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Exploring citizen science as a tool for engaging zoo visitors with animal welfare

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Abstract

Global biodiversity losses are at an all-time high and conservation science is a priority discipline. Citizen science (providing opportunities for the public to play an active role in research projects) has been identified as a powerful tool for tackling conservation issues. Its use in zoos has been limited to date, despite the recognised link between public understanding and empathy for animals, and pro-conservation behaviours. Understanding and improving zoo visitors' assessments of animal welfare is important for improving the likelihood of positive experiences and learning (in relation to conservation education) during zoo visits. The aim of this project was to engage zoo visitors in a citizen science animal behaviour project and evaluate (i) visitors' understanding and assessment of animal welfare and (ii) the feasibility and limitations of generating behavioural records through visitor participation, using video-derived observations as a reference dataset to aid interpretation. The project was undertaken at The Fenn Bell Conservation Project ($n = 76$ observers) and Twycross Zoo ($n = 155$ observers) during summer 2023. Zoo visitors were given a multi section questionnaire which included behavioural observations of animals and perceptions of affective state, a question on a description or definition of animal welfare and a question asking them to state from where they had gained their knowledge of animal welfare. Zoo visitors' definitions of animal welfare incorporated multiple recognised welfare domains, while their welfare ratings were broadly consistent with positively and negatively valenced behavioural descriptors. Visitors generally enjoyed the experience with 79.08% saying they found the process rewarding. Engagement with citizen science through behavioural studies in zoos is an area that should be considered more widely, as it has the potential to make significant contributions to educational provision within zoos, supporting the work of modern zoos.

1 Introduction

Global biodiversity losses are at an all-time high and conservation science is a priority discipline [1]. Zoos and aquariums (hereafter zoos) are now considered as centres of conservation excellence [2] and their purpose in society is more important than ever. Citizen science, broadly defined as 'the active engagement of the general public in

scientific research' [3], can be a powerful tool for improving conservation efforts, knowledge, encouraging public action [4] and wildlife monitoring [5]. Enabling public participation in scientific research has resulted in positive wildlife conservation outcomes [6]. Citizen science has two distinct aspects: citizen 'science' where the focus is on the participants collecting useable data and citizen 'engagement' where the focus is on engaging with citizens, rather than quality of the science [7]. The application of citizen science in zoos has been less explored despite the use in wildlife monitoring and the role it plays in fostering stronger connections between people and nature [8] and the potential benefits from utilising citizen engagement models to support zoo missions in relation to conservation education.

Zoos have a legal and ethical duty to ensure high standards of animal welfare, whilst also contributing towards worthwhile conservation, education and research activities. These duties were traditionally detailed under the 'four pillars' model [9]. Rose and Riley [10], suggested the inclusion of a fifth 'wellbeing' pillar, applying to both human (e.g., enhancing access to nature) and animal (e.g., providing opportunities for animals to meet their behavioural needs). Spooner et al. [11] then introduced the concept of the 'sphere of influence'. This new model acknowledges the multifaceted nature of modern zoos and better recognises their role within society on a local, national and global scale. Communication of welfare science and public education forms a major part of this model. Successful communication of welfare science involves an understanding of how visitors view and perceive animal wellbeing as the display of animals who the public believe to be experiencing good welfare is integral to capturing public trust [12]. Furthermore, inducing empathy in the public is important in the work of zoos; encouraging behaviour changes which may contribute to species conservation [13] and generally increasing conservation interest [14].

Exposure to animals, interaction with the habitats in which animals live and experiences of naturalistic exhibits have positive impacts on visitor perceptions in relation to zoos, animals and conservation initiatives [15]. Zoos have an opportunity to nurture connections between public and individual animals [16] through a suite of multisensory interactions [17]. Developing a relationship with an animal is important in the development of empathy, as is the process of assessing animal wellbeing [17]. However, zoos must strike a balance between providing opportunities for the public to view and engage safely with animals and providing suitable environments for animals to promote positive welfare with opportunities for choice and control.

Research has indicated that zoo visitors have positive experiences (including a feeling of greater connectedness to the animals) following behavioural observations of animals, particularly where the animals are active [16, 18, 19]. Behavioural observations enable zoo visitors to engage in citizen science, which may have positive implications for both zoo visitors and the zoos themselves. Citizen science within zoos in the UK has focused on initiatives such as the British and Irish Association of Zoos and Aquariums (BIAZA) 'spotted on site' campaign. This campaign encourages staff and visitors to make records of native species seen at zoological sites (BIAZA [20]). Whilst projects like these contribute highly important data on species biodiversity and is beneficial in terms of species and ecological awareness and encouraging visitors to be more engaged with their environments, opportunities for visitors to foster connections with individual animals within the zoo could be taken further. Creating experiences for zoo visitors which both support

knowledge development and inspire conservation mindedness is a critical aspect of the work of modern day zoos [21].

A significant proportion of zoo-based research is behavioural [22, 23], likely due to the inexpensive nature of behaviour observations and the opportunity to capture 'real time' data on current animal experiences. Although animal behaviour observations support evidence-based management approaches in zoos [24, 25], the collection of large-scale numerical datasets across an entire organisation may require a large time investment, making it impractical in the work of some animal care staff within zoos [26]. It is estimated that worldwide, more than 700 million people visit zoos and aquariums each year [27]. If zoos could implement citizen science projects for the public to conduct behavioural observations during their visits, they could provide engagement experiences for visitors whilst also potentially capturing data which could provide an increased understanding of how animals are spending their time during zoo opening hours. Whilst the concept sounds promising, there is little research into the impacts of implementing citizen science in zoos for the purposes of behavioural data collection and consideration is needed for possible issues with validity and reliability of observations [28], before these data could be useful for zoos.

This pilot study aimed to provide zoo visitors with an opportunity to engage in a citizen science animal behaviour research project at two zoos in the UK. The project was designed to utilise methods that encouraged visitors to reflect on the welfare and behaviour of the animals they were observing. The objectives were to: (1) explore the feasibility of engaging zoo visitors in short animal behaviour observations as part of a citizen science research activity, (2) capture visitor perceptions of animal affective states, (3) understand what visitors believe to be good animal welfare and (4) explore the feasibility and limitations of generating behavioural records through visitor observations, using systematically coded CCTV footage as a reference dataset.

2 Methods

2.1 Study sites and subjects

Subjects were two, unrelated, adult Asian small-clawed otters (*Aonyx cinereus*) (1.1) housed at The Fenn Bell Conservation Project (hereafter Fenn Bell) and two, unrelated, adult Rothschild giraffe (*Giraffa camelopardalis rothschildi*) (2.0) housed at Twycross Zoo (hereafter Twycross). Study subjects were chosen as they were considered relatively easy to consistently see from public viewing areas, with higher visitor dwell time, and were able to accommodate the installation of recording equipment to enable remote behavioural observations simultaneously to the citizen science observations.

2.2 Visitor surveys

Posters including a QR code at the relevant species habitat invited zoo visitors to take part in a citizen science activity which involved them observing the animals and answering a series of questions using an online form created using JISC Surveys (Supplementary material 1). The questionnaire was split into four distinct parts: (1) animal behaviour observations, (2) qualitative assessment of animal experiences, (3) animal welfare assessment and (4) the citizen science process. Surveys were open continuously from 28 July to 10 September 2023 at Fenn Bell and on 5 days from 24 July to 23 August 2023 at Twycross. Due to the time required to complete the entire survey, to maximise the rate

of completion, visitors were only required to complete part 1 and part 4, with part 2 and 3 labelled as optional. All visitors gave informed consent and confirmed they were over the age of 18 before completing the questionnaire and data were stored in line with GDPR guidelines. No identifying data were collected.

