Circus and zoo animal welfare in Sweden, assessed using existing official animal welfare control data

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Abstract
Multi-facility epidemiological studies assessing associations between animal-based measures and resource- and management-based measures at circuses and zoos are needed because of the relatively low numbers of each species kept at each facility, but these can be difficult to carry out. Existing data from official animal welfare control could be the answer to some of these problems. In this paper we report the analysis of these data for circus and zoo animals in Sweden for 2010 to 2014. There were 42 inspections of 38 circuses and 318 inspections of 179 zoos. For animal-based measures at routine inspections of circuses and zoos, respectively, 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 cleanliness. In addition, the zoo checklist assessed whether animals were kept in groups as appropriate, finding non-compliance in 17.0% of inspections. The most frequent non-compliances with resource- and management-based measures at routine inspections of circuses were 41.7% for space and 38.5% for exercise requirements. For zoos, 29.4% did not comply with space followed by 28.8% for enrichment requirements. In multivariable analysis of data pertaining to zoos, facilities that had inadequate or unsafe housing and space design, nutritional requirements that were not met, or inadequate bedding materials were more likely to be non-compliant with at least one of the animal-based measures. The checklists should be improved to better capture animal-based welfare outcomes, and benchmarking of risk and trends over time is recommended.

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

Introduction

The welfare of animals has become increasingly important in today's society. Circuses and zoos are in the spotlight, 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 have 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, behaviour) bring about positive and negative experiences within the fifth domain (mental or affective state), combining to give the welfare status of the animal (Mellor & Beausoleil 2015, Mellor, et al. 2015). Advances in animal welfare science have pointed to animal-based measures (i.e. physical, behavioral, and mental) being key (Carlstead, et al. 2013, EFSA Panel on Animal Health and Welfare 2012), though historically, assessment of animal

welfare has involved recording a combination of resource- and management-based measures (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 indicate the welfare status of the animal. The issue here is that in circuses and zoos the number of animals of each species is often too small to conduct sufficiently powered epidemiological studies for identification of risk factors. Thus multi-facility epidemiological studies using animal-based welfare measures are advocated, for example as carried out in the Elephant Welfare Project (Carlstead, et al. 2013), but such studies can be difficult to implement, not least because of the lack of standardised animal-based measures.

In Sweden, the Swedish Board of Agriculture (Jordbruksverket; JV) requires that all operations using animals in performances at circuses, variety shows or other public entertainment (from here on in referred to as 'circuses') and at zoological parks and gardens or public exhibitions ('zoos') be registered and inspected. Inspections according to standardised checklists are conducted by official animal welfare control inspectors on behalf of the County Administrative Boards and results have been recorded in a database since 2009. 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 display animals similar to each other, however in circuses certain species (e.g. monkeys, exotic predators) are not permitted to perform (Djurskyddsförordning 1988). Circuses on tour are required to be inspected every year (Djurskyddsmyndigheten 2007), and 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 (Djurskyddsmyndigheten 2004).

This study describes five years of data on assessment of resource-, management- and animal-based measures at circuses and zoos in Sweden. We identify measures for which non-compliance is most frequently found, detect correlated measures, discuss the adequacy of current animal-based measures, and provide evidence that continued recording of data could be used in future epidemiological studies to identify risk factors for poor circus or zoo animal welfare.

Methods

Data sources

Complete data from official animal welfare controls in all 21 counties of Sweden from 1 January 2010 to 31 December 2014 were provided by JV. The official animal welfare control database consists of data from standardised checklists and has been detailed previously (Hitchens et al., submitted). Data pertaining to compliance with legislative requirements for animals used in circuses and zoos (Djurskyddsmyndigheten 2004, Djurskyddsmyndigheten 2007) were extracted from this database for analysis. 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.

There were 18 control points (CP) on the circus checklist (Supplementary Table 1) and 31 CPs on the zoo checklist (Supplementary Table 2). We categorised CPs related to the physical state of the animals and their provision of social contact (i.e. group housing for birds and mammals) as animal-based (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, 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 intended also 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 (e.g. petting zoos), we did calculate the total number of domestic and production animal species at the site.

