

1 **Abstract**

2 Advances in animal welfare science have led to a high number of studies published for farm,
3 laboratory and zoo animals, with a huge breadth of innovative topic areas and methodologies.
4 This paper investigates the different approaches used to undertake welfare research in farm,
5 laboratory and zoo animals due to the variety of constraints that each group brings. We also
6 set recommendations to how groups can support each other in moving forwards to reduce
7 animal suffering and promote a life worth living, a goal that all parties aim to achieve. We
8 propose that researchers develop more collaborations across species, in particular to focus on
9 the applied component of animal welfare and utilizing positive welfare indicators; facilitate
10 knowledge transfer and share good practice worldwide; and accept small *n* based studies that
11 can still be scientifically robust and provide individual-based steps into advances in our
12 knowledge. Ultimately, we need to be progressing animal welfare science to a point beyond
13 legislative needs, and ensure that ‘high animal welfare’ becomes an additional mission
14 statement for all animal-based industries.

15

16 **Keywords:** farm, five freedoms, captivity, positive welfare indicator, animal behavior

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19 **Introduction**

20 Definitions of animal welfare have advanced following the progression in our scientific
21 knowledge and advances in societal interest and influence. Definitions have ranged from a
22 focus on biological fitness (Barnett & Hemsworth, 1990), the state of an individual in relation
23 to its environment and its ability to cope with changes (Broom, 1991), and the ‘mind, body
24 and nature’ concept (Duncan & Fraser, 1997), with a more recent emphasis towards animal
25 emotion and affective states (Guesgen & Bench, 2017; Paul & Mendl, 2018). Thanks to
26 advancing definitions, animal welfare science has increased in its scientific rigour and journal
27 outputs, which accentuates the scientific and public interest in the field.

28 Animal Welfare Science is an applied science, and research in this area generally has the aim
29 of providing captive animals with the best possible life that can be provided. This presumably
30 is the priority of welfare research, whether undertaken with animals on farms, in laboratories,
31 or in zoos. There have traditionally been three different approaches to this goal: by ensuring
32 animals are healthy and live long lives, by promoting positive affective experiences (i.e.
33 keeping animals happy), and by allowing animals to perform positive behaviors they would
34 have been able to do in the wild (Fraser, 2009). All three approaches have varying influences
35 and methodologies within farm, laboratory and zoo welfare research. Farm and laboratory
36 welfare research (henceforth referred to as farm/lab research) has usually had access to large
37 numbers of individual animals, and can thus choose a sample size to ensure statistical
38 robustness (Dell et al., 2002). However, these animals represent just a small number of
39 species. In addition, researchers have generally been able to make substantial experimental
40 manipulations, such as removing confounding variables, setting up control groups and
41 manipulating environments and sometimes animals, again with the aim of achieving a robust
42 experimental design (Johnson and Besselsen, 2002). Zoo researchers, by contrast, have to
43 deal with small numbers of individuals, but of a huge range of different species; furthermore,

44 manipulation is rarely possible unless it is part of everyday husbandry procedures, and
45 confounding variables can rarely be removed (Hosey et al., 2013).

46 Because of this, farm/lab and zoo-based welfare research have tended to follow different
47 routes, though there have been some notable areas where zoo welfare has been able to utilize
48 concepts and procedures developed in an agricultural context, such as the assessment of
49 human-animal relationships and the benefits they bring (Ward and Sherwen, 2019). Since
50 both are concerned with essentially the same thing, i.e. the welfare of captive animals, we
51 must consider how the two traditions can be better brought together to provide a convergent
52 approach to this field. The aim of this paper is to investigate the different approaches used to
53 undertake welfare research in agricultural, laboratory and zoo animals due to the variety of
54 constraints that each group brings. We also aim to set recommendations to how groups can
55 support each other in moving forwards to reduce animal suffering and promote a life worth
56 living, a goal that is to be achieved by all parties.