2.2.1 Part 1: animal behaviour observations

Zoo visitors were asked to observe the study animal for two minutes. Once the two-minute observation was completed they were asked to record the presence/absence of behaviours witnessed using a pre-defined ethogram (Tables 1 and 2). Behaviours

Table 1 Otter ethogram, adapted from Bandoli et al. [29]

Behaviour	Description	Behaviour as written for the zoo visitor
Walking/running	Animal is moving around the enclosure in a non-repetitive manner	Walking/running
Swimming	Animal is partially or fully submerged, locomoting through the water	Swimming
Engaging with stream	Animal is interacting with the stream in the enclosure	Engaging with stream
Resting alone	Animal is lying in a relaxed state with the head down. No other otters are nearby.	Resting alone
Nesting	Animal is interacting with nesting material or manipulating the nest/bedding area	Nesting (e.g., moving bedding)
Foraging	Animal is looking for food items, usually involves moving with the head on the floor near to enclosure substrate	Foraging (e.g., searching for food)
Vocalising	Animal is making a noise	Vocalising
Eating/Drinking	Animal is acquiring or consuming food items or water	Eating/Drinking
Playing alone	Animal is manipulating and engaging with objects in a playful manner	Playing alone
Grooming self	Animal is performing grooming behaviour on themselves including scratching the body or rubbing itself on an object	Grooming self
Positive social behaviours	Animal is engaged with another member of its group in a playful manner (e.g., chasing, play fighting, grooming of others)	Positive Social Behaviours (e.g., grooming other, playing together, resting together)
Negative social behaviours	Animal is engaged with another member of its group in an aggressive manner (e.g., fighting)	Negative Social Behaviours (e.g., fighting)
Abnormal repetitive behaviours	Animal is performing species-specific abnormal behaviours. These behaviours are typically repetitive and will occur for > 3 s. Behaviours may include: hair plucking, continuous pacing, route tracing, repetitive object manipulation.	Abnormal Repetitive Behaviours (Animal is performing repetitive behaviours for more than 3s, may include pacing back and forth rapidly in a small space, head rolling, etc.)
Mounting	Animal is climbing on top of the other animal from behind and may be attempting to engage in copulatory behaviour	Mounting (Animal is mounting the other)
Looking at Observer/visitors	Animal is watching the observer or paying interest in visitors	Looking at observer/visitors
Looking at staff	Animal is watching and/or paying interest in staff members	Looking at staff
Other	Any behaviours which have not been mentioned	Other
Out of sight of the observer	Animal cannot be seen properly and therefore a behaviour cannot be recorded	Out of sight of the observer

Table 2 Giraffe ethogram, adapted from Koopman et al. [30]

Behaviour	Description	Behaviour as written for the zoo visitor
Walking/running	Animal is moving around the enclosure in a non-repetitive manner	Walking/running
Standing still	Animal is inactive, not focusing on anything in particular, eyes may be open or closed	Standing still
Eating/Drinking	Animal is acquiring or consuming food items or water, including browsing	Eating/Drinking
Chewing the cud (ruminating)	Animal is chewing and swallowing a ball of already ingested food	Chewing the cud (Animal is chewing and swallowing a ball of already ingested food)
Grooming self	Animal is performing grooming behaviour on themselves using mouth or foot. May also include scratching or rubbing the head or body on an object	Grooming self
Positive social behaviours	Animal is engaged with another member of its group in a playful manner (e.g., chasing, play fighting, grooming of others)	Positive social behaviours (e.g., grooming other, playing)
Negative social behaviours	Animal is engaged with another member of its group in an aggressive manner (e.g., fighting)	Negative social behaviours (e.g., sparring)
Abnormal repetitive behaviours	Animal is performing species-specific abnormal behaviours. These behaviours are typically repetitive and will occur for > 3 s. Behaviours may include: hair plucking, continuous pacing, route tracing, head rolling.	Abnormal Repetitive Behaviours (Animal is performing repetitive behaviours for more than 3s, may include route tracing, head rolling or licking bars)
Mounting	Animal is climbing on top of the other animal from behind	Mounting (Animal is mounting another giraffe)
Looking at observer/visitors	Animal is watching the observer or paying interest in visitors	Looking at observer/visitors
Looking at staff	Animal is watching and/or paying interest in staff members	Looking at staff
Other	Any behaviours which have not been mentioned	Other
Out of sight of the observer	Animal cannot be seen properly and therefore a behaviour cannot be recorded	Out of sight of the observer

included in the ethogram were a combination of species typical behaviours that include positive, negative and neutral welfare indicators. The same ethogram was used for visitor and video-based behavioural observations to enable comparison between data sources (Sect. 2.3). Additional contextual information (e.g., location of the animal and time of day) was collected as part of the visitor survey but was not analysed as it was outside the scope of the present study.

2.2.2 Part 2: qualitative assessment of animal experiences

At the end of part one, visitors were asked if they wished to answer ten further questions on the assessment of animal affective states (for simplicity and to encourage participation, this was described as 'animal feelings' in the questionnaire). If they declined, they were directed to Part 4 (the citizen science process) which took them to the end of the questionnaire. Visitors who selected 'yes' were asked to undertake a simple qualitative assessment of the experience of the animal they had observed by scoring eight terms

using a numeric rating scale ranging from 1 to 10 (Table 3). Visitors were asked to record this using a whole number with anchors provided within the question for guidance. A plus (+) or minus (-) was added to each term to help them with part 3 (welfare assessment of the animal). Visitors were told that terms with a (+) mean this is considered to be indicative of positive welfare, and the higher the animals are scoring on this term the better the welfare state is; terms with a (-) mean this is considered to be indicative of poor welfare and the higher the animals are scoring on this term the poorer their welfare state is.

2.2.3 Part 3: public perception of animal welfare

Following completion of the animal observations there was a short section on visitor perception of welfare. Here visitors were asked to describe or define welfare and say where they had learned that definition. Then on a scale of 1 to 10 (1 being worst imaginable and 10 being best imaginable), assess the welfare state of the animals they had been observing with an open-ended free text question for them to expand on why they believed this was the case.

2.2.4 Part 4: the citizen science process

The final section of the questionnaire was designed to capture how the public found the process of engaging in behavioural observations as part of this citizen science project. Questions pertained to the ease with which they had navigated the process, their thoughts on the length of the observation and their confidence in their abilities to undertake the work, how rewarding the process was, whether or not they would engage in an initiative like this in the future and how frequently they visited the zoo.

