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Research article

What is the evidence for the effectiveness of husbandry and management interventions for the conservation and welfare of captive animals? A systematic map protocol

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Abstract

Biodiversity is being lost at an alarming rate, much greater than natural background extinction. This crisis has highlighted the potential role of zoos, aquariums, and other captive facilities to mitigate the loss of biodiversity, although their ability to do so is sometimes questioned. Amongst other factors, zoos and aquariums have experienced challenges in sustaining viable populations under managed care (i.e. in captivity), identifying appropriate circumstances and approaches for reintroduction, and addressing societal concerns pertaining to the welfare of captive animals. Robust science-based methodologies must be developed and the effects of zoo- and aquarium-based practices assessed, in order to improve captive animal health and welfare, to better manage captive populations, and to optimise the success of population management and conservation breeding programmes. There is, therefore, an increasing need for evidence-based husbandry and management of captive animals for conservation. This study proposes a systematic map of research on husbandry interventions and practices associated with improving the conservation and welfare of captive animals, for better managing their breeding, and for other, related outcomes. This map, which will be freely available to all, will improve knowledge of the available evidence for both the commonly used and lesser known interventions and practices aiming to improve the welfare and conservation of captive animals, by answering several questions: Which studies have measured the effects of any possible management and/or husbandry interventions/practices on the conservation and welfare of captive animals? Which husbandry interventions/practices and outcomes have been studied, and which ones are lacking published evidence? For the purpose of this map, this study will focus on captive animals kept in zoos and aquariums but will consider evidence from other captive environments where appropriate. This paper provides the protocol outlining the methods designed to identify and collate into a systematic map the available global evidence for the effectiveness of husbandry interventions and practices for the welfare and conservation of captive animals.

Introduction

Biodiversity is being lost at an alarming rate, much greater than natural background extinction (Pimms et al. 2014). As a result of the current biodiversity crisis (Singh 2002; Ceballos et al. 2019), we may be undergoing the Sixth Mass Extinction.

Zoos, aquariums, and other captive facilities (referred to as 'zoos and aquariums' hereafter for brevity) have the potential to reduce the threat of extinction. By maintaining animal populations in captivity, they are protected from immediate extinction and other external pressures and threats. Captive facilities can thus serve as modern 'Noah's Arks', maintaining 'assurance populations' for the future (Soulé et al. 1986; Bowkett 2009); however, management strategies need to be developed and perfected, particularly for endangered species that are rarely or not yet kept in managed care (e.g. the vaquita *Phocoena sinus*; Goldfarb 2016; Rojas-Bracho et al. 2019). More recently, this Ark paradigm is being replaced by an alternative 'integrated approach' that recognises the wider contribution that captive facilities can make to biodiversity conservation (Hutchins and Conway 1995; Keulartz 2015; Breithoff and Harrison 2018; Minteer et al. 2018).

Indeed, zoos and aquariums have an important role to play in global biodiversity conservation both ex situ and in situ. Ex situ this role is fulfilled through conservation breeding programmes and population management, zoo-based research, and visitor education, action and advocacy (Che-Castaldo et al. 2018; Minteer et al. 2018; Consorte-McCrea et al. 2019), while in situ it is fulfilled by supporting and participating in field projects (including the translocation and reintroduction of captive and wild origin animals), or by working directly with local communities (Matamoros-Hidalgo 2002; Gusset and Dick 2010; Zimmermann 2010; Crudge et al. 2016; Gilbert et al. 2017). However, the appropriateness and effectiveness of the conservation, education and research goals that modern zoos work towards are sometimes questioned (Redmond 2010; Reiser 2017).

