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Article

Human Bycatch: Conservation Surveillance and the Social Implications of Camera Traps

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Abstract

Camera traps are widely used in conservation research and practice. They can capture images of people ('human bycatch'), but little is known about how often this happens, or the implications for human rights, wellbeing, or conservation. We surveyed authors of published ecology and conservation studies that used camera traps. Over 90 percent of respondents reported that their projects had captured images of people, in most cases unintentionally. Despite this, images of people were widely used to inform conservation practice, demonstrating that camera traps are a key tool in emerging regimes of conservation surveillance. Human behaviour caught on camera included illegal activities and acts of protest. Some respondents reported positive conservation impacts of human bycatch, for example in law enforcement. However, others reported negative social impacts, such as infringing privacy and creating fear. We argue that these findings reveal a breach of commitment to do no harm and could undermine conservation success if they exacerbate conflict. Over 75 percent of respondents reported objections to or direct interference with camera traps, confirming opposition to their deployment. Many respondents recognise and take steps to mitigate these issues, but they are rarely discussed in the literature. Policy guidelines are needed to ensure the use of camera traps is ethically appropriate.

Keywords: Bycatch, camera traps, biodiversity conservation, monitoring, privacy, social impact, surveillance, vandalism, environmentality

INTRODUCTION

Motion-activated cameras, referred to as camera traps or trail cams, have become widely available and affordable for photographing wild animals (O'Connell et al. 2011). The fact that they are triggered automatically by movement (typically with infrared systems) enables the monitoring of wildlife remotely and relatively non-invasively, making camera traps less intrusive and less time demanding than other surveillance techniques (e.g. those involving physical capture-mark-recapture). As a result, camera traps have become an increasingly widespread and standardised tool in conservation and ecological research and practice (Adams 2017). For example, between 1991 and 2004 the number of publications using camera traps per year was consistently below 50, but there was then a steady increase after 2005 to over 200 publications/year by 2012-2014 (Rovero and Zimmerman 2016). Images collected with camera traps have been used for a range of conservation and ecological purposes, including the production of species inventories and abundance estimation (Rowcliffe and Carbone 2008) and individual identification (e.g. of tigers from stripe patterns; Yu et al. 2013). Recently, there has been a call for an extensive scaling-up of camera trapping effort, with the aim of producing a global network of remote cameras, researchers and citizen scientists to monitor biodiversity trends (Steenweg et al. 2017).

Whilst camera traps are often deployed with the intention of taking images of wildlife, they can equally be triggered by humans. There is some limited existing evidence that

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inadvertent collection by camera traps of images containing humans takes place (Butler and Meek 2014). We refer to this as human 'bycatch', by analogy to bycatch of non-target species in fisheries. In addition, camera traps are sometimes specifically used by researchers to take images of people, with the aims of monitoring the interaction of people and wildlife species (e.g. tigers, Pusparini et al. 2018), the impact of human activity on ecosystems, or the detection of wildlife crime (Betts 2015; Hossain et al. 2016). Surveillance is a "close watch kept over someone or something" (Merriam-Webster 2018). Whether or not taken deliberately, photographs of people taken by camera traps have the potential to form part of conservation surveillance, which we define as close watch kept over someone or something for conservation purposes.

The use of camera traps in the surveillance of people in conservation contexts follows the rise of surveillance in wider society, particularly in security and policing by state and private agents. There is a growing critical literature on the politics of surveillance, and its role in the exercise of power (e.g. Dobson and Fisher 2007; Wall 2016). A key frame for understanding such surveillance is Foucault's notion of the 'panopticon', and the practices of governance that create docile and self-disciplined bodies (Lyon 2006). Technological change transforms the possibilities of surveillance, bringing reduced costs and increased efficiency and flexibility. It ushers in new geographies of surveillance, up to and including voluntary self-surveillance using location-based data from mobile devices (Dobson and Fisher 2007).

