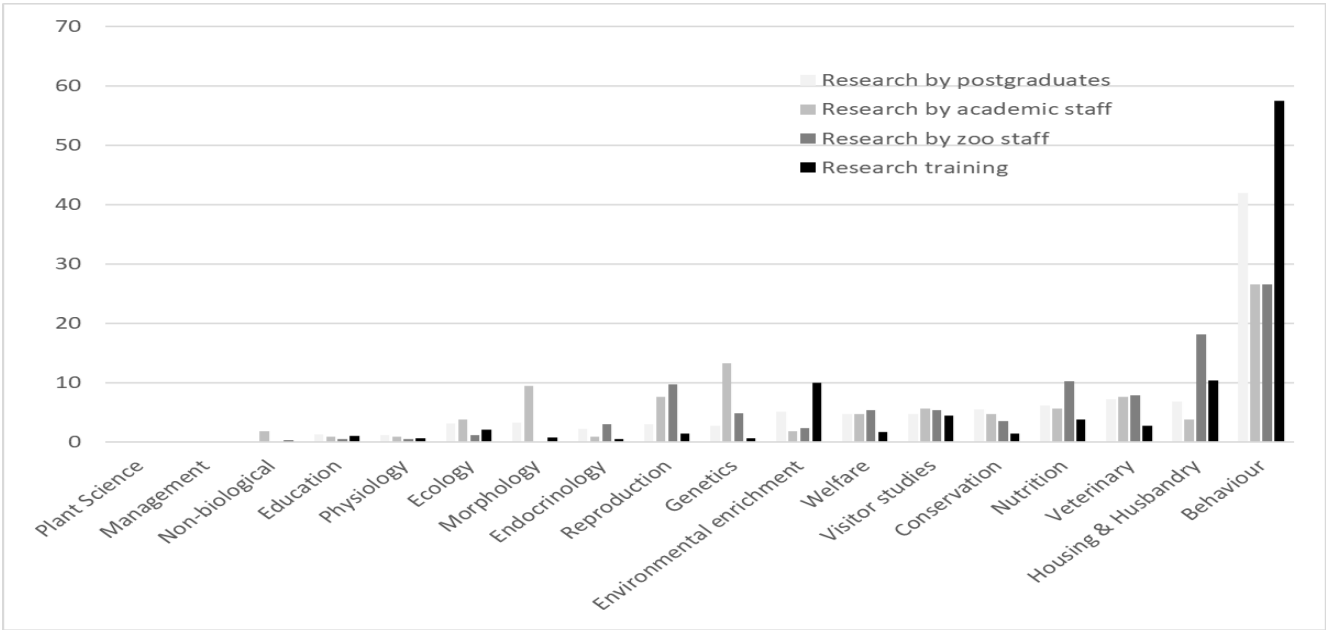

Figure 5. Percentage of research and research training projects classified by subject grouping of the project.