Zoos and aquariums experience multiple challenges in fulfilling their conservation roles, such as experiencing difficulty sustaining viable captive populations of a diverse range of taxa as part of conservation breeding programmes (Lees and Wilcken 2009), and of identifying appropriate circumstances and approaches for reintroduction of captive-bred animals (Marshall and Spalton 2000; Maran et al. 2009; Read et al. 2011; although reintroduction is not the concern solely of zoos and aquariums, but also of collaborating conservation organisations), leading to limited success of such programmes. Recent studies have also shown that a relatively small proportion of species in zoo and aquarium collections are globally threatened (Conde et al. 2013; Martin et al. 2014; Dawson et al. 2016; Biega et al. 2017; Che-Castaldo et al. 2018; but see Bowkett 2014). While it is undoubtedly sometimes necessary to keep non-threatened species in zoos and aquariums, for instance for research and educational purposes where using threatened species would be too risky, a higher representation of endangered species (in terms of absolute numbers rather than proportions) is likely needed. Furthermore, zoos and aquariums also face the challenge of ensuring optimal animal welfare when under managed care. Animal care in zoos and aquariums, particularly those that are accredited by respected regional zoological associations, has certainly improved over the past decades. Even so, continuous improvement must be sought. Additionally, there are also societal concerns pertaining to the rights, health and welfare status of captive animals, which remains a topic of controversy (Powell and Watters 2017; Minteer et al. 2018). This includes the ideology that animals ought to remain in the wild under any circumstances, but also concerns arising from perceived substandard housing and husbandry practices (hereafter referred to simply as 'husbandry'), that—even when inaccurate—zoos and aquariums must address.

Poor husbandry and welfare in captive animals can be difficult to determine and assess, but can be indirectly evidenced by the occurrence of diseases and/or injuries, reduced longevity and fecundity, the display of stereotypies and/or other abnormal behaviours (although it should be noted that the aetiology of stereotypies and abnormal behaviours is not always clear), elevated levels of stress hormones, and changes in socialisation and vocalisation (Wolfensohn et al. 2018). In addition, captivity was recently shown to alter crucial aspects of species and individual health and fitness (such as their microbiomes; Bates et al. 2019; Vaissi et al. 2019), which in turn can jeopardize ex-situ conservation as well as re-introduction programmes (Allan et al. 2018; Yao et al. 2019). Reciprocally, good husbandry and welfare is also difficult to determine and assess, but various models can be used to evidence it (e.g. A Life Worth Living, Five Freedoms, Five Domains; Mellor et al. 2015; Mellor 2016; Wolfensohn et al. 2018). In some circumstances, welfare goals relating to individual animals may conflict with conservation goals relating to populations or species (Fraser 2010). This conflict can arise, for instance, in zoos and aquariums where management strategies require transportation between facilities or removal of individuals not needed for population viability. Whether it is for ethical, political, economic, cultural or conservation-oriented reasons, zoos and aquariums have a duty of care towards their captive animals, and are morally obligated to ensure that their husbandry practices aim to achieve optimal levels of health, welfare and overall quality of life wherever possible.

Therefore, there is an urgent need for evidence-based husbandry and management of captive animals for conservation, based on robust methodologies and tested zoo- and aquarium-based practices, in order to improve health and welfare, and to optimise the success of conservation breeding programmes.

Evidence-based conservation and management of captive animals has been advocated by experts (Melfi 2009) but remains under-used. Indeed, there exists a considerable amount of published and/or reported evidence and accounts of husbandry practices that document their effects on captive animals, which could be used to inform decisions. However, studies of zoo and aquarium husbandry appear to be dispersed across many literature sources, which means that this evidence is not easily accessible to practitioners, hindering effective evidence-based practice. Moreover, it is likely that the published evidence may show some significant biases (for instance towards particular species) and may be based on small sample size and non-robust experimental designs.

Identifying and reviewing the evidence for a specific topic (e.g. improving the welfare of captive carnivores) is a time-consuming and sometimes costly exercise. In general, the assessment of the evidence base is approached on a case-by-case basis and different stakeholders independently conduct evidence reviews relative to their specific application or enquiry. This approach is an inefficient use of resources, being repetitive and time-consuming.

