

Research article

The contributions of EAZA zoos and aquaria to peer-reviewed scientific research

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Abstract

Zoos have tremendous potential and responsibility to conduct research, which is a key part of the European Association of Zoos and Aquariums' (EAZA) Code of Ethics. Yet, the contributions of EAZA institutions to peer-reviewed literature have never been quantified. By conducting an exhaustive Web of Science (WoS) database search, the peer-reviewed research contribution from 291 EAZA members in the period 1998–2018 was quantified. A total of 3345 peer-reviewed manuscripts were published in the 21-year period. The research output increased over time, with more than a threefold increase during the last decade. More than two-thirds of all EAZA member institutions published during the time period, but contributions were markedly skewed, with only seven institutions responsible for more than 100 publications each, thus contributing 37% of the total output. The top three research areas were zoology, veterinary sciences, and environmental sciences and ecology, with the two former attributing to twice as many publications as the latter.

Introduction

The crux of modern zoo and aquarium work is species conservation. Only through healthy self-sustaining captive populations that fulfil the role as exhibit and education animals, as well as insurance or rescue populations, are zoos and aquaria able to realise their obligation to preserve nature and demonstrate its diversity. The role of zoos and aquaria thus goes far beyond displaying animals. Welfare, management, veterinary care, education, conservation and research are key parts of the expectations and requirements from national authorities (The Council of the European Union 1999), the public (Ballantyne and Packer 2016) and professional organisations such as the European Association of Zoos and Aquariums (EAZA) (Reid et al. 2008; EAZA 2015). A key component in advancing

zoos and aquaria is scientific research and knowledge-sharing. Modern zoo management fosters pertinent research questions on a daily basis, which need to be answered to continue the positive development of zoos as conservation centres. Such questions are unlikely to be answered by the established universities alone. EAZA represents and links more than 400 zoos, aquaria, national federations and other organisations in 47 countries. In addition to furthering the professional standards of member zoos and aquaria with regard to the care and accommodation of the animals kept in their collections, EAZA also facilitates cooperation in the key mission areas of conservation, education and research. Although part of the expectations of the surrounding community, and part of the mission statement of many zoos, the scientific output of zoological institutions has been incompletely quantified.

Recently, a quantitative and qualitative analysis of the contribution of 228 members of the predominantly North American Association of Zoos and Aquariums (AZA) to peer-reviewed research was reported (Loh et al. 2018). A mean of 24.6 publications, including peer-reviewed articles, book chapters and proceedings, per member institution over the 21-year time span from 1993 to 2013 was found. With a total of 5,175 publications in the study period and a marked rise in numbers in recent years, it was concluded that “a strong publication record indicates expertise and expands scientific knowledge, enhancing organizational credibility.”

Quantifying the contribution of zoos and aquaria to scientific research is highly relevant in order to explore their research output and how their efforts contribute to advancing scientific knowledge. The vast majority of the institutions included in the AZA study (Loh et al. 2018) were situated in the United States, with a handful located in Mexico, Canada, Singapore, Hong Kong and Argentina. Documentation of the scientific contributions of zoos and aquaria in other regions of the world remains absent. The purpose of this investigation was to quantify the research contribution of EAZA members, predominantly located in Europe and the Middle East, through examining: i) the number of publications and associated citations by all EAZA members in the period 1998–2018; ii) the distribution and development of publications according to research areas; and iii) which factors could have affected the output.

Materials and methods

The research contribution of each of the 291 active EAZA member institutions (EAZA 2018) was quantified for the period 1998–2018 (inclusive) during May to July 2019. During initial data collection, test searches were conducted in the following databases: Web of Science (WoS) “All databases”, WoS core collection, PubMed and Ovid (including Agricola, Agris, CAB abstracts, Embase, Zoological records and Ovid Medline). Each of these databases had difficulty meeting a standardised search protocol (e.g., they intermittently failed to include affiliation, relevant publications or research areas). Owing to the vast difference in search results based on database and search method, WoS “All databases” was selected as it generated the highest number of relevant results, based on the criteria defined below, and allowed for a standardised data collection. It was found that conducting searches from different institution logins resulted in different search results, based on which scientific journals the given institution subscribes to. As a result, the login that had access to the largest number of scientific journals was chosen.