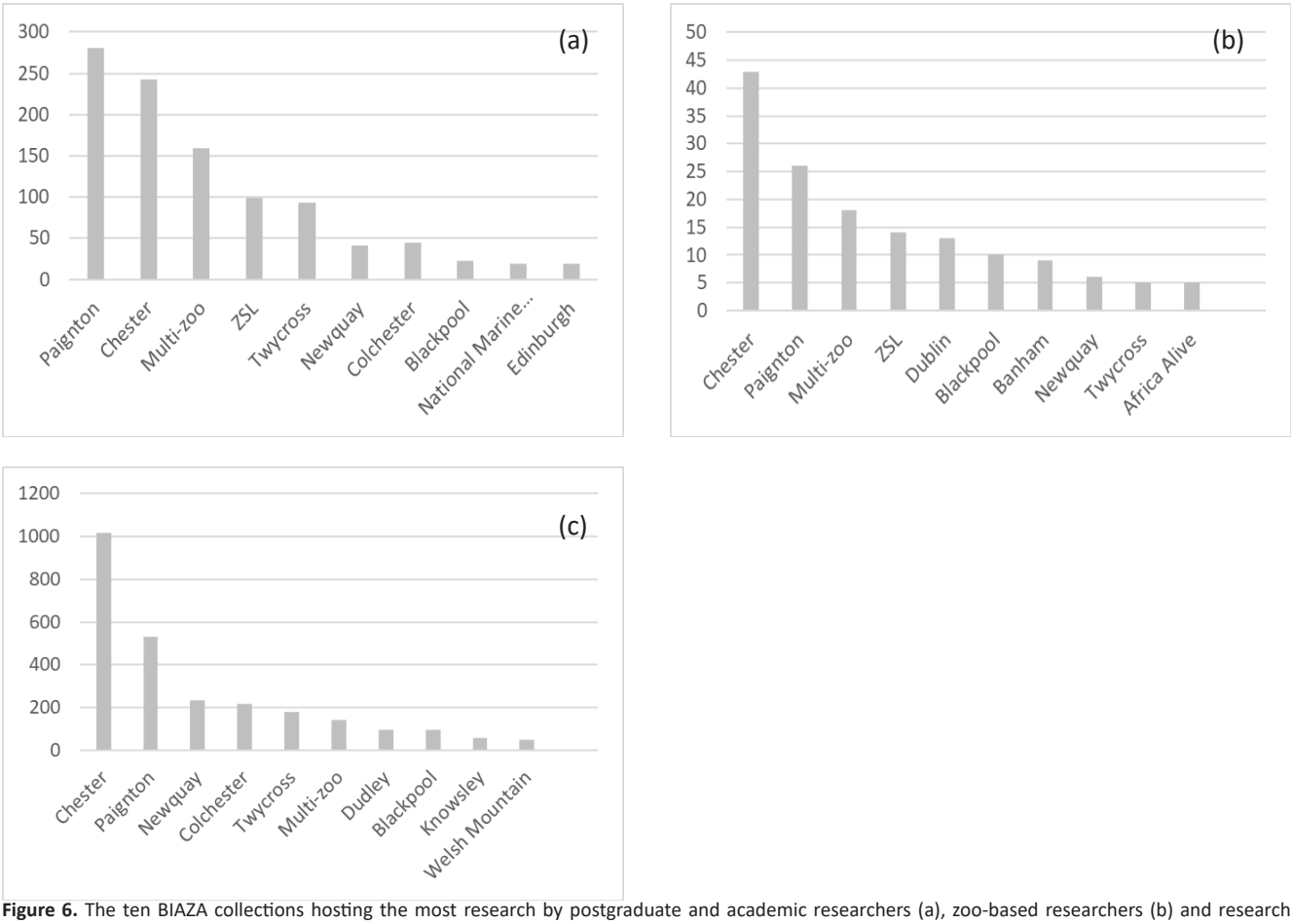

Figure 6. The ten BIAZA collections hosting the most research by postgraduate and academic researchers (a), zoo-based researchers (b) and research training (c) projects.

with just three orders (Phoenicopteriformes, Sphenisciformes and Psittaciformes) together accounting for 46% of bird research projects and 67% of bird research training projects. There was no obvious taxonomic skew among reptile projects, which roughly reflected species diversity among the different orders, or in the other major taxonomic categories, where project numbers were too low to indicate a skew.

Research topic

Identification of research subject as one of the 38 categories was possible for 1269 research projects and 2891 research training projects. These are shown as percentages, condensed into 18 categories, in Figure 5. In all research categories, the majority of projects were behavioural, and this skew was most pronounced in research training (57.6%) and postgraduate projects (42%), with