Despite its potential usefulness, and although evidence is available for the effects of husbandry interventions on the health and welfare of captive animals, no systematic review or map of that evidence is available to date. A systematic map is a rigorous, objective and transparent evidence synthesis methodology which aims to collate and describe the captured evidence into a 'catalogue' (James et al. 2016). To ensure it achieves its intended rigour, objectivity and transparency, it is standard for systematic maps (as well as systematic reviews in general) to publish a peer-reviewed protocol ahead of the work (Collaboration for Environmental Evidence 2018). Systematic maps incorporate a large variety of elements from each of the evidence catalogued, and therefore can be extremely valuable in answering the wide array of multi-faceted questions that practitioners may have.

The systematic map proposed here will focus on published research (peer-reviewed and non-peer reviewed, see 'methods' below) on husbandry interventions and practices associated with improving the conservation and welfare of captive animals, and other related outcomes. This map stems from an earlier pilot project that produced mini-synopses of evidence for the effect of selected husbandry and conservation interventions on specific taxonomic groups (see Jonas et al. 2018). Cataloguing all the available published research on the topic will improve knowledge of the available evidence for those interventions and practices that aim to ensure the welfare and conservation of captive animals. Ultimately, this systematic map aims to facilitate evidence-based conservation and management of captive animals by identifying and collating the available evidence.

Stakeholder engagement and future work

This protocol has been developed in consultation with the British and Irish Association of Zoos and Aquariums (BIAZA), which has provided the funds for this systematic map, the Conservation Evidence group at the University of Cambridge (Sutherland et al.

2019a), and staff at Wild Planet Trust (Paignton Zoo, UK), all of whom could be considered stakeholders. BIAZA is a membership body representing 123 zoos and aquariums in the UK and Ireland (https://biaza.org.uk). Wild Planet Trust runs two zoos which are members of BIAZA and was previously involved in the 'Management of Captive Animals' short synopses produced by Conservation Evidence (Jonas et al. 2018).

In addition, an advisory board made up of over 25 international conservationists, academics, and zoo- and aquarium-keeping staff, with expertise in captive animal husbandry and conservation has been formed. Some of the advisors also represent national and international organisations and professional bodies, such as BIAZA, EAZA (European Association of Zoos and Aquariums), AZAB (Brazilian Association of Zoos and Aquariums) and PAAZA (Pan-African Association of Zoos and Aquariums), amongst others. These experts will input into the evidence mapping at three key stages: a) informing elements of the systematic map protocol, such as identifying key sources of evidence (i.e. journals and reports) or suggesting metadata to include, b) reviewing the systematic map protocol and developing a comprehensive list of husbandry interventions and practices that will be included in the final systematic map, and c) reviewing the draft systematic map. The initial advisory board is listed in Appendix A1, although additional experts may be added during the production of the map. The final list will be published with the map.

The authors of this systematic map and its protocol include leaders from two of these groups of stakeholders, and this map is expected to be of direct interest to each of these groups and their members/users, as well as other stakeholders in zoos and aquariums across the world.

It is envisioned that this map will be useful for researchers, policymakers and practitioners, including zoo and aquarium keepers, managers and conservationists, to identify relevant evidence when making decisions relating to captive animal management. The map could also be used to prioritise primary research on identified knowledge gaps or secondary research on knowledge clusters. For instance, the Conservation Evidence Synopsis on Farmland Conservation (Dicks et al. 2014) was based on a systematic map that was published in Environmental Evidence (Randall and James 2012; along with protocol by Randall 2008). In addition, a systematic map of evidence for the agricultural and environmental impacts of cassava farming practices (for which a protocol has recently been published; Shackelford et al. 2018) is currently being produced and aims to inform a similar Conservation Evidence-style synopsis.

It is the aim for the systematic map produced following this proposed protocol to be used to support a Conservation Evidence-style synopsis on a selected topic (which will be chosen based on the outcomes of the systematic map), and which will build upon the pilot mini-synopses already completed by Jonas et al. (2018). Such a synopsis of the evidence would benefit stakeholders, such as researchers and zoo and aquarium professionals, by providing freely accessible and digestible evidence for the effects of specific interventions (e.g. Dicks et al. 2014). Therefore, this protocol, as well as the subsequent map and the related synopsis, will use wording that is standardised to the Conservation Evidence project and its subject-wide synthesis methodology (Sutherland et al. 2019b).

