The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK
www.ufaw.org.uk

Animal Welfare 2017, 26: 373-382
ISSN 0962-7286
doi: 10.7120/09627286.26.4.373

Circus and zoo animal welfare in Sweden: an epidemiological analysis of data from regulatory inspections by the official competent authorities

PL Hitchens*†‡, J Hultgren§, J Frössling§#, U Emanuelson¶ and LJ Keeling‡

† Equine Centre, Faculty of Veterinary and Agricultural Sciences, University of Melbourne, 250 Princes Hwy, Werribee, VIC 3030, Australia
‡ Swedish University of Agricultural Sciences, Department of Animal Environment and Health, PO Box 7068, SE-750 07 Uppsala, Sweden
§ Swedish University of Agricultural Sciences, Department of Animal Environment and Health, PO Box 234, SE-532 23 Skara, Sweden
# National Veterinary Institute, SE-751 89 Uppsala, Sweden
¶ Swedish University of Agricultural Sciences, Department of Clinical Sciences, PO Box 7054, SE-750 07 Uppsala, Sweden
* Contact for correspondence and requests for reprints: phitchens@unimelb.edu.au

Abstract

Good animal welfare is crucial for the success of circuses and zoos. Epidemiological studies of animal welfare that investigate associations between animal-based measures (ABMs) and resource- and management-based measures are needed. However, due to the relatively low numbers of animals within each species kept at individual facilities, such investigations can be difficult to carry out. In this paper, we report the analysis of a multi-facility epidemiological study using data from all regulatory inspections of circus and zoo animals in Sweden for 2010 to 2014. Information from 42 inspections of 38 circuses, and 318 inspections of 179 zoos was analysed. For ABMs assessed during routine inspections of circuses (n = 14) and zoos (n = 61), 9.1 and 14.3% did not comply with requirements for general care of hooves/claws and coat, 10.0 and 8.6% for body condition, and 0 and 1.7% for animal cleanliness, respectively. In addition, the zoo checklist assessed whether animals were kept in appropriate groups, finding non-compliance in 17.0% of inspections. The most frequent non-compliant resource- and management-based measures at routine inspections of circuses were for space (41.7%) and exercise requirements (38.5%). For zoos, 29.4% did not comply with space followed by 28.8% for enrichment requirements. In multivariable logistic regression analyses, zoos that had inadequate or unsafe housing and space design, inadequate bedding, or failed to meet nutritional requirements, were more likely to be non-compliant with at least one ABM. The checklists should be improved to better assess welfare status by including more ABMs; benchmarking of risks and trends over time is also recommended.

Keywords: *animal-based measures, animal welfare, circus, epidemiology, legislation, zoo*

Introduction

Animal welfare has become increasingly important in today's society. Circuses and zoos are especially in the spotlight because they are constantly in the public eye, with animal welfare scientists increasing their efforts to assess the welfare of animals kept under these conditions (Whitham & Wielebnowski 2013). The World Association of Zoos and Aquariums (WAZA) encourages its members to implement policies and procedures that exceed the national minimum legal standards. WAZA now has a new welfare strategy, based on promoting zoos and aquariums as centres for animal welfare (Mellor *et al* 2015). This strategy promotes application of a model based on the 'Five Domains' (Mellor & Beausoleil 2015).

The 'Five Domains' model is an expansion of earlier models that includes assessment of both positive and negative states of animal welfare. It explains how the physical and functional domains (nutrition, environment, physical health, and behaviour) bring about positive and negative experiences within the fifth domain (mental or affective state). These domains combined indicate the welfare status of the animal (Mellor & Beausoleil 2015; Mellor *et al* 2015). Advances in animal welfare science have pointed to animal-based measures (ABMs; ie physical, behavioural, and mental) being key (EFSA Panel on Animal Health and Welfare 2012; Carlstead *et al* 2013), although, historically, the assessment of animal welfare has involved recording a combination of resource- and management-based measures, for example, the provision of feed and shelter (Hubbard & Scott 2011). Resource- and management-based measures are important in order to identify risk factors that are associated with poor animal welfare in epidemiological analyses (EFSA Panel on Animal Health and Welfare 2012), but they do not fully indicate the welfare status of the animal. The issue here is that within circuses and zoos the number of animals from each species is often too small to conduct sufficiently powered epidemiological studies for the identification of risk factors. Thus, multi-facility epidemiological studies using ABMs as welfare outcomes are advocated (Whitham & Wielebnowski

2013), for example, as successfully carried out in the Elephant Welfare Project (Carlstead *et al* 2013; Meehan *et al* 2016). Such studies can be difficult to implement, not least because of the lack of standardised ABMs.