All EAZA-registered member names were cross-checked for alternative names and spellings, including local language. Using a combination of Google search and perusing the website of each institution, alternative names were noted and compared to the EAZA-registered name as well of the address of the institution. For each institution, all EAZA-registered and alternative names were searched for in the WoS “All databases” using “basic search” in the “address” field with “period” from 1998–2018. Standardised abbreviations and search strings were constructed for each institution name according to WoS index list and alternative spellings. For example, the truncation symbol, an asterisk, was used to search for names with differing endings or spelling variations (e.g. “Augsburg* and zoo” used to identify Augsburg zoo as well as Augsburger zoo), and pk instead of park. If zoological society was a component of any of the organisation names, the term “zool* soc*” was included as WoS abbreviates these terms in the address field. The Roman alphabet was used for any international zoo name including characters that are not on the QWERTY keyboard (e.g. Košice zoo was searched as “Koisce zoo”).

Only papers in peer-reviewed journals were included. During

the search, all journal names were looked up in a discovery service enabling an exhaustive search in many databases at once (<https://rex.kb.dk>). If the title appeared with “peer-reviewed journal” the result was accepted. If the title did not exist in the database, the publication title and journal title were searched for in Google Scholar (<https://scholar.google.dk/>), and the website of the journal was examined to establish if the journal had a peer-review process. Institutions were included as contributors of the publication if found under “reprint address” or “address” during the WoS search. Ranking of the institutional affiliation within the list of co-authors was not considered during data collection, as the aim was to disclose every research contribution of zoos and aquaria, regardless of ranking of affiliations. All relevant results were added to a marked list within WoS and citation reports were extracted for all relevant search results. A total number was obtained for peer-reviewed articles, reviews, case reports, clinical trials and letters, along with total citations and h-index (a citation index defined by the number of publications per organisation (h) with at least h citations (Hirsch 2005)). Books, book chapters, reports, news items, meeting papers and conference proceedings were not included. Lastly, all results were carefully reviewed, and if they did not fulfil the criteria, i.e. owing to type of contribution (journal, newsletter etc.) or missing affiliation with the institution, they were excluded.

Analysis

Owing to certain institutions being registered as separate entities yet being under the same parent organisation containing only EAZA-member institutions, these were combined to provide the most accurate peer-reviewed contribution from these institutions. The combined institutions are: North of England Zoological Society (Chester Zoo), Royal Zoological Society of Antwerp (Zoo Antwerpen and Zoo Planckendael), Royal Zoological Society of Scotland (Edinburgh Zoo and Highland Wildlife Park), Durrell Wildlife Conservation Trust (Jersey Zoo) and Whitley Wildlife Conservation Trust (Paignton Zoo Environmental Park, Living Coasts and Newquay Zoo). An outlier, the Zoological Society of London was treated differently, in that only contributions from London Zoo and Whipsnade Zoo were included. The Institute of Zoology which acts as a separate research institution was excluded, as it would not rightfully portray the contribution of zoos or aquaria (D. Field, personal communication). This resulted in analysis of 291 EAZA member institutions.

Factors relating to research contribution

In order to examine certain institution-related factors which may have had an influence on research output, additional information was collected for all EAZA members. The information included founding year of institutions and EAZA membership fee, which is based on number of paying visitors. Institutional age was calculated based on the founding year and their age in 2018. This information was either found on the respective websites or was provided by EAZA. Thirty-five out of 291 institutions (~12%) were founded in 1998 or later, and the remaining were founded between 1950–1997 (~56%) or before 1950 (~32%). A Pearson correlation coefficient was applied to assess for correlations between these factors and research output.