57

58 **Farm/Lab Animal Welfare Research**

59 Research has been concerned with the welfare implications of transportation on a variety of
60 species including cattle (Teke, 2013), sheep (Parrott et al., 1999; Messori et al., 2015), goats
61 (Alcalde et al., 2017), pigs (von Borell & Schäffer, 2005), rabbits (De la Fuente et al., 2007),
62 chickens (Arikan et al., 2017), and turkeys (Wein et al., 2017). Additionally, the housing and
63 health of animals has been extensively researched, for example perch type and provision for
64 broiler chickens (Bailie et al., 2018), flooring type and housing systems for dairy cattle
65 (Fjeldaas et al., 2011, Grosso et al., 2016), flooring type and presence or absence of
66 bedding/substrate for pigs (Kallio et al., 2018) and indoor versus outdoor housing systems for
67 goats (Grosso et al., 2016). Furthermore, important techniques have been devised, such as

68 cognitive bias testing in pigs (Carreras et al., 2018), or measuring how hard animals will
69 work for different treatments or housing type (Patterson-Kane et al., 2002). These areas of
70 research all outline various management techniques that can improve the animals' welfare in
71 different situations that have been seen to have a negative impact on the animals involved.

72 Through innovative technology and growing expertise over the years, animal welfare
73 scientists have developed new techniques to assess welfare. Examples include the use of
74 accelerometers to identify gait and locomotor issues linked to health and welfare complaints
75 (Kuźnicka & Gburzyński, 2017; Radeski & Ilieski, 2017), infrared thermography used as a
76 method to remotely monitor dairy cow health and welfare (Stewart et al., 2017), monitoring
77 facial expressions to measure pain (Gottardo et al., 2016; McLennan et al., 2016), ear and tail
78 posture to understand emotion (Reefmann et al., 2009; Proctor & Carder, 2014) and
79 measuring affective states that may underpin how an animal feels i.e. it's mental state (Boissy
80 et al., 2007; Kappel et al., 2017). All of these contribute towards the growing bank of
81 knowledge for farm/lab animal welfare and are applicable across all animal industries. In
82 fact, could be of huge benefit within zoo welfare science due to the remote monitoring
83 involved with some of these technologies. However, more recently some of the welfare
84 research has become more 'theoretical' in form in that it seeks to understand the mechanisms
85 underlying animals' behavioral choices, or else uses complex and time-consuming
86 experimental procedures to diagnose the affective states which might influence the welfare of
87 the animals. For example, Smulders (2017) uncovered the effects that poor environments
88 have on brain structures such as the hippocampus, and an animal's time perception has been
89 suggested as a window into their affective state (Andrews et al., 2018). Although such studies
90 as these further our understanding of the way environments bring about welfare issues, it is
91 often difficult to see how they can be applied in a day-to-day setting across all animal
92 industries, particularly in a zoo.

94 Zoo Animal Behaviour and Welfare Science

95 Growing awareness in the 1960s and 70s of the importance of considering animal welfare in
96 zoos led to the recognition of abnormal behaviors in zoo-housed animals, which were
97 attributed to poor enclosure design (enclosures that were too small and too barren), lack of
98 social stimulation, and the proximity of people (Morris, 1964; Meyer-Holzapfel, 1968;
99 Boorer, 1972). Many of the increasing number of empirical zoo-based studies in the 1980s
100 were designed to address this issue. Among them were various interventions intended to
101 stimulate animals and increase both the amount and type of their activities (Markowitz,
102 1982), now generally referred to as 'environmental enrichment'. Typically, these involved
103 comparing the behaviour of one or more animals before, during and after an intervention,
104 such as introduction of new enclosure furniture or a manipulable object. The rationale and
105 conceptual underpinnings of enrichment have been developed and refined since then, in that
106 it is seen as something that has to be tailored to individual animals according to their species,
107 behavioral ecology and individual needs. Additionally, enrichment requires a firm goal so
108 that its efficacy can be assessed (Mellen and MacPhee, 2001) and consequently
109 environmental enrichment is seen as a powerful and successful tool in improving zoo animal
110 welfare (Young, 2003) that is now utilized daily in most institutions. Here is an example of
111 where zoo researchers can offer expertise in helping environmental enrichment become an
112 implementable task in large scale housing systems and understanding which types of
113 enrichment are successful for similar taxonomic groups.