In Sweden, the Swedish Board of Agriculture requires that all operations using animals in performances at circuses, variety shows or other public attractions (from here on referred to as 'circuses') and at zoological parks and gardens or public exhibitions ('zoos') be registered and inspected (Swedish Animal Welfare Agency 2004, 2007). Inspections according to standardised checklists are conducted by official animal welfare inspectors on behalf of the County Administrative Boards. Inspection results have been recorded in a database since 2009 (Swedish Agency for Public Management 2011). These checklists contain control points (CPs) that cover the minimum standards regarding how animals should be kept and managed (as outlined by the Animal Welfare Act [1988] and the Animal Protection Ordinance [1988]). Circuses and zoos may exhibit similar species, however in circuses certain species (eg monkeys, exotic predators) are not permitted to perform. Circuses on tour are required to be inspected every year. Those that are not touring come under regulations for the appropriate domestic or production animal species, or under the regulations for exotic and non-domesticated animals in zoos.

This study analyses five years of data on assessment of ABMs and resource- and management-based measures at circuses and zoos in Sweden. Measures are identified for which non-compliance is most frequently found, correlated measures are detected, the adequacy of currently used ABMs is discussed, and evidence is provided that continued recording of data could be used in future epidemiological studies to identify risk factors for poor circus or zoo animal welfare.

Materials and methods

Data sources

Complete data from official animal welfare inspections in all 21 counties of Sweden, from the 1st of January 2010 to the 31st of December 2014, were provided by the Swedish Board of Agriculture. The official animal welfare control database consisted of information from standardised checklists and has been detailed previously (Hitchens *et al* 2017). The data were collected by trained inspectors (n = 26 inspectors at circuses; n = 96 inspectors at zoos), employed by the County Administrative Boards, during inspections of premises that keep animals (control sites) according to Regulation (EC) 882/2004, using standardised checklists. Data pertaining to compliance with legislative requirements for animals used in circuses and zoos were extracted for analysis.

There were 18 CPs on the circus checklist (see Supplementary Table 1 in the supplementary material to papers published in *Animal Welfare* on the UFAW website: https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material) and 31 CPs on the zoo checklist (Supplementary Table 2; https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material). We categorised CPs related to the physical state of the animals and their provision of social contact (ie group housing for birds and mammals) as ABMs (circus CP-3 to 5; zoo CP-4 to 7). CPs that related to the holding of a permit for commercial operation, sufficiency of personnel, supervision, care, enrichment, conditions during performance, documentation, buildings and accommodation, feed and water, veterinary care, and other deficiencies, were categorised as resource- and management-based measures of welfare. For each of the CPs, the inspection result was recorded as compliant, non-compliant, no control carried out (the particular CP was not assessed), or not applicable.

Data specific to each circus and zoo included its location, information on the type of animal species kept and any other animal-related activities conducted at the site besides the keeping of animals for performance or display. We calculated the total number of different animal-related activities. We had also intended to calculate the total number of animal species, but we did not have information on each individual exotic species. However, because most circuses and many zoos do not keep exotic animals (eg petting zoos), we calculated the total number of domestic and production animal species at the site instead.

We analysed data specific to each inspection including the year of inspection and the control type (reason for inspection). Control type was categorised into four groups: (i) normal or routine inspections, which included circuses and zoos selected based on random sampling, risk of non-compliance, or directed by the County Administrative Board; (ii) complaint inspections, which were conducted as a result of complaint by, for example, a veterinarian or the general public; (iii) follow-up inspections, including return visits to check on deficiencies identified at previous inspections; and (iv) application inspections, which were related, for example, to an application for a permit to conduct a commercial activity.

Statistical analysis

Statistical analyses were conducted using Stata®, version 13.1 (StataCorp, College Station, TX, USA). To investigate associations between the animal-based CPs and other potential risk factors, including the resource- and management-based CPs, we conducted univariable logistic regressions. Odds ratios (OR) and their 95% confidence intervals (CI), adjusting for clustering on circus or zoo (to account for multiple inspections), are presented. The level of statistical significance was set at 5%. For this analysis, we created an aggregate ABM as the binary welfare outcome in the models: (0) if the inspection complied with all controlled animal-based CPs or (1) if the inspection did not comply with one or more of the animal-based CPs. We conducted a power analysis to estimate how many years of data would be required in order to produce a multivariable model for the circus and zoo data. For the zoo data only, risk factors from univariable analyses with 20% statistical significance or less were entered into a multivariable logistic regression model using backward step-wise elimination, and retained if they were statistically significant at 5%. Linearity of continuous variables was assessed by generating Box-Tidwell power transformations (Box &

https://doi.org/10.7120/09627286.26.4.373 Published online by Cambridge University Press

Table 1 Descriptors of circuses and zoos inspected as part of official animal welfare inspections in Sweden from 2010 to 2014, stratified by type of inspection.