Table 3 Definitions of qualitative phrases provided to the public

Qualitative phrase	Definition	Anchors
Content/relaxed (+)	Appears at ease/relaxed, tranquil, seems satisfied and free from tension.	1 = Not Content/relaxed 10 = Content/relaxed
Agitated (-)	A state of uncertainty which can be accompanied by physical restlessness and overreaction to stimuli. Scanning environment in a tense and anxious fashion.	1 = Not agitated 10 = Agitated
Frustrated (-)	Reacting to seeking a goal without success; can be violent towards others or objects. Angry body posture.	1 = Not Frustrated 10 = Frustrated
Comfortable (+)	Relaxed body posture, animal appears at ease in the environment, relaxed responses to stimuli.	1 = Uncomfortable 10 = Comfortable
Wary (-)	Sometimes nervous, paused reaction to some stimuli, unwilling to move in or out of an area, may be accompanied by listening and smelling. It is a slow and calm behaviour.	1 = Not Wary 10 = Wary
Confident/not fearful (+)	Animal is behaving in a positive, assured manner. Not particularly showing signs of fleeing, or otherwise fearful of the environment.	1 = Not confident/fearful 10 = Confident/not fearful
Distressed (upset) (-)	Animals seem to be suffering from a loss, may search the environment restlessly or without apparent purpose.	1 = Not Distressed 10 = Distressed
Lively/engaged with the environment (+)	Appears interested in the environment and/or engaged with objects or individuals, has a generally positive demeanour.	1 = Not lively/engaged with the environment 10 = Lively/engaged with the environment

2.3 Video observations

To provide a structured behavioural reference dataset for interpretation of visitor-generated behavioural records, video footage was gathered at each animal enclosure. Four video cameras at Fenn Bell (Yale 1080p HD CCTV security system) and three video cameras at Twycross (Hikvision DS-2CD2622FWD-IS- 4MP VF IR Bullet Network IP Camera) were temporarily installed, for the duration of the study. Cameras were installed at least two weeks prior to data collection. Data were collected from 11am – 3pm on each day that public observations were being undertaken using instantaneous scan sampling with a one minute inter scan interval, observing both animals [31]. Scan sampling was selected as a practical method for generating a structured behavioural record across the study period. Videos were analysed by two members of the project team, experienced in data collection and familiar with the species: DS reviewed the otter footage and DW reviewed the giraffe footage. Videos were coded according to the same pre-defined ethograms developed for visitors (Tables 1 and 2). Behaviours were recorded as present or absent during each scan. These observations were used to generate activity budgets and provided a reference dataset for contextualising visitor-generated behavioural records during subsequent analyses (Sect. 2.4.2).

2.4 Data analysis

Data were collected at two sites housing different species and engaging distinct visitor populations due to their geographical locations. Consequently, analyses and results are presented separately for each species, but discussed collectively where appropriate. Data analysis involved two related datasets: visitor survey responses and video-derived behavioural observations. Visitor survey data were first processed and analysed, including aggregation of behavioural observations to create the dataset used for subsequent comparison with video-derived behavioural records (Sect. 2.4.1). Visitor-reported behaviours were then compared with video-derived behavioural observations (Sect. 2.4.2).

2.4.1 Processing and analysis of visitor survey data

Not all visitors opted to complete all aspects of the survey. Wherever possible all data were retained and used in subsequent analyses. Total number of respondents included in relevant analyses are reported in the results.

2.4.1.1 Part 1: Animal behaviour observations All visitors completed part 1 of the surveys, on animal behaviour observations within each zoo. Data were compiled across all visitors per day. Data were only used in further analyses if at least two visitors had completed the observation within each one-hour time period. This ensured that hourly summaries incorporated observations from multiple visitors rather than a single visitor. Visitor observations were combined within each hour, with a behaviour classified as present if at least one visitor reported observing it during that period. Hourly observations were then further aggregated across each study day to determine whether each behaviour was detected during the day. Both hourly and daily summaries were retained to characterise the behavioural information generated through short visitor observations at two complementary temporal scales: the hourly summary describes behavioural occurrence at a relatively fine temporal scale, while the daily summary describes the cumulative behavioural occurrence recorded across a study day. These summaries were used descriptively

to explore the feasibility of generating behavioural records through visitor participation and were not intended to provide measures of agreement or observer performance.

2.4.1.2 Parts 1 to 3: Comparison between qualitative scores and public perception of animal welfare Data were analysed using RStudio (R Studio Team [32]). For the otter and giraffe datasets, analyses were conducted separately. Each participant's qualitative adjective scores and overall welfare score were retained as individual observations and no averaging was undertaken across visitors, days or observation periods. Spearman's rank correlation coefficients were calculated between all pairwise combinations of the eight qualitative adjectives to explore relationships among visitor assessments of animal affective state. In addition, Spearman's rank correlation coefficients were calculated between each qualitative adjective and the overall welfare score assigned by the same visitor. Visual depiction of those relationships was undertaken using the 'corrplot' [33] and 'Hmisc' [34] packages. These analyses were exploratory and aimed to identify patterns of association among related qualitative welfare descriptors and overall welfare scores. Correlations were interpreted based on the direction and magnitude of associations alongside P-values, rather than as independent hypothesis tests.

2.4.1.3 Part 3: Assessment of animal welfare and what welfare means to zoo visitors To understand zoo visitor perceptions of animal welfare, survey respondents were asked how they would describe or define animal welfare and from where they had learned this definition. Responses that consisted solely of an evaluation of the welfare state of the focal animals (e.g., "Great" or "Excellent") were excluded from thematic analysis. Responses that included both a welfare assessment and indicators used to make that assessment (e.g., "Very good. Both animals seem very happy") were retained. Retained responses were analysed using deductive qualitative content analysis, with the Five Domains model [35] providing the coding framework. Definitions were coded according to whether they referred to physiological welfare (Domains 1–3: nutrition, environment and health), behaviour (Domain 4), and/or mental state (Domain 5) ([35]; Redwings Horse Sanctuary [36]). Responses could be assigned to more than one domain where appropriate. Descriptive statistics were used to summarise the frequency with which each domain was represented in participants' definitions. Coding was undertaken independently by EW and DS, with any discrepancies discussed between the coders until consensus was reached.

Responses referring to animals being cared for, living in suitable environments or particular aspects of the environment (e.g., space provision, well fed) were coded as physiological welfare (Domains 1–3). Responses referring to affective state (e.g. happy behaviour, mental wellbeing) were coded as mental state (Domain 5). Responses were coded as behaviour (Domain 4) where participants referred to enrichment, interaction with the environment, or the expression of natural behaviours. Although broad terms were not considered evidence that visitors explicitly understood each individual welfare component, responses referring to overall quality of life or animal wellbeing were coded as relating to all three welfare components because these concepts reflect the integrated nature of animal welfare within the Five Domains model. This coding approach therefore captured general recognition of welfare as a holistic concept rather than explicit knowledge of each individual domain.

Visitors were also asked from where they had learned their definition of animal welfare. Participants could select multiple sources from a pre-defined list (at this zoo, at another zoo, at an educational facility, from tv/a documentary, other). Where participants selected "other", responses were reviewed for applicability to the pre-defined categories and re-categorised where appropriate. Participants could select multiple sources of knowledge. Therefore percentages represent the proportion of respondents selecting each option and totals exceed 100%.

2.4.1.4 Part 4: The citizen science process Descriptive analyses were undertaken to understand the impact of the citizen science process on the zoo visitor and to investigate the demographics of the persons who took part in the data collection process, in order to determine who the most likely respondents are in such initiatives.