114 Another approach to improving welfare in zoo-housed animals concentrated on identifying
115 how different aspects of housing (such as enclosure size and complexity, or group size and
116 composition) and husbandry (such as provision of food or animal capture) affected

117 behaviour, and hence welfare. Again, this typically involved the study of a group of animals
118 in one enclosure (e.g. Goerke et al., 1987; Ogden et al., 1990), though some studies were
119 achieved across a number of different zoos (e.g. Wilson, 1982; Perkins, 1992). Nevertheless,
120 general principles could be derived through the review of many different studies, each of
121 which was relatively small scale (eg Price & Stoinski, 2007; Fabregas et al., 2012). Recently
122 the breadth and variety of zoo welfare studies have increased, with new approaches such as
123 the study of personality (Tetley & O’Hara, 2012) and human-animal relationships (Hosey,
124 2008;Patel et al., 2019), as well as the application of assessment techniques such as social
125 network analysis (Rose & Croft 2015) and cognitive bias (Bethell 2015, Clegg 2018).

126 From early in this history, zoo-based researchers have been encouraged to form
127 collaborations with academic institutions (Moran & Sorensen, 1984; Kleiman, 1985;
128 Fernandez & Timberlake, 2008), which potentially offer access to skills, equipment and
129 funding that may not be otherwise available to the zoo. This has led to valuable research on
130 the influence of zoo environments on welfare, but the additional notion of providing animals
131 with the opportunity to perform the behaviours they would do in the wild has led to a
132 substantial emphasis on enrichment as a way of increasing behavioural diversity or promoting
133 “missing” behaviours. However, although these have massive benefits for the animals
134 involved, the sheer variety and number of species is an impediment to the development of
135 zoo welfare as a predictive science. At least one possible way out of this is the development
136 of comparative assessment (Mason 2010), which seeks patterns of responding to captivity
137 across different species while controlling for phylogeny. Zoo research needs to distinguish
138 between the ‘case study’ and ‘predictive/evaluative’ approaches to research that may make
139 zoo-based research more palatable to other fields of welfare science.

140

141 **Research logistics**

142 The scientific benefits of researching farm/lab animal welfare are linked to the large datasets
143 available due to the sheer numbers of animals involved within these industries. In 2016, data
144 suggest that in the UK alone there were in excess of 33.9 million sheep, 10 million cattle, 4.8
145 million pigs and 161 million chickens (FAOSTAT, 2016). In 2016 in the USA, there were
146 16,400,000 lab rodents (mice and rats) and 183,237 guinea pigs (Coleman & Heagerty,
147 2019). Animal behaviour and welfare research dedicated to these animals therefore creates a
148 large impact value for potential funding bodies and opens various external funding grants.

149 In zoos, these numbers are just not possible and there have been concerns about the design of
150 zoo studies regarding the issues of small sample sizes and ecological validity with single
151 animal or single enclosure studies. Concerns are raised with the fear that these might
152 undermine the scientific value of zoo research and discourage academic researchers from
153 becoming involved (Hosey, 1997; Stoinski et al., 1998; Swaisgood & Shepherdson, 2005).
154 Small *n* studies, however, can be statistically robust (Bishop et al., 2013), and ecological
155 validity is not an issue if the answer we seek in our research is about those particular animals
156 in that particular enclosure (Saudargas & Drummer, 1996; Kuhar, 2006). Since this is often
157 the case with zoo research, there has been a call to continue with small-scale subject research
158 (Whitham and Wielebnowski, 2013). As we move to more individualized methods of
159 measuring welfare such as qualitative behaviour assessment (Wemelsfelder & Lawrence,
160 2001; Wemelsfelder et al., 2000; 2001). We hope to understand the impact that certain
161 individual traits (Carlstead et al., 1999) or keeper-animal interactions (Ward & Melfi, 2015,
162 Carlstead et al., 2018) may have on welfare. We suggest that these small-scale studies play an
163 important role in understanding how stressors impact on individuals rather than at a
164 group/herd level. It could be that farm/lab research increase their uptake of these studies.