In particular, digital devices, such as fixed cameras and mobile drones (Unmanned Aerial Vehicles, UAVs), open up new dimensions in the recording, sharing and analysis of images of individual people. They offer the potential to identify and track individuals (e.g. using face recognition software) as central elements in law enforcement or the exercise of power through a security apparatus. The use of drones in warfare (combining surveillance with military engagement) has been particularly widely debated (e.g. Gregory 2011), as has the adoption of these technologies and governance regimes into policing, in a radical extension of routine police surveillance and control (Wall 2016).

Advances in surveillance technologies and falling prices have allowed widespread adoption of digital surveillance technologies in conservation. Drones have been heralded as revolutionary in ecology (Anderson and Gaston 2013; Koh and Wich 2012), but their deployment for conservation raises numerous issues of safety, privacy and psychological wellbeing (Sandbrook 2015), as it does in other contexts (Purdy 2011; Amoore 2014). In particular, intensive surveillance regimes have been identified as an integral element in new regimes of conservation governance. Surveillance is central to the enhanced policing of protected areas to counteract problems such as poaching (e.g. Lunstrum 2014), to the extension of conservation coercion beyond the confines of protected areas in processes of 'green securitization' (Kelly and Ybarra 2016), and to the intelligence-gathering techniques of military-style counter-insurgency conservation (Duffy 2016). The threat of physical enforcement of conservation rules can be as important as actual violence (Lombard 2016). Thus, fear of arrest is a powerful (although potentially self-defeating) dimension of conservation surveillance (Humle et al. 2014).

Camera traps may not seem as problematic as drones in terms of surveillance, but they reflect the same intensification of conservation governance regimes. The deployment of camera traps in and around protected areas (for example on wildlife trails) and their ability to take images of people, allow the movements and activities of people using the same routes to be monitored and analysed. Images of people captured by such cameras may be used to inform research, management and law enforcement activities. Thus, in the Bukit Barisan Selatan National Park in Sumatra, a network of camera traps monitored presence of tigers, other wild mammals and people, and allowed estimated daily activity patterns of tigers, their prey species, and what was defined as 'illegal human presence' (collectors of non-timber forest products, 'bird poachers', and 'armed poachers'; Pusparini et al. 2018). Such camera trap imagery may potentially offer improvements strictly in terms of biodiversity conservation outcomes (for example by restricting poaching). However, the use of such images raise obvious concerns about privacy, civil liberties or fear of arrest. Pebsworth and LaFleur (2014: 122) raise a number of ethical questions for researchers using camera traps to consider, such as how best to protect the privacy of people caught on camera or what to do with images of people engaging in illegal activities. Others have highlighted objections to use of digital devices in conservation areas because they destroy the sense of 'wildness' enjoyed by visitors (e.g. objections to using radio collars to track grizzly bears in US National Parks; Benson 2010).

The use of surveillance technologies by conservation actors can be interpreted as part of a wider effort to create disciplined conservation actors. Fletcher (2010, 2017) builds on Foucault to show how techniques of governance give rise to different forms of environmentality under neoliberalism (c.f. Agrawal 2005). Conservation initiatives to create protected areas and protect wildlife put rules in place that constrain where people may go, and what they may do there, and the enforcement of these rules can be aided by the use of surveillance technology. These practices exercise power over people and seek to turn them into environmentally-friendly subjects who support conservation objectives and avoid damaging behaviors such as hunting or forest clearance (Agrawal 2005; Fletcher 2010).

To date, there has been only limited discussion in the research literature of the possible social implications of using camera traps for conservation. A recent article in *The Conversation* outlined the extent and determination with which camera traps are damaged in theft attempts in Australia, even when they are advertised as code locked and therefore of little or no use to the thief (Meek 2017). Similarly, a survey of camera trap users (primarily in Australia and the United States) revealed that 31% of them experienced some form of damage to their cameras (Butler and Meek 2014). Moreover, depending on the legislation specific to each country, researchers who

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disseminate images of humans may face the risk of litigation for breaches of privacy, irrespective of whether the researchers were party to the distribution of the images (Butler and Meek 2013; Meek and Zimmerman 2016).