2.4.2 Comparison of visitor and video behavioural observations

To quantify how animals spent their time, behavioural data from video recordings were expressed as the percentage of scans per hour in which each behaviour was observed (number of observations divided by the total number of scans conducted during each one-hour observation period; 60 scans per hour) and averaged across the study period. Video observations were then aggregated into one-hour periods corresponding to periods in which visitor observations were available. Behaviours were subsequently classified as present or absent for each hour and each study day. Visitor-generated and video-derived behavioural records were summarised at hourly and daily temporal resolutions to facilitate descriptive comparison between data sources. Only periods with corresponding visitor observations were included in the analyses. Vocalisations, looking at the observer and looking at the camera were excluded for the otters because these behaviours could not be reliably recorded by both methods. The proportion of observation periods in which behaviours were recorded as present or absent by both datasets was calculated as a descriptive measure of behavioural detection. Because visitor observations and video observations differed in duration, with the video dataset providing increased opportunities for behavioural detection, and were not collected as paired observations, these analyses should not be interpreted as measures of observer accuracy, reliability or validation. Rather, they should be interpreted as an exploratory comparison of behavioural occurrence rather than a direct assessment of observer performance. Formal inter-observer agreement statistics were therefore not applied.

2.5 Ethics

The project was approved by Harper Adams University ethics committee (project #0442-202306-STAFF). Permission to conduct the study was granted by Fenn Bell and Twycross Zoo prior to the commencement of data collection. All visitors completed an informed consent statement before starting the questionnaire (Supplementary material 1). The statement outlined how anonymised data would be used, including publication of study findings, and participants could withdraw by choosing not to submit the questionnaire.

3 Results

3.1 Otters (The Fenn Bell Conservation Project)

Overall, 76 people completed the survey and behavioural observations on the otters at Fenn Bell. Data from two or more zoo visitors was available over six hours within five days. Mean number of visitors per day at Fenn Bell was 3.4 (range 2–7). Analysis of video recordings indicated that otters spent the majority of observations out of sight of the cameras (mean percent of observations per hour ± SD, 67.4%±26.8). Of the in-sight observations the majority of time was spent engaging in positive social behaviours or locomoting around the enclosure. Grooming, mounting, negative social and abnormal repetitive behaviours were not observed (Fig. 1).

Visitor-generated and video-derived behavioural records were summarised to determine the proportion of observation periods in which behaviours were detected by both data sources. Behavioural detection by both data sources was more frequently observed when records were summarised at the daily rather than hourly level. At the daily level, both data sources recorded walking/running on all study days and neither data source recorded abnormal repetitive or negative social behaviours. Eating/drinking, mounting and engagement with the stream were recorded by both data sources during 80% of daily observation periods. The greatest differences in behavioural detection between the two data sources were observed for positive social behaviour and grooming. Instances occurred in which behaviours were recorded in the video-derived dataset but not the visitor-generated dataset, and vice versa (Supplementary material 2, S2.1). At the hourly level, neither dataset recorded abnormal repetitive behaviours or negative social behaviours during any observation period. Walking/running, mounting and eating/drinking were recorded by both datasets during 80% of observation periods (Supplementary material 2, S2.2).

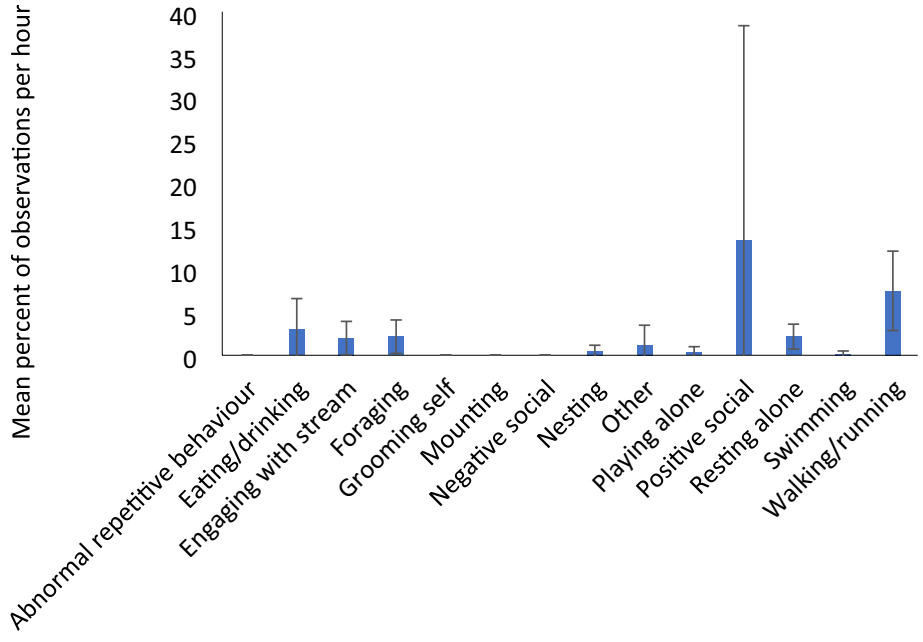

Fig. 1 Otter activity captured from video cameras at Fenn Bell. Data were collected over six hours across five separate days. Otters were out of sight for 67% of observations. Error bars are standard deviation

3.1.1 Correlations between qualitative terms

The qualitative assessment for the otters was completed by 69 participants. Correlations were observed between the eight qualitative terms: content/relaxed, agitated, frustrated, comfortable, wary, confident/not fearful, distressed, lively/engaged with the environment (Fig. 2).

3.1.2 Correlations between qualitative scores and public perceptions of welfare

Sixty-eight visitors also provided a score for welfare state of the otters. Correlations were observed between public scores for welfare and qualitative terms for the otters. There were positive correlations between welfare scores and the adjectives: 'Content' ($R_s(66) = 0.511$, $p < 0.001$, 'comfortable' ($R_s(66) = 0.439$, $p < 0.001$), 'confident' ($R_s(66) = 0.265$, $p = 0.028$) and 'lively/engaged' ($R_s(66) = 0.355$, $p = 0.003$). There was a negative correlation between welfare scores and 'frustrated' ($R_s(66) = -0.391$, $p < 0.001$. There were no correlations between welfare and the adjectives 'agitated' ($R_s(66) = 0.219$, $p = 0.073$), 'wary' ($R_s(66) = 0.606$, $p = 0.092$) and 'distressed' ($R_s(66) = 0.002$, $p = 0.988$). Median and interquartile ranges of scores for each adjective are included in Supplementary material 3 (Table S3.1).