Objectives of the review

Primary objectives (questions)

The primary objectives of this systematic map will be to answer the following questions:

1. Which studies have measured the effects of any possible management and/or husbandry interventions/practices on the conservation and welfare of captive (kept in zoos, aquariums, or other captive facilities) animals?

2. Which husbandry interventions/practices and outcomes have been studied (knowledge clusters) and which ones are lacking published evidence (knowledge gaps)?

Secondary objectives

Secondary objectives for this systematic map will be to answer the following question:

3. What is the distribution and abundance of studies between outcomes/metrics, species or species groups, countries/facilities, and years? In other words, where are the knowledge gaps or knowledge clusters in this map relative to each of these subsets of evidence?

As stated above, an additional objective will be to inform the production of a Conservation Evidence-style synopsis of evidence for a selected topic. A Conservation Evidence synopsis is a form of subject-wide evidence synthesis (sensu Sutherland et al. 2019b) in which narrative summaries of scientific studies are written in a standardised form (typically one paragraph per study, with information on study location, study design, methods, target species or habitats and main results). The choice of topic for the synopsis will be informed by the outcome of the systematic map and apparent distribution of evidence. This synopsis will act as a proof of concept and model for further synopses to be produced on other topics based on the systematic map.

Methods

Searching for articles

Keyword or string searches will not be used as the standard method for the creation of this systematic map. Literature will be in the majority obtained from 1) the Conservation Evidence discipline-wide literature database, and 2) from comprehensive systematic searches of additional subject-specific literature sources. This database was built over time following the Conservation Evidence 'subject-wide evidence synthesis' (SWES) methodology, described in Sutherland et al. (2019b). Briefly, entire journals, organisational reports and databases have been fully searched at title and abstract level (initially) for studies testing the effects of conservation interventions on any aspects of biodiversity. Evidence from all around the world has been included in this database. For the systematic map, additional searches will be undertaken to complement the existing Conservation Evidence discipline-wide literature database. However, only English language articles and studies will be included. While searching only English language sources of evidence may potentially introduce some bias to the review process (Amano et al. 2016), project resources and time constraints do not currently allow for a wider scope.

Databases

As stated above, the Conservation Evidence discipline-wide literature database will be searched for any studies that tested interventions relating to the conservation, population management (captive breeding or population control) and/or husbandry of animals in zoos and aquariums. All the journals (and years) listed in Appendix A2 have already been systematically searched using the SWES methods and relevant papers relating to the management of captive animals have been added to the Conservation Evidence discipline-wide literature database. Other databases that will be searched are listed in Table 1 below.

Specialist journals

In addition to the journals listed in Appendix A2 (whose search results have been collated in the Conservation Evidence discipline-wide literature database), the following specialist journals in the field of zoos and aquariums, and/or in the field of animal

Table 1. List of specialist databases (excluding the Conservation Evidence database) that will be systematically searched for relevant studies.

Specialist databases	Website
Enrichment Records – poster database*	http://enrichmentrecord.com/
Association of Zoos & Aquariums (AZA) Publications Database*	https://www.aza.org/research-and-science
Refinement and environmental enrichment database for lab animals	http://www.awionline.org/lab_animals/biblio/refine.htm

Table 2. List of specialist journals that will be systematically searched for relevant studies. * denotes specialist journals that will be searched in priority.

Journal
Animal Welfare*
Animals*
Applied Animal Behaviour Science*
Aquarium Science and Conservation*
International Zoo Yearbook*
Journal of Applied Animal Welfare Science*
Journal of Zoo and Aquarium Research*
Zoo Biology*
Journal of Zoo and Wildlife Medicine (former Journal of Zoo Animal Medicine)*
Animal Conservation*
Endangered Species Research*
Marine Mammal Science*
Animal Nutrition*
Journal of Applied Animal Nutrition*
Anthrozoös
Ursus
Frontiers in Psychology (Vol 10)
International Journal of Primatology
American Journal of Primatology
Animal Behavior and Cognition
Animal Reproduction Science
Journal of Animal Physiology and Animal Nutrition
Primates
Der Zoologische Garten
Theriogenology
Journal of Threatened Taxa
Animal Behaviour