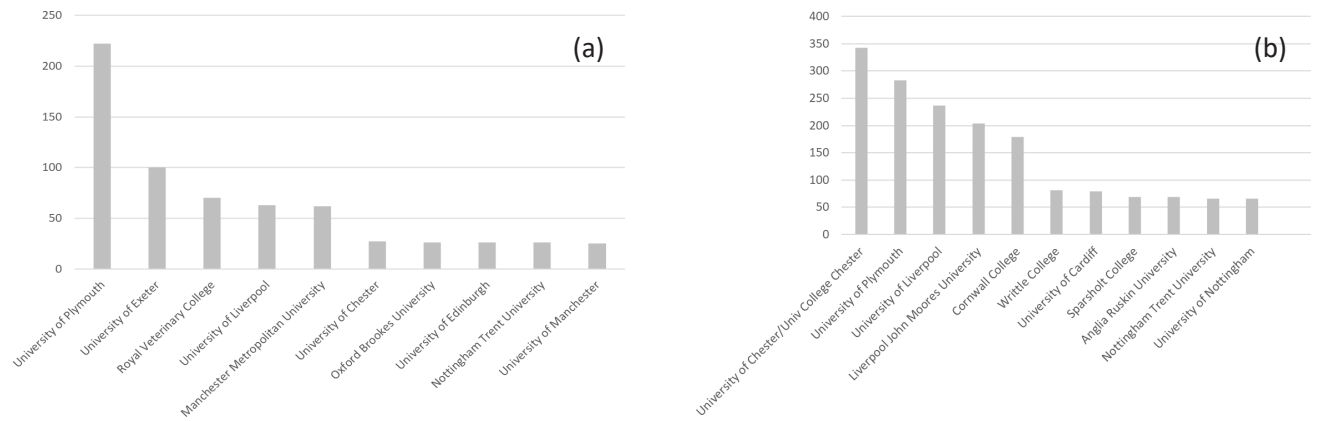

Figure 7. Host academic institutions for the highest number of research (a) and research training (b) projects in BIAZA collections.

less of a skew in research by academic and zoo-based researchers (both 26.7%). In the latter two categories, the next most important topic was Genetics (for academic researchers, 13.3% of projects) and Housing & Husbandry and Nutrition (for zoo-based researchers, 18.2% and 10.3% of projects, respectively). A small number of projects are not directly related to animal or plant biology at all, but concern topics like Education (15 research and 32 research training projects), Management (2 research and 2 research training projects) or other non-biological subjects such as Philosophy and Theology (4 research and 7 research training projects).

Collection

Projects were undertaken at 38 different BIAZA collections (research: 1127 projects in 34 collections; research training: 2844 projects in 36 collections). Additionally, there were 177 research and 140 research training projects which were classified as multi-zoo, plus 16 and three respectively which took place outside the zoo (including in situ projects), and six altogether whose site was not identified. The 10 collections hosting the most projects in each category are shown in Figure 6. All categories are dominated by just two collections, Chester Zoo and Paignton Zoo, who together host 51.8% of research training projects and 44.2% of research projects.

Academic institution

There are 246 different academic institutions in the database, covering 18 different countries. The institutions that contributed the most research and research training projects are shown in Figure 7. Those institutions shown in Figure 7a are the source of 48% of research projects, while those shown in Figure 7b are the source of 56% of research training projects carried out in BIAZA collections.

Discussion

The data presented here give a good indication of the current state of research and research training in BIAZA collections, and their growth over the past three decades. It should, however, be borne in mind that a number of collections are missing from the database. BIAZA currently has 121 full member collections (BIAZA 2019), and the database contains details from 38 of them (31.4% of the total). This is a considerably lower return rate than was found in surveys of research in AZA zoos (Finlay and Maple 1986, Stoinski et al. 1998), but does include most of the large BIAZA collections, where most of the research is likely to be concentrated. It is not possible to tell from the database whether this absence means that these zoos are not involved in research, or whether they have just failed to submit details. The data obtained, however, do facilitate answering the research questions set out in the Introduction.

Quantity and growth of research and research training

The majority of research (as opposed to research training) in BIAZA collections is clearly being done by postgraduate students rather than professional staff (Figure 1). This component of research activity in zoos has seen a substantial increase during the past 20 years, and this has corresponded to an increase in the provision of behavioural, welfare or conservation-based postgraduate provision within the Higher Education (HE) sector in this period. Some of this increase is due to formal links between collections and higher education institutions to develop new academic provision at postgraduate level (and indeed at undergraduate level in some cases), but the database does not collect information on this, so it is not possible to give systematic evidence. There is some indication (Figure 2) that this growth in zoo-based postgraduate research may now be starting to plateau. Research by academic and zoo staff occurs in much smaller quantity, and while there appears to have been some slight growth at the start of this century, the number of new projects started annually has remained relatively constant since.