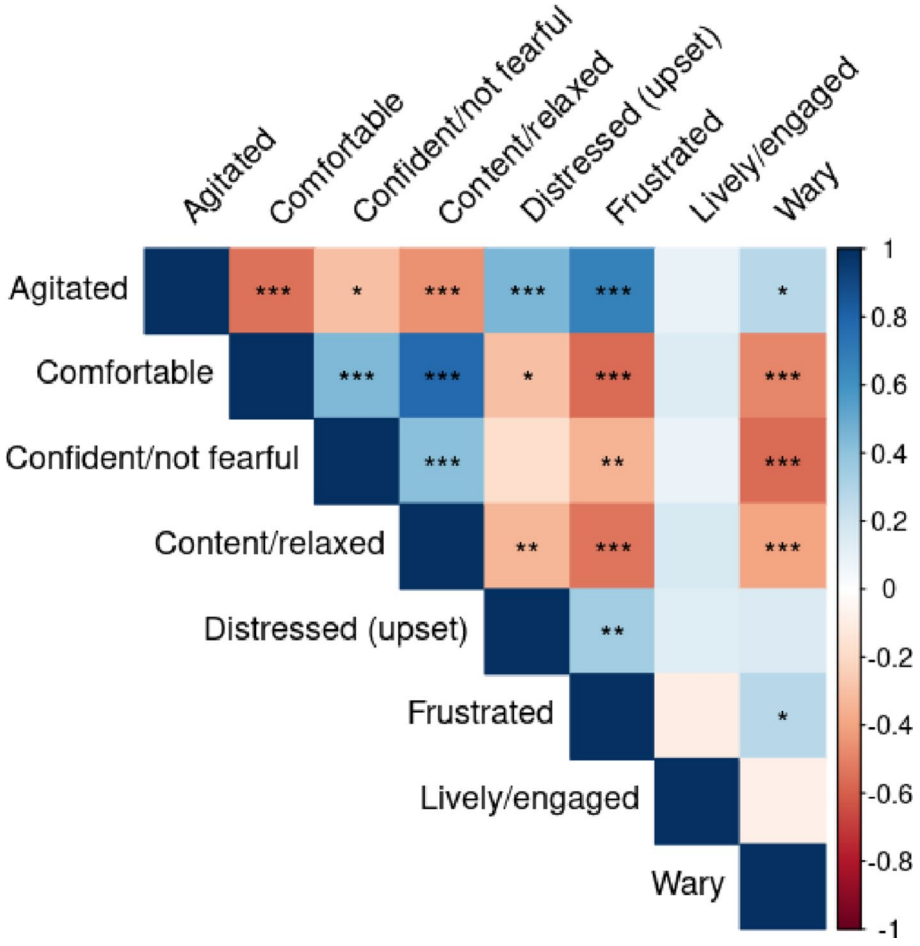

Fig. 2 Results of Spearman's rank correlations to determine correlations between qualitative adjectives used in the questionnaire to describe affective states in the otters at Fenn Bell. Shading represents Spearman's rank correlation. P values are represented as: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

3.1.3 Definitions of welfare

Of the 76 participants, $n = 68$ provided a definition of welfare. Of these, nine responses were excluded from thematic analysis because they consisted solely of an assessment of the focal animals' welfare rather than a definition of welfare. The final sample used for coding was $n = 59$ definitions. The most frequently occurring category was physiological welfare, which was referred to by 51 participants (86%). Mental state was referred to by 38 participants (64%), and behavioural aspects by 24 participants (41%).

The most frequently occurring theme was physiological, with it being referred to by $n = 51$ (86%) visitors. Implications of mental welfare was referred to by $n = 38$ (64%) visitors and behavioural aspects were referred to by $n = 24$ (41%) visitors. Examples of welfare definitions provided by visitors to the zoo are provided in Table 4.

The depth and detail of the definition varied amongst visitors, with some providing descriptive examples in relation to positive welfare experiences and others summarising their thoughts in a few key words. The majority of visitors had covered aspects of welfare which related to either one ($n = 20$) or two ($n = 24$) of the identified themes. An additional $n = 15$ visitors covered all three aspects of animal welfare, e.g., 'Looking after the wellbeing of animals', 'Meeting an animals emotional, physical mental and health needs and wants as natural as possible via diet, environment and enrichment', 'Very well kept, content and stimulated'.

A total of $n = 59$ zoo visitors answered the question in relation to where they had learned their definition of or knowledge in relation to, animal welfare. Knowledge was reported as being from an educational facility ($n = 25$), tv/documentary ($n = 24$) and from zoos ($n = 17$ from Fenn Bell and $n = 19$ at another zoo). 'Other' was selected by $n = 9$ visitors, expansions upon this answer suggested knowledge had come from their own general knowledge or experiences, family and friends, and the internet.

3.1.4 Citizen science engagement and other visitor factors

Of the people who reported how frequently they visited the zoo ($n = 71$), the majority visited less than once a year ($n = 26$, 37%). The remaining visitors were equally distributed: once every six months to one year ($n = 15$, 21%), once every one to six months ($n = 17$, 24%) and once a month or more frequently ($n = 13$, 18%).

Of the 75 respondents, the majority ($n = 71$, 95%) said they would engage in this sort of process again. Three were unsure, and only one said they did not wish to engage with this sort of thing in the future. The majority ($n = 66$, 88%) also found the process rewarding, $n = 7$ were unsure and $n = 2$ did not find the process rewarding. The majority of respondents ($n = 72$) stated they were confident they could identify all of the behaviours

Table 4 Examples of welfare definitions which were aligned to the three themes

Theme	Examples from visitors at Fenn Bell
Physiological	'Natural surroundings and hiding spots from crowds. Large enclosure' 'How they are cared for' 'Providing space, warmth, food, drink and shelter for animals'
Behaviour	'Being able to live in comfort and express natural behaviours' 'How well they are looked after, in a suitable environment, look healthy, behaving normally for their species.'
Mental state	'Animal happy' 'Comfortable and content' 'Happy relaxed animals'

A full overview of all of the responses is included in Supplementary material 4 (Table S4.1)

listed in the ethogram, $n = 2$ did not feel confident and a further $n = 1$ did not answer the question.

3.2 Giraffes (Twycross zoo)

Overall, 155 zoo visitors completed the survey on the giraffes at Twycross with a mean of 27 observers per day (range 14 to 41), capturing data over 18 h across 5 days. Analysis of video recordings indicated that giraffe spent the majority of observations eating/drinking (mean percent of observations per hour ± SD, 37.5%±15.4), standing and locomoting around the enclosure. Mounting was never observed and abnormal repetitive behaviours were very rarely observed (0.5%) (Fig. 3).

As with the otters, behavioural occurrence recorded within the visitor-generated and video-derived datasets was summarised at daily and hourly temporal resolutions. Behavioural detection by both datasets was more frequently observed when records were summarised at the daily level. At the daily level, chewing the cud, eating/drinking, standing and walking/running were recorded by both datasets on all study days, while negative social behaviour was not recorded by either dataset. Mounting, looking at staff, looking at visitors and abnormal repetitive behaviours were recorded by both datasets on 80% of study days. The greatest differences in behavioural detection between the two data sources were observed for grooming. Behaviours were recorded exclusively within either the visitor-generated or video-derived dataset on some observation days (Supplementary material 5, Table S5.1). At the hourly level, chewing the cud was recorded by both datasets during all observation periods and negative social behaviour was not recorded by either dataset. Walking/running, standing, mounting and eating/drinking were recorded by both datasets during 90% of observation periods (Supplementary material 5, Table S5.2).