Development of contribution to research area

A list of unique publications was created by removing the duplicates of those published via collaboration of more than one EAZA member institution. The relevant peer-reviewed publications for all institutions with more than one publication were analysed for the top 30 research areas assigned by WoS. Each publication was reviewed, and the classified research areas were manually extracted from the publication information provided by WoS. To

Table 1. Overview of top 10 publishing EAZA member institutions (age refers to 2018).

Institution	Publications	Citations	Average no. of citations	h-index	Age (years)
Royal Zoological Society of Antwerp (Zoo Planckendael and Zoo Antwerpen)	255	4785	18.76	35	62
Copenhagen Zoo	198	4885	24.67	27	159
Zoologischer Garten Köln	184	1368	7.44	20	158
North of England Zoological Society (Chester Zoo)	170	2934	17.26	28	87
Royal Zoological Society of Scotland (Edinburgh Zoo and Highland Wildlife Park)	167	2270	13.59	25	105
Moscow Zoo	139	1101	7.92	18	154
Durrell (Jersey Zoo)	131	1503	11.47	17	59
Bristol, Clifton and West of England Zoological Society (Bristol Zoo)	83	686	8.23	11	182
Aalborg Zoo	67	439	6.55	10	83
Zoologická zahrada Liberec	64	669	10.45	15	99

further investigate the most prominent research areas and their development over time, the number of publications per research area per year were collated to allow for analysis of the development throughout the 21-year timespan. A single publication could be assigned to several research areas; however, this did not affect the total number of publications contributed by each institution.

Results

EAZA members contributed a total of 3,345 publications in the years 1998–2018, which amounts to a mean of 11.5 publications per institution. Almost two thirds of all institutions (65.3%) had between one and 100 publications (Figure 1) while 32% had no

registered peer-reviewed publications. Seven institutions each had more than 100 publications, namely Royal Zoological Society of Antwerp (Zoo Antwerpen and Zoo Planckendael), Copenhagen Zoo, Zoologischer Garten Köln, North of England Zoological Society (Chester Zoo), Royal Zoological Society of Scotland (Edinburgh Zoo and Highland Wildlife Park), Moscow Zoo and Jersey Zoo (Table 1), thus contributing 37% of the total output. The 3,345 publications were cited a total of 45,821 times, but no correlation was found between the number of publications and times cited (Table 1).

During the period 1998–2018, an increase in the number of peer-reviewed publications from EAZA zoos and aquaria was observed (Figure 2). From 2008 to 2018, the increase was more than threefold. The distribution of publications within the top

Table 2. Top 10 Web of Science research areas.

Research area	Number of publications 1998-2018
Zoology	1056
Veterinary sciences	972
Environmental sciences and ecology	548
Biodiversity conservation	424
Science and technology	242
Behavioural sciences	206
Reproductive biology	180
Evolutionary biology	151
Genetics and heredity	148
Marine and freshwater biology	127

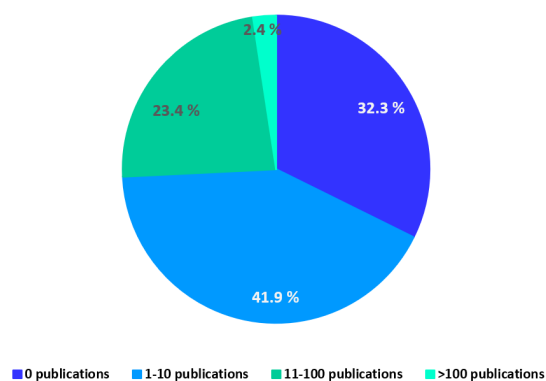
**Figure 1.** Distribution of number of publications by EAZA member institutions.

Table 3. Top 10 journals where EAZA member institutions published peer-reviewed papers, and their relative contribution to the total number of papers.

Journal	Number of publications	% Contribution
Journal of Zoo and Wildlife Medicine	198	5.9
Zoologische Garten	134	4.0
PLoS ONE	128	3.8
Zoo Biology	102	3.1
International Zoo Yearbook	94	2.8
Zootaxa	60	1.8
Veterinary Record	59	1.8
Fauna Bohemiae Septentrionalis	51	1.5
Journal of Zoo and Aquarium Research	42	1.3
International Journal of Primatology	38	1.1

three research areas followed the same trend as the total number of publications, with an increase, which was amplified from 2008 onwards. The top two research areas were zoology and veterinary sciences, with twice as many search results as number three on the list, environmental sciences and ecology (Table 2 and Figure 2). An exhaustive list of research areas can be seen in Supplementary Table 1.