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: (1) normal or routine inspections, that included circuses and zoos selected based on random sampling, risk of non-compliance, or directed by the County Administrative Board; (2) complaint inspections, which were conducted as a result of complaint by e.g. a veterinarian or the general public; (3) follow-up inspections, including return visits to check on deficiencies identified at previous inspections; and (4) application inspections, which were related, for example, to an application for a permit to conduct a commercial activity.

Statistical analysis

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 animal-based measure as the binary 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 model using backward stepwise elimination and retained if they were statistically significant at 5%. Linearity for continuous variables was assessed by generating Box-Tidwell power transformations. Model diagnostics conducted included the Hosmer-Lemeshow's goodness-of-fit test, link test, and variance inflation factor (VIF<10).

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 pairwise 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.

Statistical analyses were conducted using Stata, version 13.1 (StataCorp, College Station, Texas, USA).

Results

Site and inspection characteristics

A total of 52 circuses and 224 zoos were registered with the Swedish Board of Agriculture. During the 4-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. The reasons for inspections were normal (n=14 and 61; circus and zoo animal inspections, respectively), because of a complaint (n=11 and 89), follow-up on deficiencies identified at a previous inspection (n=6 and 55), and application for a permit

to conduct commercial activities (n=11 and 113). Multiple inspections were conducted on some control sites over the four years; there was one inspection at 35 circuses and 117 zoos, two inspections at 2 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 present the outcome of all official animal welfare controls of circuses and zoos, respectively. For normal (routine) inspections only (i.e. those that were not 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 their 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 measures for circuses, but a strong correlation between non-compliance with three of the four animal-based measures (general care, body condition, and cleanliness) at zoos (rho=0.66-0.77, $P < 0.05$).

The most frequent non-compliances with resource- and management-based control points in circuses during normal (routine) inspections were for space (41.7%), exercise (38.5%), and transport (16.7%) requirements. For zoos, 29.4% of normal (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 has a CP for 'other deficiencies' (circuses CP-18, zoo CP-31) that did not relate to any of the other more detailed CPs that had to be checked. 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 is included in assessments of zoos, but not circuses), and animal-based welfare measures such as aggression and behavioural problems. For zoos, inspectors provided additional details for only 26 (42.6%) of the 61 other deficiencies. This is 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 (e.g. tags, brands), activities conducted or species obtained that had not been authorised by JV, 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 control points, 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 is at the mean was 10% and one standard

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

	Normal			Complaint		Monitoring		Application[1]		Total[2]
	Directed	Risk	Random	Unwarranted	Veterinarian, general public, other	Previous normal	Previous notification	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[3]
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[4] 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[3]
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[4] 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. [1] Application to JV to conduct a circus event or public exhibition [2] 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). [3] The row total does not equal the total number of premises because multiple inspections were conducted at the same premises for differing reasons. [4] Only information on domestic and production animal species are collected.

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; however, we would need to conduct another 213 inspections to reliably fit a multivariable model on the circus checklist data, equating to another 10 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 animal-based outcome and variables studied, with the exception of the CP for other deficiencies (OR 16.67; 95% CI 1.10, 252.25; $P = 0.042$) (Table 2 and 3).

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 control of circuses and zoos in Sweden, 2010-2014

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 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, Gotland and Öland	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 [1]	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

Variable	Circus		Zoo	
	OR (95% CI)	p-value	OR (95% CI)	p-value
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

[1] Domestic and production animal species only.

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	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.

For zoos, risk factors significantly associated with non-compliance with at least one of the animal-based outcome measures 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 e.g. advertising, keeping prohibited animals, keeping poultry and keeping horses for leisure purposes. Inspections for the purposes of an application were less likely to be non-compliant with animal-based outcomes compared to normal inspections (Table 2). Resource- and management-based CPs associated with non-compliance with the aggregate animal-based outcome measure were 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 or exercise (Table 4).