	Normal or routine			Complaint		Follow-up		Application†		Total‡
	Directed	Risk	Random	Unwarranted*	Vet, general public, other	Previous routine	Previous complaint	Circus	Public exhibition	
Circuses										
Inspections (n)	11	2	1	7	4	5	1	9	1	42
Control sites (n)	11	2	1	7	4	5	1	8	1	38§
Inspections per site Median (IQR)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)
Species per site# Median (IQR)	2 (1–4)	1 (1–1)	3 (3–3)	1 (1–2)	1.5 (1–2.5)	1 (1–1)	1 (1–1)	1.5 (0–3)	5 (5–5)	2 (1–3)
Activities per site Median (IQR)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–2)	1 (1–1.5)	1 (1–1)	1 (1–1)	1 (0–1.5)	1 (1–1)	1 (1–1)
Zoos										
Inspections (n)	44	16	1	37	52	26	29	–	109	318
Control sites (n)	40	13	1	29	42	21	17	–	87	179§
Inspections per site Median (IQR)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–1)	1 (1–2)	–	1 (1–1)	1 (1–1)
Species per site# Median (IQR)	2.5 (1–5)	4.5 (2–9)	3 (3–3)	2 (1–5)	1 (1–4)	4 (1–8)	3 (1–4)	–	3 (1–6)	3 (1–6)
Activities per site Median (IQR)	1 (1–1)	1.5 (1–2)	1 (1–1)	1 (1–1)	1 (1–2)	1 (1–1)	1 (1–2)	–	1 (1–2)	1 (1–2)

For continuous variables, the median and interquartile range (IQR) are presented.
† Application to the Swedish Board of Agriculture to conduct a circus event or public exhibition.
‡ Total includes inspection types that have not been detailed here – application for an operating permit (circus, n = 1; zoo, n = 1) and other public inspection (zoo, n = 3).
§ The row total does not equal the total number of premises because multiple inspections were conducted at the same premises for differing reasons.
# Only information on domestic and production animal species were collected.
* Non-compliance could not be verified.

Tidwell 1962), using the boxtid module in Stata® (Royston 2013). Standard model diagnostics conducted included the Hosmer-Lemeshow's goodness-of-fit test (Hosmer & Lemeshow 1980), Tukey-Pregibon link test to assess model specification (Pregibon 1980), and generation of variance inflation factors to assess multicollinearity of variables in the final model (with values greater than ten indicating collinearity) (Chatterjee & Hadi 1986; Fox & Monette 1992).

A review of the free-text comment field in the database was conducted for CPs identified as a risk factor in multivariable analysis of zoo animal welfare. For each comment, we identified the taxonomic order of the species (or in some instances, multiple species).

We also performed a Principal Component Analysis (PCA) to investigate whether the resource- and management-based CPs were correlated, and to identify groups of key composite variables. We obtained pair-wise tetrachoric correlation estimates of the binary compliance data (0 = compliant; 1 = non-compliant) (Edwards & Edwards 1984), and then conducted the PCA on the correlation matrix (StataCorp 2013). The scree test, Kaiser criterion and proportion of variance were used to determine the number of meaningful principal components. A varimax orthogonal rotation was used to maximise the sum of variances of the squared loadings (Kaiser 1958). Absolute value loadings greater than 0.30 were considered for inclusion on the component.

Results

Site and inspection characteristics

A total of 52 circuses and 224 zoos were registered with the Swedish Board of Agriculture. During the five-year study period, there were 42 inspections at 38 (73.1%) of the registered circuses and 318 inspections at 179 (79.9%) of the registered zoos. Inspections were conducted routinely (circus, n = 14; zoo, n = 61), because of a complaint (circus, n = 11; zoo, n = 89), as a follow-up on deficiencies identified at a previous inspection (circus, n = 6; zoo, n = 55), or because of an application for a permit to conduct commercial activities (circus, n = 11;

zoo, n = 113). Multiple inspections were conducted on some control sites over the five years; there was a single inspection at 35 circuses and 117 zoos, two inspections at two circuses and 35 zoos, three inspections at one circus and 13 zoos, and four or more inspections at 14 zoos.

Descriptors of all control types are presented in Table 1. In addition to the keeping of circus animals, other activities reported to be conducted at circuses were the keeping (n = 6) or selling (n = 1) of companion animals, the keeping of horses used professionally (n = 3) or for leisure purposes (n = 1), and transporting animals other than when moving locations during a circus tour (n = 3). The most frequently reported activities at zoos, apart from the keeping of zoo animals, included public demonstrations or exhibitions (n = 231), an animal park (n = 43) or wildlife reserve (n = 21), the keeping of poultry (n = 36) or animals for meat production (n = 33), the keeping (n = 31) or selling (n = 8) of companion animals, keeping horses used professionally (n = 13) or for leisure purposes (n = 27), transporting animals (n = 9) and education (n = 5).