In this paper we seek to address the lack of literature on the social implications of camera traps deployed for conservation and ecology research. Our aim is to provide the first significant empirical study of these issues, and to use this empirical base to engage with and enhance existing theoretical debates. We set out to answer the following research questions— 1) How often do camera traps take pictures of people, and is this deliberate? 2) What are people caught on camera doing? 3) What do researchers do with these images, and why? 4) How often do people interfere with camera traps or object to their use, and why? 5) What are the conservation implications of the collection of human images by camera traps? 6) Are these implications discussed by researchers? 7) What approaches are used to maximise positive and minimise negative outcomes for people, and are they effective?

MATERIALS AND METHODS

Systematic literature review

We carried out a systematic search of the peer-reviewed literature on conservation and ecological studies based on the field-deployment of camera traps. In December 2016, we searched the Web of Science database for 'camera trap', and six alternative terms used by McCallum (2013; Appendix 1). The search was specified within the biological categories also outlined by McCallum (2013; Appendix 1[1]), and we employed the 'Topic' setting (which searches within paper title, abstract and keywords). This produced 2,392 hits. We downloaded the 'full record' for these hits, which included the title, author names, abstract, keywords, year of publication and corresponding author email address. Using the title, abstract and keywords, we identified those papers which were based, at least in part, on the field deployment of camera traps (defined as fixed, movement-activated cameras) to study free-ranging animals and/or humans for ecological and/or conservation research purposes (full inclusion/exclusion criteria Table A1 in Appendix 1). As a general rule, if we were still in doubt about an article after having read the title, abstract and keywords, the article was included.

Once we had a list of relevant articles (1,324 in total), we compiled the email addresses of the corresponding author for each article. In cases where the email address of the corresponding author was not readily available from the Web of Science export, we searched the internet for it, and if that failed, we looked for the email address of the first author, second author, etc. After eliminating duplicate contacts, the full list contained 973 email addresses, to which our online survey was emailed. Where possible, we also downloaded the full text for each of the relevant articles (1,265 articles downloaded).

Online survey

We created an online survey using SurveyMonkey (SurveyMonkey Inc.) to be sent to the corresponding author of each camera trap study we identified[2]. The survey was divided into four overarching sections—1) Camera trap deployment details 2) Human interactions with camera traps 3) Human images collected by camera traps 4) General views on camera traps and people.

To make our results as relevant to current practice as possible, we asked respondents to answer the survey using their most recent project based on the deployment of camera traps (which may not have been the project discussed in the paper from which their email address was extracted).

After testing the distribution of the survey with 36 contacts, we decided to distribute the survey using the 'email invitation' tool on SurveyMonkey. The remaining 937 contacts were surveyed this way between March 1st-3rd, 2017. A total of 73 email addresses were found to be inactive. From these, we were able to find alternative current email addresses for 36 authors, who were surveyed on March 8th (also using the 'email invitation' tool). A reminder was sent on March 13th. The survey was finally closed on April 4th.

Data analysis

Data from the online survey were extracted and cross-tabulated to answer our research questions. Qualitative data were analysed using Atlas.ti (Atlas.ti 2014). We first read through all of the responses for each open-ended question, coming up with a list of codes as we did so (e.g. for general views on the conservation implications of using camera traps to take images of people: 'Help law enforcement', 'Deters damaging activity'). We then re-read the responses, tagging them with the relevant codes. We were thus able to produce quantitative counts from qualitative responses. Quantitative data were summarised using SurveyMonkey, and statistical analysis was carried out using SPSS (IBM Corp 2016).

Data from the published papers were used to answer our research question about whether social issues relating to camera traps are being discussed in the camera trap literature. We searched the papers for terms relevant to the impacts of camera trap on people (such as 'social', 'ethic', 'privacy' and 'surveillance') and the impacts of people on camera traps (such as 'theft', 'sabotage'; see Table 4 for full list of search terms). Where possible we only used the root of the word in order to capture all relevant instances (e.g. 'poach' so that 'poacher' and 'poaching' were included). To determine whether each instance was relevant to camera trap research, we read the paragraph in which the term featured.

Limitations

Our online survey sample was designed to provide a well-defined sample frame of camera trap researchers. However, we acknowledge that by identifying respondents

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through their publications it is likely that our sample is biased towards researchers, leaving out those who use camera traps exclusively as practitioners. It is also possible that in some cases corresponding authors on research papers may have had less exposure to camera trapping issues in the field than their junior colleagues.