The top five journals publishing research by EAZA members were Journal of Zoo and Wildlife Medicine (198 publications), Zoologische Garten (134 publications), PLoS ONE (128 publications), Zoo Biology (102 publications) and International Zoo Yearbook (94 publications) (Table 3).

When investigating factors relating to research contribution, no significant correlation was found between total research output and paid attendance/membership category ($r=0.3270$), yearly fee ($r=0.3140$), or institutional age ($r=0.2503$).

Discussion

With a total of 3,345 articles, reviews, letters, clinical trials and case reports published in the 21-year study period, it is evident that EAZA zoos and aquaria are contributing a large quantity of peer-reviewed scientific research. When looking into the contributions from each institution, the mean number of publications is ~11, however a large proportion of institutions (~32%) did not publish at all in the time period investigated, reflected in the median value of 2. Institutions with 1–10 publications accounted for ~42% and only 2.4% of the institutions contributed with more than 100 publications (Figure 1 and Table 1). Although no correlation was found between the number of publications and number of citations, the top 10 publishing institutions had a high number of citations (Table 1). The number of citations often reflects how broad the subject matter is. It could thus be speculated that the institutions with higher average number of citations contributed with scientific research of the broadest use to the scientific community.

Over the 21-year time period, there was a steady increase in the number of publications, but the more than threefold increase from 2008 to 2018 stands out (Figure 2). It is speculated that this