welfare, will be systematically searched for all volumes and issues published before the end of 2019 (or until the last published issue if discontinued before the end of 2019). These journals (listed in Table 2) were identified through expert judgement by the project researchers and the advisory board. It may not be possible to search all the journals listed within the timeframe of this project. Journals with an * will be searched in full to prioritise searches considered likely to yield higher numbers of relevant studies. Other journals will be searched as time allows following the order presented.

Keyword searches

Many more journals, volumes and years than those listed in Appendix A2 have been systematically searched by Conservation Evidence as part of its wider project but are not listed here. These journals (or volumes/years), which are listed on their website, were searched prior to the conceptualisation of this systematic map, and unfortunately not all studies relevant to the management of captive animals were extracted. At the time those journals were searched, the Conservation Evidence inclusion criteria, although including captive breeding, did not include all other interventions relating to the management of zoo animals (e.g. nutrition, enrichment, enclosure design, etc.). As such, these are not listed in Appendix A2 as they are not considered as having been searched for the purpose of the map.

Nevertheless, for a select few of those journals (selection based on suggestions by advisory board members; listed in Table 3) a keyword search will be carried out within each of them with the aim of finding all studies focussed on actions for the management of captive animals, which had not been included during previous Conservation Evidence searches. As those selected journals have already been systematically searched using the SWES method for all other interventions, it was decided due to time constraints not to systematically search them again (only the latest issues not yet searched by Conservation Evidence will be searched using the SWES method, hence these are also listed in Table 2). The keyword string that will be used to search for relevant studies within each of those journals are: captiv* OR aquar* OR zoo OR husbandry. It is believed that this will be sufficient in capturing most or all the relevant studies.

Specialist report series

Specialist reports, newsletters and bulletins relevant to captive animals will be targeted, as listed below in Table 4. During searches, every article title and abstract/summary (published before the end of 2019) will be scanned. It may not be possible to search all of those listed within the timeframe of this map. Reports will be searched in the order presented below.

Other searches

Where a published systematic review is found for an intervention, all studies reviewed as well as the systematic review itself will be included. Where a non-systematic review is found for an intervention, all relevant studies referenced within it will be included, but the review itself will not be, unless it also provides new or collective data. Relevant studies cited in other publications included in the systematic map (for instance in their introduction section) will not be included due to time restrictions.

PhD, Masters or undergraduate theses will not be systematically searched due to time constraints and the fact that they are not located in a centralised repository that is easily searchable. However, they will be included if referenced in a review article (see above) or suggested by the advisory board, if they were not subsequently published elsewhere.

Screening process

Publications will be screened in two stages: (1) using titles and abstracts and (2) using full texts. At each stage, it will be decided

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Table 3. List of specialist journals that had previously been systematically searched by Conservation Evidence, but without extracting all relevant ex-situ studies, and that will be searched using specific keywords.

Specialist journals
Animal Conservation
Endangered Species Research
Marine Mammal Science
American Journal of Primatology

Table 4. List of specialist report series that will be systematically searched for relevant studies. * denotes specialist journals that will be searched in priority

Specialist report species
Enrichment Records (magazine)*
ZooQuaria (quarterly publication of EAZA)
Shape of Enrichment
International Zoo News
Drum and Croaker
Laboratory Primate Newsletter
Froglog

whether to include a publication or whether to exclude it from the map, based on the eligibility criteria (see below). The number of publications included/excluded at each stage will be recorded, and a list of the studies excluded at stage 2 (full text) will be recorded, together with reasons for exclusion.