Non-compliance at inspections

Supplementary Tables 1 and 2 (https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material) present the outcome of all official animal welfare inspections of circuses and zoos, respectively. For routine inspections only (ie those that were not a follow-up or due to a complaint) and at circuses and zoos, respectively; 9.1 and 14.3% did not comply with requirements for general care of hooves/claws and coat of the animals; 10.0 and 8.6% for the animals' body condition; and 0 and 1.7% for the animals' cleanliness. In addition, the zoo checklist assessed whether social contact was appropriate or not, finding 17.0% non-compliant inspections. Using the results from all visits, we found no correlation between these animal-based CPs for circuses, but a strong correlation between non-compliance with three of the four animal-based CPs (general care, body condition, and cleanliness) at zoos (rho = 0.66–0.77; P = 0.001–0.029).

The most frequent non-compliances with resource- and management-based CPs in circuses during routine inspections were for space (41.7%), exercise (38.5%), and transport (16.7%) requirements. For zoos, 29.4% of routine inspections did not comply with space requirements, followed by non-compliance with enrichment (28.8%), and enclosure design to minimise the risk of injury (16.0%).

Each checklist had a CP for 'other deficiencies' that did not relate to any of the other more detailed CPs that had to be checked (in circuses this was CP-18 and in zoos it was CP-31). Six other deficiencies were identified during circus inspections and 61 other deficiencies during the zoo inspections. For circuses, these related to non-disclosure of all animal species being exhibited, environmental enrichment (a CP that was specifically included in assessments of zoos, but not circuses), and ABMs, such as aggression and behavioural problems. For zoos, inspectors provided additional details for only 26 (42.6%) of the 61 other deficiencies. This was because comments in the database were not compulsory before 2012. However, the types of 'other deficiencies' that were recorded on multiple occasions at zoos included lack of permanent identification of animals (eg tags, brands), activities conducted or species kept that had not been authorised by the Swedish Board of Agriculture, lack of documentation on species, their maintenance procedures and inadequate biosecurity precautions.

Power analysis

We conducted a power analysis to determine whether we had sufficient data to identify risk factors for poor welfare at circuses and zoos in a multivariable logistic regression model. Based on the mean compliance results for the resource- and management-based CPs, and using a conservative estimate, we assumed that the probability of the inspection being non-compliant with at least one of the animal-based CPs when the risk factor was at the mean was 10% and one standard deviation above the mean 30%. Assuming 80% power at 5% significance, we would need at least 255 inspections to identify significant risk factors fitted in a multivariable model. Due to missing data on the zoo checklist, the final multivariable model (n = 237 observations) was generated at 75% power. We would need to conduct another 213 inspections to reliably fit a multivariable model on the circus checklist data, equating to another ten years of inspections (assuming 20 inspections a year, as per year 2014). Therefore, only a univariable analysis was carried out on the circus data.

Univariable analyses

For circuses, there were no significant associations between the aggregate ABM outcome and variables studied, with the exception of the CP for other deficiencies (OR 16.67; 95% CI 1.10, 252.25; P = 0.042) (Tables 2 and 3).

For zoos, risk factors significantly associated with non-compliance with at least one of the animal-based CPs at inspection were geographic location, not being notified of the inspection, a greater number of other animal-related activities, using animals for other types of display (eg advertising), keeping prohibited animals, keeping poultry and keeping horses for leisure. Inspections for the purposes of an application were less likely to be non-compliant with animal-based CPs compared to routine inspections (Table 2). Resource- and management-based CPs associated with non-compliance with the aggregate ABM included non-compliance with requirements for a permit, inadequate facilities or care for sick or injured animals, lack of enrichment, inadequate space and design of facilities, nutritional and water requirements not met, poor cleanliness and hygiene, inadequate bedding, and lack of outdoor access and exercise (Table 4).

For both circuses and zoos, there were no significant differences across the five years in occurrence of non-compliance with the aggregate ABM (Table 2), however, for zoos, non-compliance with cleanliness decreased to zero in 2013 and 2014 (P = 0.011).

https://doi.org/10.7120/09627286.26.4.373 Published online by Cambridge University Press

Table 2 Univariable analysis of premises and inspection characteristics associated with non-compliance with an aggregated animal-based outcome, adjusted for clustering on control site, and based on official animal welfare inspections of circuses and zoos in Sweden from 2010 to 2014.