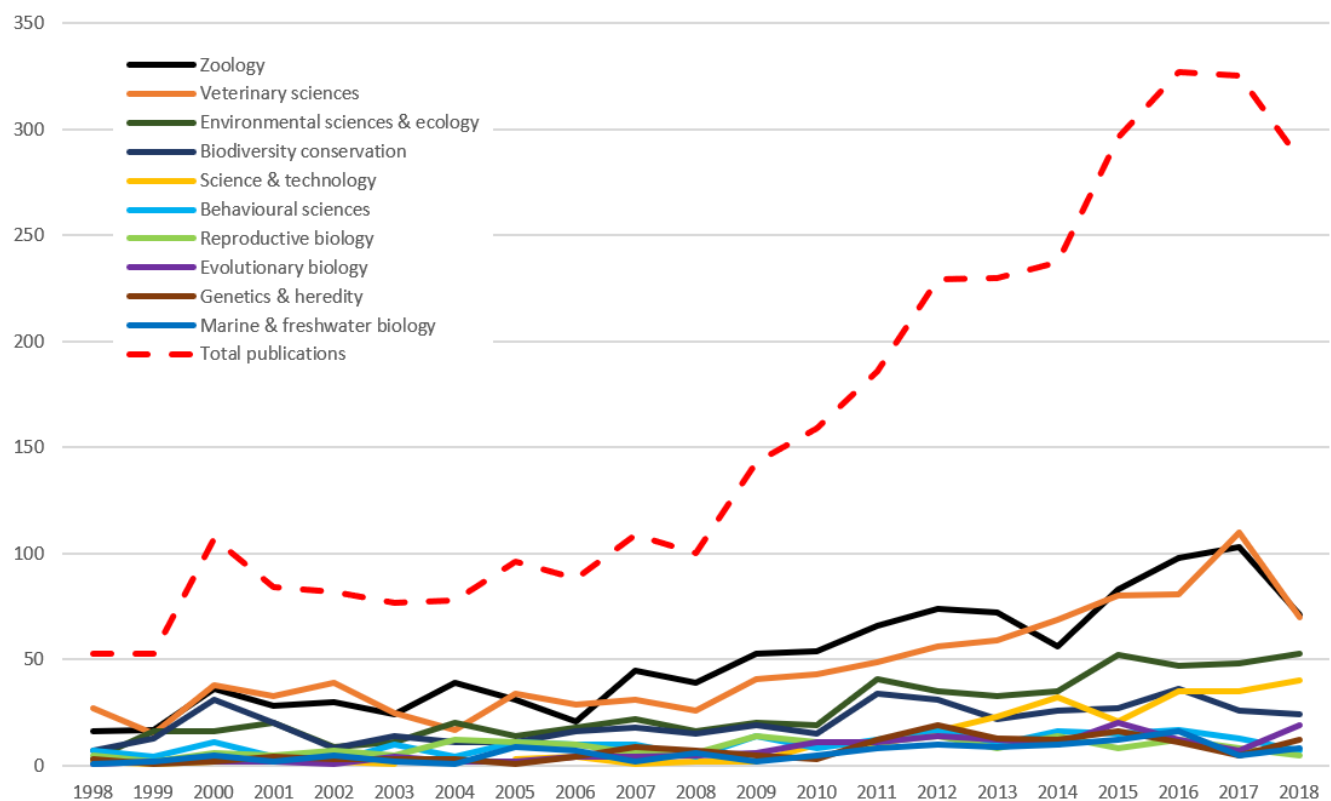


Figure 2. Development of number of publications within top 10 research areas between 1998–2018.

“sprint” could be partly induced by internal promotion of the relevance of research by EAZA. In 2008, the EAZA research strategy outlining ways for zoos to contribute to research was published (Reid et al. 2008), followed by the “EAZA future search”, outlining the visions for the future work of EAZA member institutions, which was implemented in the EAZA Strategy and Action Plan for 2009–2012 (EAZA 2009). Both publications might have prompted member zoos and aquaria to conduct and publish research. However, considering the lag time from idea to publication, the effect—if any—of these publications would be expected late in the period. It could be argued that the threefold increase in recent years, rather than being a general trend, is skewed due to specific actions by the 2.4% of zoos and aquaria each with more than 100 publications. However, the increase is still evident after excluding the seven most publishing institutions (supplementary Figure 1). A partial explanation for the peak in 2016–2017 and the apparent decline in publications in 2018, may be the creation of the Zoo Health Management specialty within the European College of Zoological Medicine. This newly established specialty college invited established zoo practitioners to become specialists recognised de-facto. One of the criteria for qualifying for this recognition was a set number of publications, and both the *Journal of Zoo and Wildlife Medicine* and the *Journal of Zoo and Aquarium Research* experienced a surge in submissions in 2015–2016 ending around the deadline of April 2017.

The top three research areas for EAZA member institutions were zoology, veterinary sciences, and environmental sciences and ecology (Table 2). This closely resembles the findings for AZA member institutions (Loh et al. 2018), and likely reflects the rather pragmatic approach of many zoos of using research as a tool to solve everyday problems. There is enormous potential for more fundamental science research, as well as research targeted directly towards informing in-situ conservation.

Using WoS “All databases” provided a standardised reliable means of retrieving publications and was shown to produce the largest amount of search results. However, as with any database, there is a risk that certain journals are not included, potentially leading to an underestimation of the research output. In addition, some institutions use several alternative names, some of which had publications registered under them. Although extensive searches for alternative names were undertaken, it is acknowledged that there might be names that were not included, which for the affected institutions will result in an erroneously low number of publications. Alternative institutional names create a challenge for zoos and aquaria, as they make it difficult to investigate the contributions to scientific research, arguably making it more difficult for such institutions to brand themselves as scientific contributors. It would increase visibility and thus benefit individual institutions as well as organisations such as EAZA, if institutions restricted themselves to publish under a single name. In either case, the main focus of this investigation was to elucidate the magnitude of publications from EAZA institutions, not to compare individual zoos.

The effects and implementation of research are difficult to measure. However, the increasing output observed during the 21-year period, as well as the number of citations, indicates that the scientific research produced by EAZA members is being acknowledged and used as inspiration for further research. In addition, 154 publications were produced in collaboration between two or more institutions, indicating cross-institutional collaborations. Chester Zoo and Copenhagen Zoo were the most collaborative organisations with 19 and 16 publications involving authors from other zoos, respectively.