Links and collaborations between zoos and academic institutions have been advocated for a long time (Moran and Sorensen 1984; Chiszar et al. 1993). Such collaborations potentially give the zoo access to resources which they otherwise might not have, such as the manpower to physically do the research, or specialist apparatus and equipment; and also gives new perspectives which can improve the design of research projects (Kleiman 1985). Research priorities have often been very different between academic and zoo researchers (Hosey 1997), but a great deal of overlap of interests have now become apparent (Fernandez and Timberlake 2008), and academic-zoo collaborations are now widespread (Macdonald and Hofer 2011). In a survey of trends in the 25-year history of the journal *Zoo Biology,* zoos were the primary institutional affiliation of 37.6% of authors, compared to 37.4% for universities (Anderson et al. 2008).

A key aspect of collaborations between zoos and academic institutions is the opportunity for research training. Zoos can provide valuable experiences for undergraduates, enabling students to develop a deeper understanding of scientific enquiry. In turn, research training exercises can inform zoos, provide baseline or pilot studies, aid in identifying future studies as well as contribute directly to knowledge and husbandry of a species (Reid et al. 2008; Rose et al. 2014). The number of projects in BIAZA collections that can be classed as research training has consistently been about double the number of all research projects. A marked increase in the number of projects between 2000 and 2014 corresponds with HE student enrolment in biological sciences, which has seen a 40% growth over the last decade (HESA 2019). Shifting student demand is reflected in the provision of courses universities offer with biological and veterinary sciences among the courses leading in growth between 2007–2008 and 2016–2017 (Universities UK 2018). While there is some evidence of a decline in research training projects in BIAZA collections since 2014, this is likely due to zoos' compliance in reporting of research projects rather than a decline in student projects, as biological and veterinary sciences has continued to show yearly growth (HESA 2019).

Zoos provide the platform for formal education research training, which underpins both the conservation research and conservation education mission of the modern zoo. Of course, not all research training projects will inform current practice, and many undergraduates who undertake project work in zoos are unlikely to become researchers. However, the project work they carry out, and the skills they develop in the zoo setting, are relevant to their degree qualification and thus both parties benefit from the association (Kleiman 1985; Fernandez and Timberlake 2008).

Spread of research activity across taxa

Research projects and research training projects show a largely similar pattern of spread across taxonomic categories, in which by far the majority are on mammals (76% of research projects, 79% of research training projects), with much smaller numbers in other groups. This pattern reflects neither the species-richness of these groups nor their representation either as numbers of species or of individuals in accredited collections (Hosey et al. 2019). Mammals predominate in AZA research as well (Stoinski et al. 1998), as well as in papers published in *Zoo Biology,* where 73% of articles were on mammals in the journal's first 15 years (Wemmer et al. 1997), and 74.8% in its first 25 years (Anderson et al. 2008). Indeed, it

is also true of the literature as a whole, where 53% of papers with their first author affiliated to a zoo were found in a literature search to be on mammals (Maple and Bashaw 2010).

The taxonomic skew within the mammals is a familiar one too. The figures given by Stoinski et al. (1998) for AZA-accredited zoos are numbers of zoos undertaking projects rather than number of projects, making a comparison with the present data difficult; nevertheless 41% of these zoos were undertaking research on great apes, 47% on other primates, and 63% on carnivores, so the primate-carnivore bias appears to be the case in AZA zoos as well. Furthermore, in the first 25 years of *Zoo Biology*, primates accounted for 35.5% and carnivores 23.4% of papers on mammals (Anderson et al. 2008). This bias accords almost perfectly with the rankings of what are regarded as the most charismatic animals (Albert et al. 2018), and it may be that there are more welfare concerns for these (Hosey et al. 2019), but it does not accord too closely with the conservation importance of these, compared with more neglected species. Probably similar considerations explain the taxon skew in bird research. None of the AZA surveys indicate what sorts of birds are the subjects of research, and no birds figure in the top 20 charismatic animals (Albert et al. 2018), but most people would probably agree that among birds, penguins, parrots and flamingos are the most charismatic.