Variable	Circus		Zoo	
	OR (95% CI)	***P*-value**	**OR (95% CI)**	***P*-value**
Inspection factors				
Control type				
Normal	Ref		Ref	
Complaint	1.33 (0.15, 11.55)	0.794	0.84 (0.40, 1.74)	0.635
Follow-up	–		1.32 (0.57, 3.09)	0.517
Application	0.67 (0.05, 8.95)	0.760	0.21 (0.09, 0.52)	**0.001**
Not notified of inspection	1.83 (0.18, 18.94)	0.611	3.02 (1.67, 5.43)	**< 0.001**
Year				
2010	Ref		Ref	
2011	1.33 (0.05, 33.12)	0.861	2.77 (0.74, 10.33)	0.130
2012	–		2.29 (0.66, 7.95)	0.190
2013	–		2.50 (0.74, 8.48)	0.141
2014	0.71 (0.05, 9.24)	0.791	1.91 (0.53, 6.93)	0.325
P-value for trend		0.715		0.463
Season				
Autumn	Ref		Ref	
Winter	–		1.10 (0.53, 2.28)	0.798
Spring	0.56 (0.04, 7.84)	0.663	0.83 (0.38, 1.83)	0.646
Summer	0.83 (0.06, 11.97)	0.893	1.19 (0.53, 2.66)	0.676
Site factors				
Regions[†]				
Småland and the islands	Ref		Ref	
Stockholm	–		5.71 (0.86, 37.81)	0.071
East middle Sweden	–		5.00 (0.79, 31.80)	0.088
South Sweden	–		12.00 (2.30, 62.55)	**0.003**
West Sweden	–		12.36 (2.25, 67.88)	**0.004**
North middle Sweden	–		12.80 (1.69, 96.66)	**0.013**
Middle Norrland	–		13.18 (2.03, 85.54)	**0.007**
Upper Norrland	–		11.29 (1.76, 72.43)	**0.011**
Number of animal species*	0.64 (0.29, 1.42)	0.276	1.00 (0.91, 1.10)	0.932
Number of activities	0.57 (0.23, 1.39)	0.213	1.27 (1.09, 1.49)	**0.003**
Animals prohibited	–		7.89 (1.90, 32.82)	**0.004**
Activities				
Education	–		1.24 (0.24, 6.38)	0.794
Animal park	–		1.61 (0.69, 3.77)	0.274
Wildlife reserve	–		1.18 (0.40, 3.46)	0.768
Public exhibition of animals	–		0.68 (0.36, 1.28)	0.227
Other animal display	–		2.29 (1.28, 4.12)	**0.005**
Pet shop	–		0.74 (0.08, 6.98)	0.792
Pet/companion animal	–		1.89 (0.67, 5.39)	0.231
Keeps hobby horses	–		2.59 (1.11, 6.04)	**0.028**
Professional horse establishment	–		1.92 (0.60, 6.10)	0.269
Poultry-keeping	–		2.68 (1.24, 5.81)	**0.012**
Egg production	–		5.24 (3.86, 7.11)	**< 0.001**
Meat production	–		1.92 (0.81, 4.57)	0.138

* Domestic and production animal species only. Significant *P*-values are given in bold.
[†] NUTS (Nomenclature of Territorial Units for Statistics) codes of Sweden, Level 2 national areas (ISO 3166-2).

Table 3 Univariable analysis of control points on the circus checklist associated with non-compliance with an aggregate animal-based outcome, adjusted for clustering on control site, and based on official animal welfare inspections of circuses in Sweden from 2010 to 2014.

Control points	Compliancy	Aggregate animal-based outcome			
		Compliant	Non-compliant	OR (95% CI)	*P*-value
Space (CP-8)	Compliant	21	2	Ref	
	Non-compliant	9	2	2.33 (0.28, 19.41)	0.433
Exercise (CP-10)	Compliant	24	2	Ref	
	Non-compliant	7	2	3.43 (0.39, 30.49)	0.269
Interior design (CP-15)	Compliant	27	1	Ref	
	Non-compliant	4	2	13.50 (0.90, 202.97)	0.060
Transport (CP-17)	Compliant	13	2	Ref	
	Non-compliant	6	1	1.08 (0.08, 14.64)	0.952
Other deficiency (CP-18)	Compliant	25	1	Ref	
	Non-compliant	3	2	16.67 (1.10, 252.25)	**0.042**

ORs are not presented where the CP predicted the failure or success of the outcome perfectly.
Significant *P*-values are given in bold.

Multivariable analysis

Risk factors associated with poor zoo animal welfare at inspection included type of inspection, where inspections that were due to a complaint (OR 0.30; 95% CI 0.10, 0.94; $P = 0.039$) or application (OR 0.08; 95% CI 0.02, 0.29; $P < 0.001$) had lower odds for non-compliance with the aggregate ABM compared to routine inspections; inadequate housing design and space (OR 6.38; 95% CI 2.27, 17.98; $P < 0.001$); unsafe design of housing (OR 6.47; 95% CI 1.93, 21.77; $P = 0.003$); nutritional requirements not met (OR 10.48; 95% CI 1.85, 59.54; $P = 0.008$); inadequate bedding materials (OR 5.01; 95% CI 1.07, 23.53; $P = 0.041$); and other deficiencies reported (OR 3.63; 95% CI 1.68, 7.86; $P = 0.001$).

The finding that poor welfare was more likely to be observed at inspections conducted on premises where there was no notification of the impending inspection did not remain in the multivariable analysis because it was confounded by control type. Most inspections due to a complaint were not notified (88%) while most application inspections were notified (4% not notified). To test this relationship further, we generated models stratified by control type and found that not being notified of the inspection was not significant in any model.