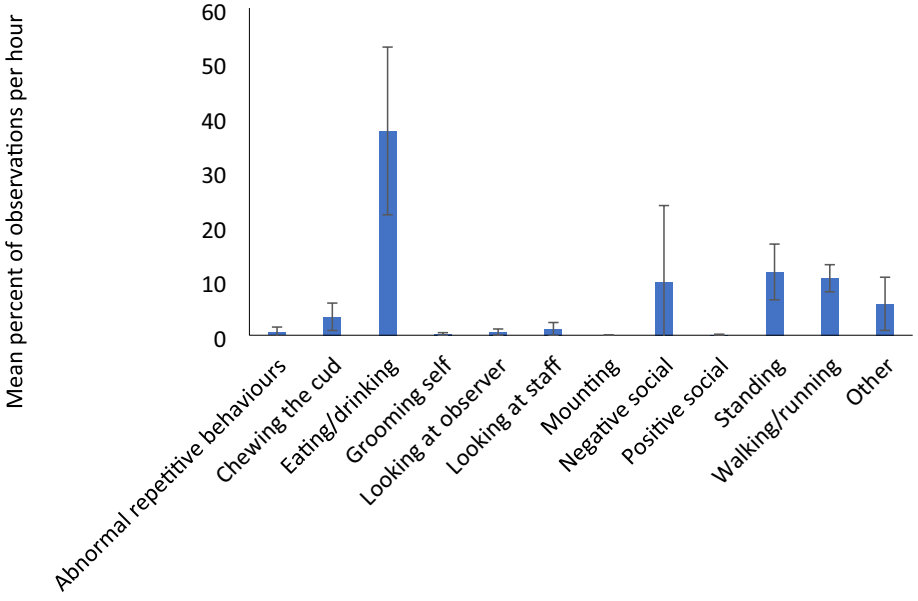

Fig. 3 Giraffe activity captured from video cameras at Twycross. Data were collected over 18 h across five separate days. Giraffe were out of sight for 19% of observations. Error bars are standard deviation

3.2.1 Correlations between qualitative terms

The qualitative assessment for the giraffes was completed by 128 participants. There were a number of correlations between qualitative terms (Fig. 4).

3.2.2 Correlations between qualitative scores and public perceptions of welfare

A score for welfare state of the giraffes was provided by 127 participants. Correlations were observed between public scores for welfare and qualitative terms for the giraffes. Positive correlations were found between welfare scores and the adjectives: 'content' ($R_s(125) = 0.396$, $p < 0.001$), 'comfortable' ($R_s(125) = 0.302$, $p < 0.001$), 'confident' ($R_s(125) = 0.315$, $p < 0.001$) and 'lively' ($R_s(125) = 0.213$, $p = 0.016$). Welfare scores were negatively correlated with the adjectives 'agitated' ($R_s(125)$=-0.189, $p = 0.033$), 'frustrated' ($R_s(125)$=-0.197, $p = 0.027$) and 'wary' ($R_s(125)$=-0.178, $p = 0.046$). There was no correlation between welfare scores and the adjective 'distressed' ($R_s(125) = 0.137$, $p = 0.123$). Median and interquartile ranges of scores for each adjective and welfare scores are included in Supplementary materials Table S3.1.

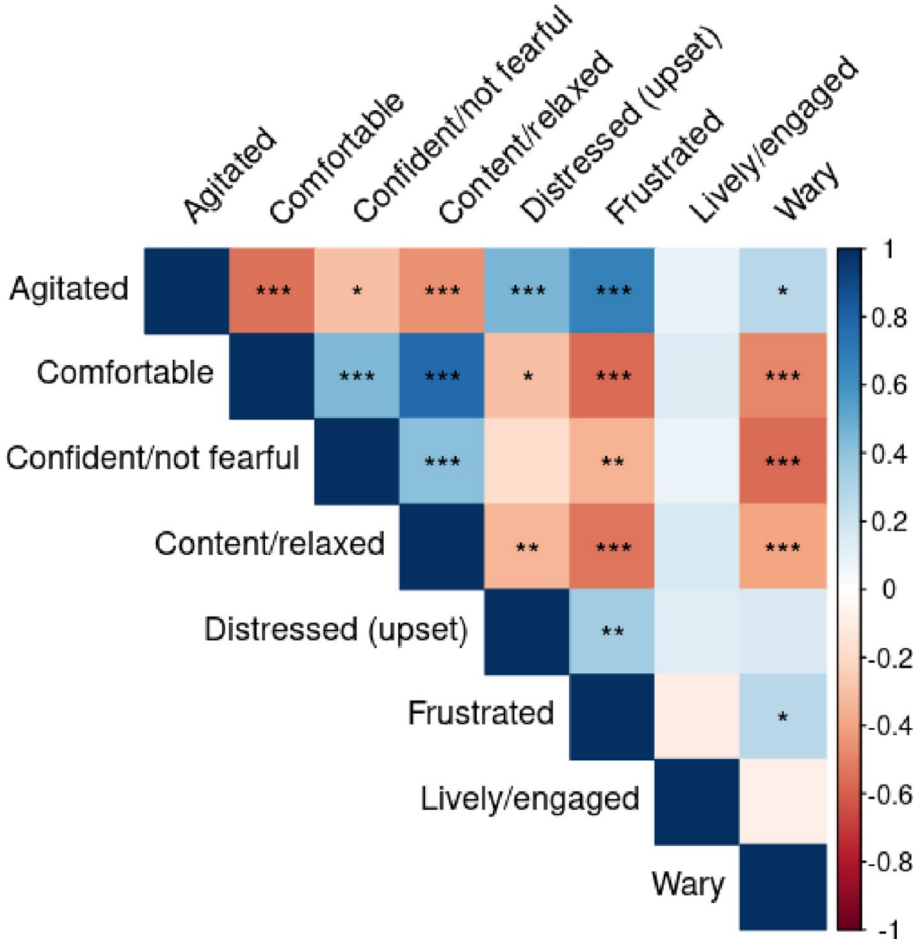

Fig. 4 Results of Spearman's rank correlations to determine correlations between qualitative adjectives used in the questionnaire to describe affective states of the giraffe at Twycross. Shading represents Spearman's rank correlation. P values are represented as: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 5 Examples of welfare definitions which were aligned to the three themes

Theme	Examples from visitors at Twycross
Physiological	'How well they are looked after' 'The upkeep and maintenance of living environment' 'Food and space available'
Behaviour	'Content animals displaying natural behaviours' 'The freedom to express natural behaviours, no pain and fulfilling their basic needs'
Mental state	'Happy and healthy' 'They look very comfortable and relaxed.'

A full overview of all of the responses is included in Supplementary material 4 (Table S4.2)

3.2.3 Definitions of welfare

In total, 97 zoo visitors answered the question on their definition of welfare. One response was excluded from thematic analysis because it consisted solely of an assessment of the focal animals' welfare rather than a definition of welfare. The final sample used for coding was $n = 96$ definitions. The most frequently occurring theme was physiological, with it being referred to by $n = 89$ (93%) visitors. Implications of mental welfare was referred to by $n = 52$ (54%) visitors and behavioural aspects were referred to by $n = 23$ (24%) visitors. Examples of welfare definitions provided by visitors to the zoo are provided in Table 5.

The majority of visitors had covered aspects of welfare which related to either one ($n = 41$) or two ($n = 43$) of the identified themes. Only $n = 13$ visitors covered all three aspects of animal welfare, e.g. 'The act of ensuring an animal is well cared for, naturally stimulated, at ease.' and 'Content animals who have appropriate shelter, nourishment, enrichment and health care.'

A total of 113 zoo visitors answered the question on where they had learned their definition of or knowledge in relation to animal welfare. Knowledge was most frequently reported as being from a zoo ($n = 63$ total), with the majority of those being from Twycross ($n = 45$). Learning from the tv/a documentary ($n = 39$) and then at an educational facility ($n = 37$) were the next most frequently ticked. 'Other' was selected by $n = 17$ visitors. Expansions upon this answer suggested knowledge had come from their own general knowledge or experiences including visiting zoos and seeing giraffe in their natural environment, family and friends, books, professional training and the internet.