165 Nevertheless, because of its reliance on low numbers of individuals and difficulty in setting
166 up controlled experiments, zoo welfare science suffers from the lack of recognition as a
167 serious science, as evidenced by the lower impact factors of zoo journals and the paucity of
168 grant funding for zoo research. For example on the 21st May 2018, the Biotechnology and
169 Biological Sciences Research Council (BBSRC) in the UK, had a total of 2794 awards
170 totaling £1,437,323,899 none of these dedicated to zoo research (BBSRC 2018).
171 Additionally, the poor uptake of zoo-based talks by welfare conference organizers; for
172 example the 2018 Association for the Study of Animal Behaviour (ASAB) ‘Behavioural
173 Biology in Animal Welfare Science’ meeting held in London, UK included only two from 25
174 oral presentations on zoo-housed species, and a high proportion of the non-zoo talks did not
175 allow application of the research to other animal industries or domains. Similarly, the 2018
176 Universities Federation for Animal Welfare (UFAW) conference ‘Animal Welfare across
177 Borders’ conference held in Hong Kong featured 22 oral presentations (excluding plenary
178 talks), none of which had a focus on zoo animal welfare. We feel that zoo welfare researchers
179 need to develop and adopt more predictive methods, and also utilize more of the applied
180 research ideas coming from farm/lab research; but also that the farm/lab-dominated animal
181 welfare conferences and journals need to be more accepting of the value of smaller scale zoo
182 research.

183 An additional aspect where zoos are at the forefront involves multi-institutional studies.
184 Where farm/lab studies concentrate on numerous animals housed at one location, zoo
185 researchers include multiple institutions to investigate a problem that may be similar across
186 multiple institutes, to increase the number of individuals utilized and also to increase the
187 impact of the research. Of course there are additional variables to be considered here but
188 again, appropriate statistical techniques can be applied to ensure that this is adjusted for
189 within the results; or depending on the aim of the research, this can become an independent

190 variable that we might want to consider. For example Shepherdson et al. (2004) investigated
191 fecal corticoids in two species across a number of zoos (Polar bears *Ursus maritimus*: 18
192 zoos; Clouded leopard *Neofelis nebulosa*: 4 zoos). Ward & Melfi (2013) investigated the
193 impact of positive reinforcement training on human-animal interactions for three species at
194 five different zoos and Greco et al. (2016) collected data from 67 North American zoos that
195 house elephants, to characterize and understand the variations in elephant management
196 strategies. As more data become available on behaviors of different species in zoos,
197 opportunities arise for meta-analytic studies that look at patterns of responding across
198 different taxa (Mason, 2010). Such studies have been achieved on the phylogenetic
199 distribution of stereotypies in carnivorous mammals, thus enabling the formulation of
200 predictive hypotheses about the causes of this behaviour and the species most at risk (Clubb
201 and Mason, 2007). Similar analyses have now been attempted with other behaviors and other
202 taxonomic groups (Hanzlíková et al., 2014; Pomerantz et al., 2013). Studies like these offer a
203 promising new direction for zoo welfare research (Whitham and Wielebnowski, 2013), but
204 note that they depend on the data contained in small-scale studies.