Order-specific risk factors for zoos

Information from the free-text comments field was available for 41 of the 53 (77.4%) inspections that were non-compliant with at least one of the ABMs and with the risk factors identified in the multivariable analysis of poor zoo animal welfare. For premises with inadequate housing design and space at inspection, the most common taxonomic orders referenced were Aves (n = 9 inspections; including owls, geese, ducks, and unspecified bird species), followed by Artiodactyla (n = 5; including camels, llamas, reindeer, goats, pigs), Carnivora (n = 3; wildcats, bears), Rodentia (n = 3; beaver, guinea pig), Lagomorpha (n = 2; rabbits), Squamata (n = 2; snakes, lizards), and Primates (n = 1; marmosets). For premises with unsafe design of housing at inspection these were Artiodactyla (n = 5; camels, goats, sheep, pigs), Perissodactyla (n = 2; horses), Aves (n = 1; emu), and Squamata (n = 1; lizards). On two occasions, a terrarium was classified as unsafe, but the species housed was not mentioned. For premises with unmet nutritional requirements at inspection these were Artiodactyla (n = 4; pigs, goats, moose, bison), Lagomorpha (n = 2; rabbits), Aves (n = 2; emus, pigeons, parrots), Rodentia (n = 1; guinea pig), and Fish (n = 1; order or species not specified). Finally, for premises with inadequate bedding materials, the most common taxonomic order referenced was Artiodactyla (n = 4; pigs, camels, goats, llamas, reindeer, ox), and then one non-compliant inspection each for Perissodactyla (horses), Lagomorpha (rabbits), Testudines (turtles), Squamata (snakes), Aves (emus), and Fish (unknown Order).

Principal Component Analysis

For the PCA on the circus inspection results, five components with eigenvalues greater than one accounted for 97.9% of the total variance. Component 1 included space and exercise requirements (24.6% of the variance); component 2 included waste collection, bedding quality, interior design of facilities, and adequate ventilation (negatively loaded; 19.9%); component 3 included yearly inspec-

https://doi.org/10.7120/09627286.26.4.373 Published online by Cambridge University Press

Table 4 Univariable analysis of control points on the zoo checklist associated with non-compliance with an aggregate animal-based outcome, adjusted for clustering on control site, and based on official animal welfare inspections of zoos in Sweden from 2010 to 2014.

Control points	Compliancy	Aggregate animal-based outcome			
		Compliant	Non-compliant	OR (95% CI)	*P*-value
Permit (CP-1)	Compliant	131	27	Ref	
	Non-compliant	46	20	2.11 (1.12, 3.98)	**0.021**
Personnel (CP-2)	Compliant	180	34	Ref	
	Non-compliant	6	4	3.53 (0.73, 16.98)	0.116
Maintenance (CP-3)	Compliant	206	53	Ref	
	Non-compliant	3	4	5.18 (0.87, 30.93)	0.071
Care of sick animals (CP-8)	Compliant	167	35	Ref	
	Non-compliant	6	10	7.95 (2.68, 23.61)	**< 0.001**
Enrichment (CP-9)	Compliant	178	30	Ref	
	Non-compliant	38	25	3.90 (2.08, 7.33)	**< 0.001**
Space (CP-10)	Compliant	139	22	Ref	
	Non-compliant	56	29	3.27 (1.63, 6.58)	**0.001**
Interior design (CP-11)	Compliant	185	34	Ref	
	Non-compliant	18	20	6.05 (2.73, 13.41)	**< 0.001**
Space design (CP-12)	Compliant	173	28	Ref	
	Non-compliant	25	23	5.68 (2.59, 12.46)	**< 0.001**
Petting enclosure (CP-13)	Compliant	102	24	Ref	
	Non-compliant	11	6	2.32 (0.80, 6.74)	0.123
Climate (CP-14)	Compliant	184	48	Ref	
	Non-compliant	10	6	2.30 (0.84, 6.32)	0.107
Artificial light (CP-15)	Compliant	168	39	Ref	
	Non-compliant	5	3	2.58 (0.58, 11.44)	0.211
Natural light (CP16)	Compliant	140	34	Ref	
	Non-compliant	5	2	1.65 (0.40, 6.76)	0.488
Safe design (CP-17)	Compliant	143	26	Ref	
	Non-compliant	13	12	5.08 (2.10, 12.28)	**< 0.001**
Noise levels (CP-18)	Compliant	146	36	Ref	
	Non-compliant	5	2	1.62 (0.27, 9.75)	0.597
Food and water (CP-19)	Compliant	183	52	Ref	
	Non-compliant	1	1	3.52 (0.22, 55.56)	0.371
Quality feed (CP-20)	Compliant	179	41	Ref	
	Non-compliant	3	7	10.19 (2.53, 41.00)	**0.001**
Quality water (CP-21)	Compliant	170	47	Ref	
	Non-compliant	3	9	10.85 (2.92, 40.36)	**< 0.001**
Storage (CP-22)	Compliant	190	43	Ref	
	Non-compliant	6	11	8.10 (3.18, 20.63)	**< 0.001**
Bedding (CP-23)	Compliant	164	33	Ref	
	Non-compliant	8	11	6.83 (2.35, 19.90)	**< 0.001**
Cleaning (CP-24)	Compliant	123	25	Ref	
	Non-compliant	1	2	9.84 (2.20, 43.91)	**0.003**
Outdoors (CP-25)	Compliant	130	36	Ref	
	Non-compliant	13	11	3.06 (1.23, 7.58)	**0.016**
Exercise (CP-26)	Compliant	135	34	Ref	
	Non-compliant	6	9	5.96 (2.17, 16.36)	**0.001**
Other deficiency (CP-31)	Compliant	149	35	Ref	
	Non-compliant	33	21	2.71 (1.39, 5.28)	**0.003**