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 (CP-#)	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 (CP-16)				
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	

Control points (CP-#)	Aggregate animal-based outcome			
	Compliant	Non-compliant	OR (95% CI)	p-value
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)			Ref	
Compliant	130	36		
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.

There were no significant differences across years in occurrence of non-compliance with the aggregate animal-based measures for either circuses or for zoos (Table 2), however, for zoos non-compliance with cleanliness decreased to zero in 2013 and 2014 ($P = 0.01$).

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 compared to normal 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 all models.

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 inspections (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).

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).

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. We discuss these results in the context of those reported in Britain (Draper, et al. 2013, Draper & Harris 2012) 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, the lack of appropriate social contact was the most frequent animal-based measure of welfare that was found to be non-compliant according to the Swedish legislation (Djurskyddsförordning 1988, Djurskyddslagen 1988), but this measure is not included at all in the assessment of circus animals. Non-compliance with the requirements for adequacy of general condition (i.e. hooves, claws, coat, wool) and body condition of the animals was also high at routine inspections. Non-compliance with requirements for cleanliness of animals was rare, and this is likely because both circuses and zoos display animals to the public. The only animal-based measure from the British zoo inspections asked whether “all animals on display to the public appear to be in good health?” and found that only 3% of zoos assessed by government-appointed inspectors answered in the negative. Additionally and although not an animal-based measure 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.

In this study, the four animal-based measures assessed clearly do not cover all aspects of welfare, with the most notable omissions being assessment for illness and injury, and for behavioural abnormalities (e.g. stereotypies, aggression). Additional animal-based measures were only partially captured in the CP for ‘other deficiencies’. Improvements to the checklists so that they better capture the physical health, behaviour, and mental state elements of the ‘Five Domains’ (Mellor & Beausoleil 2015) are needed. But with official controls, 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 (e.g. vocalisation), as well as presence of positive indicators such as behavioural expression (e.g. 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 validated measures for production animals (Blokhuis, et al. 2013). They have also recommended assessing positive emotional states in elephants (Carlstead, et al. 2013), 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 assessed. 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 nutritional requirements not met. Several of these were also important risk factors for non-compliance with at least one of the animal-based CPs in the univariable analysis of the circus data. The insight that it will take another 10 years before a multivariable analysis of data from Swedish circuses could be carried out, argues strongly 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 illustrates that also the inspectors themselves regarded the current checklists as lacking important criteria.

The circus and zoo animal checklists comprise 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 may make the inspections less time consuming. For example, component 1 (enrichment, space, design, bedding, and cleaning) explained a third of the information on non-compliance with resource- and management-based measures on the zoo checklist, and three of the five of these factors on the component were associated with poor zoo animal welfare in the multivariable analysis. Given that these measures are already known to be important for welfare of exotic species such as primates, big cats, and elephants (Carlstead, et al. 2013, Clubb & Mason 2007, Whitham & Wielebnowski 2013), we can only speculate that the reasons for high rates of non-compliance in these areas is due to the financial implications of designing larger and better facilities, the limited possibilities for expanding enclosures due to space restrictions, and/or the lack of knowledge of those running the circuses and zoos.

Official animal welfare control can be used to monitor welfare at circuses and zoos; however some improvements would increase the value of the database. The next steps are to further standardise inspections by increasing objectivity of the criteria used to assess each CP. With a relatively large number of inspectors conducting the visits, 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 (Keeling 2009). 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. 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 giving more objective measurements on the animal-based measures for like-species (e.g. 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 animal-based measures (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 us to determine areas that should be targeted in order to improve the welfare of circus and zoo animals. Our study suggests that strategies focussed 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 through benchmarking of trends in welfare status.