3.2.4 Citizen science engagement and other visitor factors

In total 155 people reported how frequently they visited the zoo, the majority visited less than once a year ($n = 62$, 40%) and once every six months to one year ($n = 48$, 31%). The remaining visitors were relatively equally distributed: once every one to six months ($n = 30$, 19%) and once a month or more frequently ($n = 15$, 10%).

Overall, 154 respondents answered the question on whether they would engage with this process again, 93% said they would. Out of the 153 respondents, the majority ($n = 121$, 79.08%) said they found the process rewarding. A total of $n = 8$ did not find the process rewarding and $n = 24$ were unsure. The majority of respondents felt confident they could identify all the behaviours listed for the species ($n = 135$, 88.24%), $n = 2$ respondents did not answer and $n = 18$ said they did not feel confident.

4 Discussion

4.1 Visitor perceptions of animal welfare

Evidence-based animal management, which is based on good animal welfare, is at the forefront of the work of modern zoos. It is driven by the need for zoos to provide the best standards of animal care possible, alongside improving scientific understanding, changes to legislation and evidence-based practice. Public opinion has also been a significant driver in advancing welfare for zoo housed animals [37], with public petitions contributing towards changes in the presence of animal welfare in UK politics [38]. Negative perceptions of animal welfare can lead to negative attitudes towards zoos and a reduced likelihood to engage in conservation efforts [39]. Therefore, the modern zoo must not only provide good welfare for animals, but they must also effectively communicate this with zoo visitors. As such, understanding and improving a zoo visitors interpretation of welfare is important in promoting positive experiences [40]. For building relationships with zoo visitors, it is important to both identify what zoo visitors understand about animal welfare and be able to effectively educate visitors on welfare science. From a wider societal position, it is also important for zoos to educate visitors on animal welfare and the potential impacts of humans on animal wellbeing in order to support positive interactions with domestic, exotic and wild animals, outside of the zoo visit.

A key first step in educating the public on welfare science is to understand what welfare means to zoo visitors. The results of this pilot study provide encouraging evidence that citizen science can be used to explore zoo visitors' conceptualisations of animal welfare. Whilst the Five Domains were not necessarily referenced by the public, the vast majority of answers, in some way, were able to be linked to the 5 domains model of animal welfare [35]. This suggests that visitors' definitions of welfare reflected multiple components recognised within contemporary welfare frameworks, despite not necessarily having prior knowledge of the model. There was a tendency towards physiological welfare over mental welfare and behavioural interactions, which meant zoo visitors were more likely to highlight input based measures than output based measures. However, the recognition of mental state in zoo animal welfare reflects the changing narrative within the managed animal sectors [41, 42]. The least captured category was behavioural. Behavioural interactions with people, the environment and conspecifics are an integral part of animal welfare [35] however they are possibly harder to articulate, both in terms of educating the public but also in terms of the public capturing that aspect of welfare. As these data were captured via questionnaires, there was no chance to further explore answers. It is recommended that future research explores other social science methodologies, including focus groups with zoo visitors. If further research identifies similar trends in welfare definitions, there may be a benefit for zoos to include greater focus on the importance of positive public behavioural interactions within their welfare science education. A large proportion of the public said they had learned about welfare from the zoo they were in or another zoo, which suggests the educational material provided by zoos is being positively received by visitors, demonstrating this is an important avenue to explore.

Citizen-generated data in this study showed positive correlations between welfare scores and positively valenced adjectives such as 'content' and 'engaged', alongside negative correlations with negatively valenced adjectives such as 'frustrated'. These associations provide some evidence of construct validity [43], although the interpretation should be considered in the context that descriptors were provided to participants with

predefined positive or negative valence and that these analyses were exploratory only. As this is a potential limitation to the study, future research should explore interpretations without predefined valence to determine possible influence. Zoo visitors can have positive, negative and neutral impacts on animals [44, 45], and the ability to interpret animal behaviour and potential affective states may contribute to more informed interactions with animals. Further research is needed to explore how zoo visitors interpret animal behaviour and welfare indicators, particularly for more complex behaviours, and whether engagement with these concepts can contribute to more welfare-positive interactions with animals.

4.1.1 Engagement with the citizen science process

During this pilot study there was good engagement with the project, particularly where a researcher was present at the enclosure (at Twycross). The uptake on a daily basis was lower at Fenn Bell than at Twycross, however it is unclear whether this was due to visitors not having guidance/being encouraged to take part at the enclosure or owing to the zoo being smaller and having fewer visitors. Of those who engaged in the process, the majority found the process rewarding and reported they would be willing to engage in a similar process again. This suggests that there is the potential for opportunities for zoo visitors to engage in citizen science via behavioural observations to be beneficial to engagement within zoos, regardless of size. Bonney et al. [46], Masters [47], Young [17]. The majority of respondents at both zoos were not regular visitors, visiting less than once every six months. The fact that irregular zoo visitors were happy to engage in the process is promising as it means citizen science opportunities can be extended out beyond regular zoo visitors or zoo members. Regular zoo visitors did still engage with the process, however they were comparatively fewer. The reason for this is unclear however it is possible that longer term data collection would naturally capture more regular zoo visitors. The number of visitors who felt confidence in their own knowledge was also relatively high. Whilst confidence does not equate to accuracy, it is important that visitors feel engaged with the process and are not overwhelmed. The simplistic approach to the ethograms and the brief explanation of terms related to qualitative state may have supported this. Previous research has suggested that citizen science can lead to improved knowledge in participants [46, 47] and engaging in activities (such as watching behaviour) encourages a feeling of connectedness and empathy between visitors and animals [17], a key element of the work of zoos. As this pilot study only explored the publics engagement, overall perceived reward and confidence, further research could explore specific criteria including learning gains, empathy, conservation behaviour, dwell time and long-term changes in attitudes to determine tangible impact. Many zoos have missions which encompass inspiring zoo visitors [48–50] and providing opportunities for engagement in activities which may lead to enhanced visitor wellbeing is an important part of that process. Citizen science involving behavioural studies may be one such opportunity.

4.1.2 Behavioural records generated through citizen science: opportunities and limitations

A third element of this project was exploring the feasibility and limitations of generating behavioural records through visitor participation in a zoo-based citizen science activity. Behavioural observations are widely used to understand how animals spend their time and can contribute to evidence-based management approaches within zoological

collections. Citizen science has the potential to increase opportunities for behavioural data collection whilst simultaneously engaging visitors with animal behaviour and welfare concepts. However, previous research has highlighted concerns regarding the quality and interpretation of behavioural data collected by citizen scientists [51], whilst other studies have demonstrated that useful behavioural and ecological data can be generated under certain circumstances, particularly where appropriate project design and data filtering approaches are employed [52, 53]. Understanding the opportunities and limitations associated with visitor-generated behavioural observations is therefore important when considering the potential role of citizen science within zoological settings.