We did not ask respondents to speculate about the social impacts of their camera trap deployment, or the implications of their capture of any images of people for those people themselves. Such questions need to be asked of people who encounter camera traps, or fear encountering them, and this was beyond the immediate scope of the research reported here. We acknowledge that our respondents were also only able to provide best guesses in their answers to certain questions that we did ask, such as the motivation of those who damaged camera traps. We treated such responses with caution in our analysis. There is a risk that the same project could have been reported in our data set twice, if two authors on our contact list had collaborated on their most recent project. Careful reading of all responses suggests this only happened once (both responses were included in the analysis, for methodological consistency).

RESULTS

The survey was completed by 235 respondents. The projects described by respondents took place in 65 countries, on all continents except Antarctica, on land owned by states, private entities, communities and NGOs, and involving universities, governments, the private sector and local and international NGOs[3].

How often do camera traps take pictures of people, and is this deliberate?

Our survey responses show that camera traps very often take images of people, and that most of this is unintended (i.e. 'human bycatch'), and not deliberate human surveillance. In total, 90.1% of respondents reported that camera traps in their most recent project had taken at least one image of people (Table 1). In most projects, only a small proportion of the total images collected by camera traps included people (e.g. 41.3% of respondents said human images comprised less than 1% of total images, whereas in 3.1% of projects human images accounted for over half of all images taken; Table 1). When pooling all studies reporting 10% or more images of people, a significant relationship was found between continent and frequency of human bycatch ($\chi^2 = 26.713$, $N = 223$, $p = 0.03$). Studies in Asia and North America reported higher than expected levels of bycatch, whereas studies in Australasia and South America reported lower than expected levels of bycatch. Results for Africa and Europe were similar to those expected. 91.9% of respondents indicated that their projects did not deliberately seek to photograph people. In total, images of people were collected by 89.3% of projects that did not set out to do so.

What are people caught on camera doing?

Respondents reported a wide range of human activities taking place within camera trap images (Table 2). The way respondents described and classified those activities reveals something of the way camera trap operators interpreted the presence and activities of people in places where they expected to photograph animals. Respondents were quick to classify activities as 'illegal' or 'private': 50.7% of respondents reported images showing somebody that they judged was engaged in at least one of three 'illegal activity' categories (trespassing, illegal harvesting and other illegal activities), and 34.1% of respondents captured images of people engaging in an activity that was considered private by either the researcher (e.g. 'anything they may have preferred not to be captured on camera') or appeared to be judged private by the person in the picture (e.g. 'deliberately covering their face from the camera').

Under 'any other activities of interest' (Table 2), some respondents classified activities in a less pejorative way (e.g. "collecting forest fruits") or reported neutral responses to the camera (e.g. "looking at the camera with interest, mostly just passing without noticing"), whilst others said they had captured unusual behaviours (e.g. "we photographed people stripping and posing naked for the camera, dancing and jumping naked in front of the camera, and deliberately urinating on the camera"). In qualitative answers, respondents reported a wide range of categories of people in images. Some were framed as undesirable or illegal (e.g. 'hunters' were the most common category, 13.0% of respondents, followed by 'poachers', 8.3%, and 'ranchers/herders' 5.2%). Other classifications were more neutral (e.g. 'hikers', 4.2% and 'children', 2.1%). It is not clear from the survey how these categorisations were made by the respondents.

Table 1

The number of camera trap studies from each continent reporting various proportions of human images captured in their study (n=223)

	None	<1%	1-10%	10-20%	20-50%	>50%	Total
Africa	0	11	9	3	0	0	23 (10.3%)
Asia	3	10	14	7	2	2	38 (17%)
Australasia	4	8	1	1	0	0	14 (6.3%)
Europe	2	16	6	3	3	1	31 (13.9%)
North America	5	27	19	11	6	4	72 (32.3%)
South America	8	20	9	5	3	0	45 (20.2%)
Total	22 (9.9%)	92 (41.3%)	58 (26%)	30 (13.4%)	14 (6.3%)	7 (3.1%)	