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Supplementary Table 1. Outcome of official animal welfare controls of circuses in Sweden, 2010-2014

Control point	Variable	Description	Inspection outcome				Total Inspections	% Non-compliant[1]
			Not applicable	No control	Compliant	Non-compliant		
1	yearlycontrol	An inspection has been made under 36a § of the Animal Welfare Ordinance - A circus that exhibits animals to the public shall be controlled once a year	1	0	30	2	33	6.3%
2	wastecollection	Collection of waste in animal areas is satisfactory	1	3	37	1	42	2.6%
3	***generalcondition***	The requirements for the care of animals (hooves, claws grooming, etc.) are met	1	4	33	4	42	10.8%
4	***bodycondition***	Animal body condition is acceptable	1	1	30	1	33	3.2%
5	***cleanliness***	The animals are kept satisfactorily clean	1	1	31	0	33	0.0%
6	sickanimals	Sick / injured animals treated appropriately. Animals need special care can be taken care of in a designated area	2	8	23	0	33	0.0%
7	documentation	Requirements record keeping are met	1	19	20	2	42	9.1%
8	space	Spaces for animals under current measurement regulations	1	7	23	11	42	32.4%
9	tethering	The requirements around the tethering of animals are met	11	6	24	1	42	4.0%

10	exercise	The requirements for the exercise area of the animals is met	1	6	26	9	42	25.7%
11	stabling	Requirements of stables / display space is met	1	23	18	0	42	0.0%
12	shelter	Animals can get protection against cold, heat, sunlight, rain and wind	1	4	37	0	42	0.0%
13	beddingquality	The requirements for the use bedding and bedding quality are met	1	6	33	2	42	5.7%
14	ventilation	Ventilation requirements are met.	5	12	24	1	42	4.0%
15	interiordesign	The requirements for the design of the interior regarding injury risks etc are met	1	7	28	6	42	17.6%
16	foodwater	The requirements for food and water are met	1	5	36	0	42	0.0%
17	transport	Transport requirements are met	1	19	15	7	42	31.8%
18	otherdeficiency	No other deficiencies found during inspection	0	0	27	6	33	18.2%
Total			32	131	495	53	711	9.7%

CP-3, 4, and 5 written in bold are animal-based. [a] The percentage of non-compliance was calculated as the number of non-compliant inspections divided by the number of both compliant and non-compliant inspections, multiplied by 100.

Supplementary Table 2. Outcome of official animal welfare controls of zoos in Sweden, 2010-2014

Control point	Variable	Description	Control outcome				Total Inspections	% Non-compliant Controls[a]
			Not applicable	No control	Compliant	Non-compliant		
1	permit	Holds a permit to exhibit animals at the facility under 37 § Animal Welfare Ordinance.	45	24	173	76	318	30.5%
2	personnel	Personnel responsible for animal husbandry and care of the animals have adequate training and/or experience in relevant species: Veterinarian, Zoologist	18	60	229	11	318	4.6%
3	maintenance	Daily supervision and maintenance provided for all animals	1	34	273	10	318	3.5%
4	***socialcontact***	The requirement for social contact including mammals and birds kept in groups is met	54	37	189	38	318	16.7%
5	***generalcondition***	Hooves, claws and wool are regularly inspected and trimmed / cut as needed.	68	69	162	19	318	10.5%
6	***bodycondition***	The animals' body condition is acceptable	9	66	230	13	318	5.3%
7	***cleanliness***	The animals are kept satisfactorily clean	19	44	251	4	318	1.6%
8	sickanimals	Sick / injured animals are treated appropriately. Animals need special care can be taken care of in designated area	20	71	211	16	318	7.0%
9	enrichment	The animals are kept in an	2	18	225	73	318	24.5%