The behavioural analyses were intended as an exploratory examination of behavioural records generated through visitor participation, using video-derived observations as a reference dataset to aid interpretation. Visitor observations could not be directly paired with simultaneous video observations from the same individual observer, and the two data sources differed in observation duration. Consequently, standard measures of inter-observer reliability were not appropriate and these analyses should not be interpreted as assessments of observer accuracy, reliability or validation. Nevertheless, examining behavioural occurrence across the two data sources provides insight into the types of behavioural information that can be generated through short, opportunistic observations undertaken by zoo visitors and how these records relate to a more structured behavioural dataset collected during the same operational periods [26]. Differences in behavioural detection were more apparent for behaviours that were relatively infrequent or potentially more complex to identify (e.g., social interactions). These differences may reflect several factors, including variation in behavioural interpretation by visitors, differences in viewing opportunities between visitors and cameras, the longer observation period available within the video dataset, or the difficulty of consistently detecting behaviours that occurred outside camera views, were obscured from view, or were missed during brief visitor observation periods.

The use of video cameras to generate the reference dataset and the potential for differences in viewing opportunities (e.g., blind spots for both visitors and cameras) represent limitations of this study. However, video recording was the only practical method of generating a structured behavioural record across the required study period and reflects common approaches to behavioural monitoring within zoological settings, where direct observer presence may itself influence behaviour. The ad libitum sampling approach undertaken by visitors was intentionally selected to reflect the type of opportunistic participation likely to occur if citizen science behavioural observation activities were made available to zoo visitors outside formal educational programmes. This approach enabled exploration of behavioural records generated through visitor participation and their relationship to a more structured behavioural reference dataset, whilst highlighting methodological limitations that should be addressed in future validation studies.

When utilising citizen science data, quality assessment is recommended [54]. Previous research has suggested that zoo visitors may misunderstand complex instructions in relation to behavioural data collection and that this may impact on their ability to accurately collect data [28]. Whilst this could have influenced the visitor-generated records obtained in the present study, the current design does not permit direct assessment of this possibility. Although visitors were instructed to observe animals for two minutes, the actual duration and timing of observations were unknown and likely varied between

participants. Furthermore, visitor and video-derived data were collected using different sampling protocols and observation durations and are therefore not directly comparable in terms of behavioural frequencies or activity budgets. To facilitate exploratory assessment of behavioural detection, observations were converted to hourly presence/absence records and then summarised across the day. Whilst this approach reduced the influence of variable observation durations, it also resulted in a loss of behavioural detail. As such, the analyses presented here should be interpreted as an exploratory assessment of behavioural detection across the two data sources rather than as a direct assessment of observer accuracy, reliability or behavioural time budgets. Nevertheless, presence/absence data can provide useful information regarding the occurrence of behaviours and contribute to broader assessments of animal activity patterns.

Future research should focus on identifying factors that influence the reliability and validity of citizen science behavioural data collected in zoos. To enable more robust assessment of behavioural identification and observer performance, future studies could incorporate controlled comparisons between visitor observations and trained researcher observations conducted concurrently using matched sampling protocols. Video cameras positioned to capture the same enclosure view available to visitors would further facilitate comparisons between visitor and researcher observations while reducing variation associated with differences in viewpoint. Such approaches would enable formal assessment of inter-rater reliability and provide stronger evidence regarding the validity of different citizen science sampling protocols.

Future research should also investigate how observation duration and task design influence visitor-generated behavioural data. For example, studies could assess how behavioural records generated through shorter, immediate assessments of "what is the animal doing?" differ from those generated through longer observation periods, and whether additional support (e.g., timers or structured prompts) improves completion of observation periods and data quality. As training has been identified as a means of improving citizen science data quality [55] approaches for preparing zoo visitors to recognise target behaviours should be explored, particularly for behaviours that may be more complex to identify. This could include the involvement of zoo volunteers or educators to support visitors during citizen science activities. Finally, research should examine whether simplifying behavioural measures (e.g., recording activity state as active/inactive and enclosure location) improves correspondence between visitor-generated and structured behavioural datasets whilst still generating useful information on animal activity budgets and environmental engagement for zoological collections.

Whilst the quality and interpretation of visitor-generated behavioural records may be impacted by the complexity of the behaviour there are other potential benefits of using citizen science within zoos and it is recommended that opportunities to engage visitors in behavioural observations as part of citizen science projects are further explored. Engaging in the process of citizen science may have led to increased dwell time at exhibits. Whilst increasing dwell time alone may not increase learning [56], it may provide zoo visitors a more fulfilling experience and support longer term connections with nature through longer visits or repeat visits [57]. The process of engaging with animal observations is likely to be positive, particularly in terms of developing of empathy towards the study species. Visiting a zoo can have positive effects on human wellbeing [58] and quality of life [59]. The review of affective state of the animals and requirements for reflection

in relation to animal wellbeing may have prompted visitors taking part in the citizen science to engage at a deeper level with the animals. Increasing this engagement more generally may also provide a greater opportunity to engage visitors in other conservation education material. It is therefore recommended that opportunities to engage zoo visitors in citizen science activities are further explored and that future research examines the wider impacts of these experiences on visitor learning, empathy and conservation-minded behaviours.

5 Conclusion

Citizen science is a powerful tool for tackling conservation issues and, within zoos, it serves as an opportunity to support increased understanding of, and empathy for, animals. During this study, visitors to two UK zoos were offered the opportunity to engage in a citizen science project which involved collecting data on animal behaviour and qualitative state. Engagement with the citizen science process was positive. Visitors enjoyed the experience, and the majority found the process rewarding and said they would engage in that sort of opportunity in the future. Zoo visitors' definitions of animal welfare incorporated multiple aspects of recognised welfare domains, while their welfare ratings were broadly consistent with positively and negatively valenced behavioural descriptors of animal experiences. Visitor participation also generated behavioural records across both study sites. Comparison with a video-derived reference dataset highlighted both opportunities and limitations associated with visitor-generated behavioural observations. Whilst many behaviours reported by visitors were also represented within the video-derived dataset at a broad presence/absence level, behaviours that were infrequent or potentially more complex to identify showed greater differences in behavioural detection between the two data sources. Given differences in observation duration and sampling methodology, these findings should be interpreted as exploratory and do not constitute validation of visitor-generated behavioural records. Engagement with citizen science through behavioural studies in zoos is thus an area that should be considered more widely. Future research should explore the impacts of such activities on visitor learning, empathy and conservation engagement, whilst also utilising time-matched study designs to further evaluate the strengths and limitations of visitor-generated behavioural data.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Supplementary Material 4.

Supplementary Material 5.

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Author contributions

EW, DS, SJW, AC, NF developed the project protocol. EW, DS and DW collected data and undertook data analysis. EW and DS prepared the first draft of the main manuscript. EW, DS and DW revised the manuscript following feedback from anonymous reviewers. All authors reviewed the manuscript.

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Data availability
Anonymised data is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The project was approved by Harper Adams University ethics committee (project #0442-202306-STAFF). Permission to conduct the study was granted by Fenn Bell and Twycross Zoo prior to the commencement of data collection. The study was conducted in accordance with Harper Adams University institutional ethical guidelines including storage of data in line with GDPR and UK zoological regulations and followed relevant principles for engaging with human participants. All visitors completed an informed consent statement before starting the questionnaire (Supplementary material 1). The statement outlined how anonymised data would be used, including publication of study findings, and participants could withdraw by choosing not to submit the questionnaire.

Consent for publication
Not applicable. No identifiable participant information is included in this manuscript.

Competing interests
The authors declare no competing interests.

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