205

206 **Combined Appreciation for Animal Behaviour and Welfare Science**

207 Farm/lab and zoo researchers have had somewhat different approaches to animal welfare,
208 largely because of constraints or opportunities in the resources available to them. However,
209 for both groups, the overall goal is the same, i.e. to reduce suffering and promote a positive
210 life worth living of the animals in our care. It is therefore imperative that animal welfare
211 scientists worldwide collaborate on projects that can work towards this goal no matter the
212 species in question, for example by using funds, technology and methods in support of a
213 bigger animal welfare research community. Networks, such as the Animal Welfare Research

214 Network (AWRN, 2019) in the UK or the Global Animal Network as part of World Animal
215 Protection (World Animal Protection, 2019) are important for knowledge transfer and enable
216 expertise across a wide range of species to be circulated amongst members. However, welfare
217 researchers need to engage with this process and attend conferences and events that may be
218 slightly outside of their normal expertise to enable this sharing of good practice to develop
219 further. We would also encourage conference organizers to include more diversity in topics
220 when selecting oral presentations.

221 The understanding that animal welfare is a property of individual animals is making small n
222 studies more appropriate and more acceptable, and there is no reason why such studies should
223 not be scientifically robust and provide important information that advances the field. With
224 details on individual animal needs, gathered from research there is the potential to move
225 towards ‘animal-based’ rather than the ‘resource-based’ measures of welfare that are
226 commonly used in farm/lab situations. Within the zoo industry, there is a trend towards
227 evidence-based practice (Ward et al., 2018), which suggests that scientific knowledge
228 gathered directly from research is improving the way zoo animals are managed;
229 unfortunately, this is not always the case for farm/lab animals. However, we feel that many
230 researchers might be discouraged from following this path because of perceived difficulties in
231 obtaining funding and publishing in high quality journals. To this end, we would encourage
232 journal editors, conference organizers and funding bodies to be more accepting of this trend
233 and authors to not draw too many population-based trends from the data presented.

234 There are already beneficial welfare collaborations on varying projects; however, there is
235 always more that can be done to encourage this. Moving forwards, as a scientific field, a
236 focus towards positive welfare indicators in farm/lab and zoo animals is key. As discussed
237 above, research has previously focused on ensuring we meet the needs of the animals and
238 covering the minimum standards, but now is the time to emphasize more on what makes the

239 animals happy and how we measure it. We would encourage more researchers to embrace
240 these directions. Examples include measuring vocalizations when tickling rats (LaFollette et
241 al., 2018), occurrence of play and affiliative behaviors (Boissy et al., 2007) and measuring
242 anticipation as a means of understanding what an animal wants (Clegg et al., 2018) for all
243 farm/lab and zoo species.

244 Ideally, we need to be progressing animal welfare beyond legislative needs and developing an
245 increased standard to not only ensure sustainable productivity (whether for farming or captive
246 breeding) but also to ensure our animals have the best lives in captivity that we can provide
247 for them. Modern zoos, for example, list conservation, education, research and visitor
248 enjoyment as their aims, and we would encourage the zoo community to add ‘high animal
249 welfare standards’ to this list. It is also important to not only share new and innovative
250 techniques amongst our peers but to share good practice amongst less economically
251 developed countries. We need to ask ourselves, what do we really know about the farm and
252 zoo animal welfare needs around the globe and is there something that as experienced
253 researchers and practitioners, we can do to support them. Working more closely together,
254 there is much that the agricultural and zoo communities can do to advance animal welfare
255 theory and practice.

256

257 **Conclusion**

258 Assessing the welfare of captive animals using our perception of it is one thing, but quite
259 another to use the animals’ perceptions of their welfare. Good progress has been made in
260 doing this across the three animal groups discussed in this paper, but much of it relies upon
261 experimental techniques that are difficult or costly to carry out and therefore rely on funding
262 that is not always allocated evenly across the groups. Animal welfare science would benefit if

263 more guidance could be given by those doing this research as to how their findings could be
264 implemented practically. There has been some movement towards doing this, for example in
265 the case of judgment bias. At the same time, zoo researchers need to move more towards
266 devising ways of overcoming the difficulties of controlling variables and examples such as
267 multi-zoo research are an obvious way of doing this with recent studies increasingly using
268 this technique. Through changes like these we should hopefully move towards zoo welfare
269 science being more recognized like farm/lab research in its status and approach, while
270 providing the best welfare it can for all animals whatever the species or setting.

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