The taxonomic skew among both research and research training projects is somewhat disappointing considering that it has been pointed out for more than 20 years. Increasing the research output of zoos and collaborating universities on non-mammalian taxa must surely be a priority for the future.

The main topics of research in BIAZA collections

There is a very wide range of topics among the projects in the database, but by far the most projects, both for research training and the different research categories, are behavioural. This appears to have been a feature of zoo-based research in other arenas as well. Surveys of AZA collections also showed Behaviour to be the most prominent category, with 72% of respondent zoos carrying out this sort of research in 1986 (Finlay and Maple 1986) and 85% 10 years later (Stoinski et al. 1998). Similarly, Behaviour was the highest scoring topic (about 32%) of papers published in *Zoo Biology* in its first 15 years (Wemmer et al. 1997), dropping to 26.8% when the first 25 years of the journal were considered (Anderson et al. 2008). The skew towards Behaviour in the BIAZA database is less pronounced in projects by academic and zoo staff than by undergraduate and postgraduate students. Behaviour is an important topic in zoo science, since it underpins many of the procedures in conservation and captive animal management (Kleiman 1992, Miller et al. 2013).

Outside of this skew, the diversity of project topics is noteworthy, and includes both basic and applied research, which is a welcome development given that perceptions by the academic community of the opportunities to perform basic research in zoos have probably previously been that basic scientific research is not really feasible in a zoo setting (Hosey 1997). There are, nevertheless, some indications in the present data that university-based researchers have rather different main interests compared to zoo-based researchers (a small bias towards Genetics and Morphology in the former, Housing & Husbandry, Nutrition and Reproduction in the latter). The number of projects classified as Conservation is relatively modest (5.2% of all research projects, and 1.5% of research training projects), especially given that zoos have been criticised previously for their small amounts of conservation research (Rees 2005), but it is the case that projects of conservation significance are also classified under other headings (eg. Education, Ecology, Reproduction, Endocrinology, Behaviour) in this database.

Distribution of research and research training across different collections and academic institutions

The number of collections supplying research-related information to the BIAZA database is disappointingly low, and substantially lower than the return rates on AZA questionnaires, which are around 71% (Stoinski et al. 1998). It is unlikely that this means that the non-responding zoos are not doing research, as this category contains several collections, which are known from the literature search to be undertaking and publishing research. In the present database, both research and research training are dominated by two collections, Paignton and Chester. Both have strong links with a number of academic institutions, which can include jointly planned and organised programmes of study. It is likely that to some extent the number of projects listed for collections in the present database reflects the number and strength of academic links they have. Students and external scientists dominate AZA research activities too, primarily because of a lack of research staff at most collections (Stoinski et al. 1998). Staff in AZA zoos identify support from the chief executive officer and the presence of staff dedicated to carrying out scientific programmes as being the most important determinants of successful research (Anderson et al. 2010). The present study does not have data to judge whether this is also the case in BIAZA collections.

There is a large number of academic institutions that have contributed staff or students to undertake zoo-based research or research training projects in BIAZA zoos, but the majority of these (182 out of a total of 246 institutions, or 74%) are responsible for fewer than five projects each over the time period covered by the database. The highest ranking 10 institutions for both numbers of research and research training projects collectively account for 48% and 56% of projects, respectively. It is notable that these institutions are also geographically close to the collections which are responsible for the highest number of projects.

Conclusions

There is clearly a great deal of research and research training being both hosted and carried out by British and Irish zoos, and the objective of engaging in research activity is largely being met. While this is certainly laudable, it is also evident that there is a good deal of scope for enhancing this effort. There is a taxon bias of projects towards mammals, and a subject bias towards behavioural biology that skew the results, and researchers would be encouraged to engage with a wider array of taxa and topics. Most of the research is being carried out by academics from institutions of higher education rather than zoo staff, which is positive given the advice, noted above, that zoos form collaborations with these institutions. Finally, the opportunities for research training afforded by zoos are outstanding if measured by the number of such projects in the database, and it is a welcome sign that both these and research projects have experienced such a growth in numbers during the last 20 years.

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