ORs are not presented where the CP predicted the failure or success of the outcome perfectly.
Significant *P*-values are given in bold.

tions (negatively loaded) and transportation requirements (18.0%); component 4 included documentation requirements (negatively loaded; 17.7%); and component 5 included tethering of animals (17.7%). Other deficiencies loaded almost equally across components 1, 3 and 5 (Supplementary Table 3; https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material).

For the PCA on the zoo inspection results, five components with eigenvalues greater than one accounted for 79.4% of the total variance. Component 1 included enrichment, space requirements and design, bedding, and cleaning (33.2% of the variance); component 2 included water quality, storage requirements, and outdoor access (16.9%); component 3 included holding of a permit, interior design of facilities, outdoor access and exercise, and cleaning (negatively loaded; 11.8%); component 4 included safe design of housing and nutritional requirements (negatively loaded; 9.1%); and component 5 included care of sick and injured animals and other deficiencies (8.5%) (Supplementary Table 4; https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material).

Discussion

The two main findings in this study were the prevalence of the different welfare problems in zoos and circuses, and the identification of the main risk factors for these welfare problems. The results are discussed in the context of those reported in Britain (Draper & Harris 2012; Draper *et al* 2013) as well as the feasibility of using data gathered by official animal welfare inspectors for benchmarking trends. We highlight the importance of collaboration on data collection, especially from circuses, and consider the general potential of the approach developed in this paper for future multi-facility animal welfare epidemiological studies.

In zoos, insufficient or inappropriate pairings/grouping of animals, indicating poor social contact, was the most frequent ABM that was found to be non-compliant according to the national animal welfare legislation, but this measure was not included at all in the assessment of circus animals. Non-compliance with the requirements for adequacy of general condition (ie hooves, claws, coat, wool, etc) and body condition of the animals was also high at routine inspections. Non-compliance with requirements for cleanliness of animals was rare, and this was likely because both circuses and zoos displayed animals to the public. The only ABM from the British zoo inspections asked whether "all animals on display to the public appear to be in good health". They found that only 3% of zoos assessed by government-appointed inspectors answered in the negative, seemingly much lower than the findings in this present study. Additionally, although not an ABM and so not directly comparable with our study, 9% of the British zoos did not provide animals with an environment well adapted to meet their physical, psychological and social needs (Draper & Harris 2012). These difficulties comparing results highlight the need for consensus, so that at least some of the criteria being assessed by official government inspectors in different countries are the same. This would greatly facilitate benchmarking of key welfare issues as well as facilitate multi-facility studies of circuses and zoos.

For zoos, general care, body condition, and cleanliness, but not social contact, were strongly correlated, indicating that non-compliant zoos tended to neglect multiple ABMs. These findings are analogous to those in a previous study of equine welfare supporting the hypothesis that there is a different underlying cause for non-compliance related to social contact (Hitchens *et al* 2017). In this study, the four ABMs assessed clearly do not cover all aspects of welfare, with the most notable omissions being assessment for illness and injury, and for behavioural abnormalities (eg stereotypies, aggression). Additional aspects were only partially captured in the CP for 'other deficiencies'. Improvements to the checklists are needed so that they better capture the physical health, behaviour, and mental state elements of the 'Five Domains' (Mellor & Beausoleil 2015). However, with official inspections, as opposed to in-depth experimental studies, the measures must be simple and non-invasive to be feasible. Feasible examples from the WAZA Animal Welfare Strategy include absence of disease and injury, evidence of impact of temperature extremes, changes in behaviour (eg vocalisation), as well as presence of positive indicators, such as behavioural expression (eg playfulness, curiosity, vitality, calmness) (Mellor *et al* 2015). The Elephant Welfare Project (Carlstead *et al* 2013) has defined seven welfare outcomes that were adapted from Welfare Quality®, a project that developed practical and valid measures for production animals (Keeling 2009b). Carlstead *et al* (2013) also recommended assessing positive emotional states in elephants with play, affiliative behaviours and some vocalisations perhaps the most convenient indicators to employ (Boissy *et al* 2007) in a circus or zoo setting.