To ensure consistency and accuracy when screening publications for inclusion in the literature database, an initial test was carried out by the main author (AJL), using the Conservation Evidence inclusion criteria (Appendix A3) and a consistent set of references, and results were compared with the decisions of the experienced core Conservation Evidence team. Results were analysed using Cohen's Kappa test (Cohen 1960). As the initial results showed 'substantial' (K=0.61-0.8) or 'almost perfect' agreement (K=0.81-1.0), the author did not receive further training. However, to further validate the screening process of the main author in regards to this particular topic (conservation management of captive animals), a subsection of titles and abstracts from a specialist zoo journal will be screened by the author as well as by a second person (two years of publications from a selected specialised journal). A Kappa score will then be calculated to assess the level of agreement between the two people. If the Kappa score is less than 0.61, then another set of titles/abstracts will be screened independently by the same two people. Disagreements will be discussed and resolved, and again Kappa scores will be calculated. This process will be repeated until the Kappa score is greater than 0.61. All other publications will be screened by the main author only (AJL).

Eligibility criteria

All journal searches will follow the Conservation Evidence inclusion criteria (described in Sutherland et al. 2019b; see Appendix A3) in order for any studies meeting the criteria to be included in the wider Conservation Evidence discipline-wide literature database and be used in future Conservation Evidence synopses and projects ('economies of scale'). However, only a portion of the studies screened will be included in the present systematic map; those that match the criteria described below defined using 'PICO/PECO' terminology (P=populations/subjects, I=interventions/E=exposures, C=comparators, O=outcomes; see James et al. 2016). A record of publications that were excluded at full-text stage will be kept with reasons for exclusion and made available if requested.

Population/subject

Studies on the effects of husbandry practices on captive animals' conservation, population management, rearing and welfare, across all taxa (vertebrates and invertebrates) will be included, and those undertaken in zoos and aquariums (as well as other captive facilities where appropriate, as mentioned above) anywhere in the world. Note however that studies focussed on domestic species (e.g. dogs, cats, mice, guinea pigs, goldfish, etc.) will be excluded, even if some might be kept in zoos and aquariums (for instance as part of a petting zoo).

Interventions/exposures

An intervention has to be an action that could be put in place by a zoo/professional to improve the health and/or welfare of animals in captivity and/or improve the management of captive populations (including captive breeding and population control and/or reduction).

Studies not undertaken in the context of a zoo, an aquarium, or another relevant captive environment, such as a conservation breeding centre or a sanctuary, will be excluded (e.g. studies conducted in experimental research and/or medical laboratories or in commercial farms; those will not be included). Nevertheless, studies on species kept in farms, laboratories and aquaculture facilities that are also kept in zoos and aquariums and for which the intervention studied could be implemented in a zoo or aquarium (e.g. feeding enrichments for farmed ostriches, housing systems for farmed American minks *Neovison vison*, object enrichment for laboratory primates) represent exceptions that will be included. However, as journals that focus on practices in commercial farms or laboratories will not be searched, this systematic map should not be regarded as complete for such species and should be supplemented by evidence from that sector if they are the focus.

All zoo or aquarium-based interventions will be considered. However, interventions where the main outcome measured relates to the reintroduction or release of animals into the wild following captive-rearing or captive-breeding will not be included, as evidence for these interventions is already listed and summarised as part of taxa-specific synopses produced by Conservation Evidence (e.g. Smith and Sutherland 2014; Berthinussen et al. 2019).

Finally, studies looking at veterinary practices in zoos will not be included, for instance to treat acute injuries or to routinely vaccinate against diseases, due to the sheer number of studies in the field, and because databases focussed on the collation of veterinary evidence already exist (e.g. https://www.msdvetmanual.com/). Nevertheless, veterinary studies which target methods of population management, such as methods for captive breeding, contraception and monitoring of hormones and reproductive cycles, will be included.

Table 5. Example of the metadata extracted from a relevant study and coded using the chosen fields.