		appropriate and enriched environment						
10	space	Areas where the animal / animals are kept are an adequate size	4	40	180	94	318	34.3%
11	interiordesign	The requirements for the design of the interior regarding injury risks, etc. are fulfilled	5	31	240	42	318	14.9%
12	spacedesign	Space where the animal / animals are kept fulfil the design conditions specified in regulation	2	47	218	51	318	19.0%
13	pettingenclosure	The retreat space available for animals that the public are able to touch and pet	122	43	134	19	318	12.4%
14	climate	The animals are housed in a climate that is customised to each animal's need, and exposed only occasionally for air pollution	7	46	247	18	318	6.8%
15	artificiallight	Artificial lighting is so that supervision and care can be done without difficulty and the ability to dim lights at night	28	57	225	8	318	3.4%
16	naturallight	The requirement for windows for admitting daylight is fulfilled for species where this is required	83	42	186	7	318	3.6%
17	safedesign	Windows, lighting and electrical systems that animals can reach are protected or configured such that there is no injury risk	53	60	179	26	318	12.7%
18	noiselevels	Noise in the enclosure is at an acceptable level and frequency	32	87	192	7	318	3.5%

19	feedwater	The animals are given the opportunity for peaceful and natural intake of feed and water	3	71	242	2	318	0.8%
20	qualityfeed	The animals are given feed that ensure adequate, comprehensive and balanced nutrition	6	73	229	10	318	4.2%
21	qualitywater	The requirements for drinking water are met	29	52	223	14	318	5.9%
22	storage	The storage areas are kept satisfactorily clean and manure handling / cleaning is done so that good hygiene is maintained	14	36	247	21	318	7.8%
23	bedding	The requirements for bedding and nesting materials are met	35	52	209	22	318	9.5%
24	cleaning	Cleaning of equipment, etc. is done so that the spread of infection is prevented	22	138	155	3	318	1.9%
25	outdoors	The requirements for keeping animals outdoors are met	90	31	171	26	318	13.2%
26	exercise	The requirements for pasture, exercise areas, ground surfaces, driving routes and driving, movement and fencing are met	85	42	175	16	318	8.4%
27	wingclipping	The requirements for clipped wings of birds is met	201	99	18	0	318	0.0%
28	surgery	Surgical procedures are performed in an acceptable manner	51	157	110	0	318	0.0%
29	breeding	Animals involved in breeding do not suffer	78	139	99	2	318	2.0%
30	performance	Animals in performances are not	209	76	33	0	318	0.0%

		exposed to risk of injury, danger, pain or unnecessary stress						
31	otherdeficiency	No other deficiencies found	0	0	206	61	267	22.8%
Total			1,395	1,842	5,861	709	9,807	10.8%

CP-4, 5, 6 and 7 written in bold are animal-based. [1] The percentage of non-compliance was calculated as the number of non-compliant inspections divided by the number of both compliant and non-compliant inspections, multiplied by 100.

Supplementary Table 3. Principal component analysis of resource- and management-based control points, with orthogonal varimax rotation, based on official animal welfare inspections of circuses in Sweden, 2010-2014 (blanks are absent (loading) <0.3)

Variable	Component 1	Component 2	Component 3	Component 4	Component 5
space	0.6066				
exercise	0.5954				
yearlycontrol			-0.7307		
transport			0.4663		
wastecollection		0.3774			
beddingquality		0.4762			
ventilation		-0.6472			
interiordesign		0.4061			
documentation				-0.7574	
tethering					-0.7786
otherdeficiency	0.3311		-0.3314		0.3400

Supplementary Table 4. Principal component analysis of resource- and management-based control points, with orthogonal varimax rotation, based on official animal welfare inspections of zoos in Sweden, 2010-2014 (blanks are absent (loading) <0.3)

Variable	Component 1	Component 2	Component 3	Component 4	Component 5
enrichment	0.4123				
space	0.3605				
spacedesign	0.5360				
bedding	0.4134				
cleaning	0.3041		-0.3888		
qualitywater		0.6381			
storage		0.4841			
outdoors		0.3130	0.3094		
exercise			0.5739		
permit			0.4529		
interiordesign			0.3691		
systemaccess				0.6168	
qualityfeed				-0.6720	
sickanimals					0.6090
otherdeficiency					0.5842