While reproducible, and comparable to the recent study of AZA institutions (Loh et al. 2018), there is no doubt that the methodology used here has left out a large number of publications,

leading to an underestimation of the research output provided by EAZA member institutions. Notably, Loh et al. (2018) included proceedings and book chapters in their quantification, undoubtedly increasing the total number of publications markedly. This type of “grey literature” was deliberately omitted from this study, and the numbers are thus not directly comparable. In addition, zoos are responsible for a considerable number of publications appearing in non-peer reviewed journals. During data collection, some results were filtered because they were not published in peer-reviewed journals. It is positive that institutions are promoting their research in a non-scientific style and research published in magazines is not necessarily of poorer quality. However, to promote scientific quality and accurate knowledge-sharing, it would behove zoo researchers to aspire for peer-reviewed journals. In that way, zoos and aquaria would follow good scientific practice and ensure that progress is being made based on empirical work.

This study has focused primarily on the quantity of research; however, quality is arguably more important. As seen in Table 1, h-index ranking differs somewhat from the simple quantitative ranking among the top 10 publishing organisations. The h-index and the average number of citations, concern the scientific impact and reach of the publications. That said, a large proportion of zoo-generated research appears in specialist journals focused on zoo biology and veterinary science (e.g., *Journal of Zoo and Wildlife Medicine* (198 papers), *Zoologische Garten* (134 papers) and *Zoo Biology* (102 papers)) (Table 3), often because these are the outlets most likely to reach the immediate users of the results. Admittedly, limitations in study design and research funding might also be factors affecting which journals the research is published in. Of the top five most used journals, only “Plos One” is not specifically targeting the zoo and aquarium community, and the general impact of zoo and aquarium research would likely increase if zoo and aquarium-based authors considered a broader range of journals including non-specialist journals. Given the public attention regarding the role of zoos and aquaria, and the aspiration of zoos and aquaria towards becoming conservation centres, a future goal could be tailoring more scientific work towards questions of broader conservation use, preferable across the ex-situ and in-situ continuum. Providing research of value to conservation practitioners would help bridge the scientific gap between ex-situ and in-situ conservation, and publishing in non-specialist journals targeting a broader audience might increase awareness of the research potential of zoological institutions.

Of the 291 EAZA member institutions included in this study, 199 published in the 21-year period, and research thus seems to be an integral part of their purpose. Unlike the study by Loh et al. (2018), no attempts were made to analyse mission statements from the EAZA member institutions. As research is a key part of EAZA’s mission and Code of Ethics, it is assumed that member institutions entering into such an agreement, will aspire to deliver their responsibilities and contribute to research. It is important to note, however, that zoos and aquaria can and do contribute to research in ways other than through publishing peer-reviewed scientific research. By allowing their facilities and animal collections to be made available for research by researchers not affiliated with the zoo, they promote transparency and facilitate research and research training within many disciplines, responsibly utilising the unique resource which they steward. The research output resulting from such provision was not analysed in this study.

This study encourages zoos and aquaria to continue their high research output. In doing so, they not only contribute to answering pertinent questions and promote excellence and progress within in-situ and ex-situ conservation work, but they also make the institutions visible in the scientific community and to the public as an important contributor to scientific research and new knowledge. Many people today live estranged from the natural

world, and nature is often being rated and evaluated based on its value to humans. Therefore, zoos are important actors in bridging the gap between the modern anthropocentric world and nature. Zoos remain a controversial entity for some (Maynard 2018). However, with their enormous outreach to the public (Gusset and Dick 2011), and 140 million visits being made annually to EAZA member zoos and aquaria alone, the scientific work by zoos and aquaria holds great potential for public dissemination and education. The scientific work not only promotes conservation, but may also help improve public perception by showcasing the extensive and scientifically sound work going on behind the scenes.

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Conflict of Interest

The authors declare no conflict of interest.

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