Code fields	Example
Study reference	Depauw, S., Heilmann, R.M, Whitehouse-Tedd, K., Hesta, M., Steiner, J.M., Suchodolski, J.S., Janssens, G.P.J. (2014) Effect of diet type on serum and faecal concentration of S100/calgranulins in the captive cheetah. J*ournal of Zoo and Aquarium Research* 2, 33-38.
Publication year	2014
Journal	Journal of Zoo and Aquarium Research
Intervention type - level 1	Diet or feeding modification
Intervention type - level 2	Diet supplementation and/or modification
Exact intervention - level 3	Feed whole rabbit (to captive cheetahs) instead of supplemented beef diet
Taxa (Class) - level 1	Mammal
Taxa (Order) - level 2	Carnivora
Taxa (Family) - level 3	Felidae
Species (genus/binomial) - level 4	*Acinonyx jubatus*
Common name	Cheetah
Life stage	Adult
Outcome category	Condition
Metric	Immune function
Study design	Replicated, before-and-after study
Study year	Unspecified
Location (Country) - level 1	Denmark
Location (Zoo/Aquarium) - level 2	Ree Park Ebeltoft Safari

Comparators

To determine the effectiveness of interventions, studies must include a comparison or a counterfactual, either in time (i.e. monitoring change over time; typically before and after the intervention was implemented), or an experimental control (for example comparing sites or enclosures with and without the intervention). Alternatively, a study could compare one specific intervention (or implementation method) against another. For example, this could be comparing the welfare of captive animals using different designs of puzzle feeders, rather than with and without puzzle feeders. Furthermore, wild populations can also represent suitable comparators. Exceptions which may not have a comparator but will still be included are, for example, the success of captive breeding (i.e. a study describing the husbandry and circumstances leading to successful reproduction may not contain comparative information from when reproduction did not occur).

Outcomes/metrics

Appendix A4 presents a list of anticipated relevant outcomes/metrics used to assess the reproductive success, health and welfare of captive animals. If additional outcomes/metrics are found for these populations/subjects when screening publications, then these will be added to the list and the studies will be included in the systematic map.

Study designs

Only studies that measured the effects of an intervention on an outcome and also reported the numerical results of these measurements in the text, a figure, or a table will be included. Appendix A5 lists the study designs included. The strongest evidence comes from randomised, replicated, controlled trials with paired-sites and before and after monitoring.

Study validity and quality assessment

The evidence from each publication will not be quantitatively assessed or weighted according to quality/study design. However, to allow the readers to interpret the evidence, information will be included on the design of each study.

The validity of the studies included in the systematic map will not be critically appraised because the map is considered a subject-wide evidence base that could be used for multiple methods of evidence synthesis, with different criteria for critical appraisal. However, as mentioned above, each study will be critically assessed for relevance and inclusion.

Data extraction and coding strategy

For the purpose of the systematic map, the following metadata will be extracted and coded (Table 5): PICO/PECO components will be coded (as described above in 'Eligibility criteria'); these are information related to the study, such as study year, study site (at two geographical levels), taxa (at two taxonomic levels), study design, and intervention (at two category levels). Information related to the publication (article reference; year of publication; journal/report name) will be coded. When necessary information is missing or unclear, it will be clearly stated by coding the associated fields with the term 'unspecified' or 'unclear', respectively.

To ensure the consistency and accuracy of data extraction and the validity of data coding, the metadata from an initial 20 publications (at the full-text stage, selected at random) will be extracted and coded by both AJL and one additional person. A Kappa score will be calculated to test the agreement between these two people on selected metadata (e.g. agreement about which interventions and outcomes were studied). Disagreements will be discussed, and the eligibility criteria will be revised to show how these disagreements were resolved. If the Kappa score is less than 0.61, the threshold of 'substantial agreement' (as above), then another 10 publications will be coded by both people and compared again. This process will be repeated until the Kappa score is greater than 0.61. After this process, the metadata for all other publications will be coded by AJL only.

Study mapping and presentation

The number of publications will be analysed by intervention, country/location, taxa/cross-taxa and year, and the results will be presented as a searchable database (the 'catalogue'). This systematic map, which could be also described as a catalogue of studies, interventions, species, effects, etc., will be freely accessible online. The results will be visually presented in geographical maps of evidence aimed to show knowledge gaps and knowledge clusters, as part of an open-access manuscript presenting the systematic map.

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