Risk factors for poor animal welfare were identified. In the multivariable analysis, zoos more likely to be non-compliant with at least one of the animal-based CPs were those that had inadequate housing design and space, unsafe design of housing, inadequate bedding materials, and unmet nutritional requirements. We present, only briefly, some of the research on the importance of these specific aspects. From our analysis, although the size of the space was correlated with exercise areas in the circus data (Supplementary Table 3, component 1; https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material) and with housing design in the zoo data (Supplementary Table 4, component 1; https://www.ufaw.org.uk/the-ufaw-journal/supplementary-material), it was the design and use of the areas rather than the area size that had the greater impact. This is in agreement with, for example, a study of captive primates where the presence of objects within the environment was more highly correlated with activity level than enclosure size or usable surface area (Wilson 1982), and with a review indicating that restricted space may not be a welfare problem, provided that the design and complexity of the space are appropriate for the species and promote normal behaviours (Hosey 2005). However, other species may have distinct needs, for example, in wide-ranging carnivores there are significant negative welfare effects of enclosure

https://doi.org/10.7120/09627286.26.4.373 Published online by Cambridge University Press

size (eg increased stereotypical behaviours) (Clubb & Mason 2003). In regards to inadequate bedding materials, unhygienic, abrasive and/or unnatural materials have been found to increase foot and skin conditions, whereas biologically appropriate materials can help to stimulate natural foraging behaviour in some species (European Commission 2015). Lastly and perhaps not surprisingly, unmet nutritional requirements have historically been found to have significant welfare effects, particularly when they lead to bone or other diseases (such as in large cats and primates) (O'Regan & Kitchener 2005). With insight that it would take another ten years before a multivariable analysis of data from Swedish circuses could be carried out, there is strong argument for international collaboration around animal welfare inspections of circuses. The occurrence of 'other deficiencies' as an important risk factor for poor welfare at both circuses and zoos also illustrates that the inspectors themselves regarded the current checklists as lacking important criteria.

The circus and zoo animal checklists comprise of primarily resource- and management-based measures. Even if we suggest that there are risk factors missing, the findings of our PCA suggest that there is potential for reducing some of these important resource- and management-based CPs. This could also make inspections less time-consuming. For example, component 1 (enrichment, space, design, bedding and cleaning) explained one-third of the information on non-compliance with resource- and management-based measures on the zoo checklist and, of these, space, design, and bedding were also associated with poor zoo animal welfare in the multivariable analysis. Given that these measures are already known to be important for the welfare of exotic species, such as primates, big cats, and elephants (Clubb & Mason 2007; Carlstead *et al* 2013; Whitham & Wielebnowski 2013), we can only speculate on the reasons for high rates of non-compliance in these areas. For example, there may be limited possibilities for expansion or improvement of enclosures due to spatial or financial restrictions. Not providing species-appropriate nutrition may be related to practical difficulties in obtaining the specialised food. Although less likely to be a reason in large zoos or circuses, a lack of knowledge in the staff at small establishments regarding the basic needs of their animals probably contributes towards high non-compliance, as found in a similar study analysing regulatory inspections of premises keeping horses (Hitchens *et al* 2016, 2017).

Official animal welfare inspections can be used to monitor welfare at circuses and zoos; however, some improvements would increase the value of such inspection databases. The next steps are to further standardise inspections by increasing objectivity of the criteria used to assess each CP. Limiting the number of inspectors to those trained specifically to assess the welfare of circus and zoo animals would also be beneficial because of the tendency for different inspectors to vary significantly in their assessments, ie to reduce the effects of observer bias (Keeling 2009a). The importance of establishing consistency between inspectors was also a major outcome from the study of formal inspections at British zoos (Draper *et al* 2013).

The checklists for circus and zoo animals differ from the checklists for companion and production animals in that they are not species-specific. Species within the order Artiodactyla were the most frequently implicated as having poor welfare, but as the number of each species is unknown, conclusions regarding their susceptibility cannot be drawn. It is likely that these species are merely more common because of the relative ease in housing them. Information on the number and type of exotic animal species should therefore be included, and CPs should be modified so that they are directly applicable to the varying exotic animal species; for example, by using ABMs more relevant and objective for like-species (eg for big cats, for large mammals, for birds). Lastly, the findings in this study could be used to develop a more efficient checklist by reducing resource- and management-based measures to those that are most important, along with expanding the ABMs (both positive and negative) to better assess the welfare status of circus and zoo animals.

Animal welfare implications

Analysis of routinely collected data from official inspections can help determine areas that should be targeted in order to improve the welfare of circus and zoo animals. This study suggests that strategies focused on improving housing design, space, bedding, and nutrition are likely to have the greatest impact on zoo animal welfare; with the measuring of success of such intervention strategies made possible by benchmarking trends in welfare status.

Acknowledgements

The authors thank Formas, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning for financial support, and the Swedish Board of Agriculture and County Administrative Boards for providing animal welfare inspection data. The project is part of the Centre of Excellence in Animal Welfare Science, a Swedish collaborative research platform.

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