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Table 2
Number and percentage of total respondents reporting the capture of images of people engaged in each of several activities in their most recent camera trap project

	Never	Once	A few times	Often (more than 10 times)
Being in a place they had no legal right to be (i.e. trespassing)	126 (56.5%)	15 (6.7%)	52 (23.3%)	30 (13.5%)
Carrying harvested animals or plants in an area where this is illegal	165 (74.0%)	8 (3.6%)	39 (17.5%)	11 (4.9%)
Carrying out any illegal activity other than harvesting wildlife (e.g. carrying smuggled goods)	167 (74.9%)	12 (5.4%)	39 (17.5%)	5 (2.2%)
Carrying weapons or traps	115 (51.6%)	19 (8.5%)	67 (30.0%)	22 (9.9%)
Anything they may have preferred not to have captured on camera (e.g. performing a ritual, going to the toilet)	171 (76.7%)	21 (9.4%)	28 (12.6%)	3 (1.3%)
Deliberately posing for the camera	96 (43.0%)	17 (7.6%)	71 (31.8%)	39 (17.5%)
Deliberately covering their face from the camera	176 (78.9%)	8 (3.6%)	36 (16.1%)	3 (1.3%)
Any other activities of interest	184 (82.5%)	12 (5.8%)	20 (9.0%)	7 (3.1%)

What do researchers do with images of people, and why?

A number of respondents were aware of the potential risks of camera trap surveillance to those observed and had taken steps to reduce them. Over a quarter of respondents (26.6%) said they had a procedure in place in advance for what to do with images containing people. Examples of such procedures included not sharing or publishing such pictures (6.3% of respondents) and avoiding identifying people (e.g. blurring; 1.6%). A few respondents referenced formal protocols, for example "We use Smithsonian's e-mammal database, which does not save images of people", or "Parks Canada has protocols for deleting images immediately after classification".

In total, 44.3% of respondents claimed to have treated pictures containing people differently from those without people, regardless of whether they had a procedure in place in advance for this. Some uses of pictures were intended to have positive impacts for those photographed: for example, in 1.6 % of cases images were said to be deliberately shared in order to create goodwill among 'local people'[4]. However, almost half of respondents (44.3%) made specific use of images of people involved in illegal activities (Figure 1) in management. The proportion of projects using such images was much higher than those that deliberately set out to take images of people (only 8.1% of projects). This shows the importance of surveillance using accidental human bycatch images for management and enforcement. A few respondents (7.7%) deliberately used images showing illegal activities in ways intended either to minimise management actions against those photographed, or to protect their project by avoiding negative responses by those photographed, for example reporting images only after the project had concluded. However, a quarter of respondents (25.1%) thought that surveillance in the form of camera trap images of people had influenced conservation decisions positively (almost half these respondents, 42.6%, saw such surveillance directing conservation efforts towards hotspots of 'illegal activity').

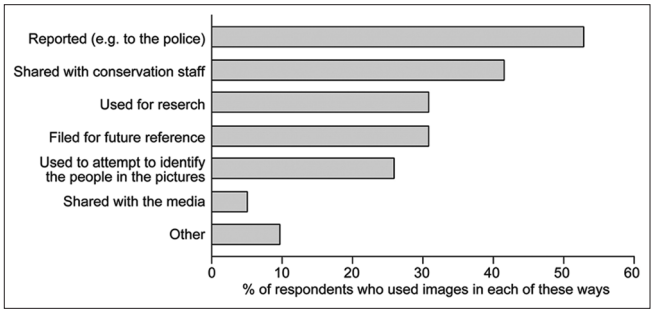

Figure 1
Proportion of respondents who used images of people engaged in illegal activities in each of the following ways (as a percentage of the total number of respondents who used images of people engaged in illegal activities (N = 104))

How often do people interfere with camera traps or object to their use, and why?

The power of camera trap surveillance is suggested by the frequency with which survey respondents reported interference with camera traps. Over three quarters of respondents (76.1%) said that at least one camera trap had been interfered with, and 73.5% said at least some of this interaction was damaging to their project (Table 3). Removal was the most common form of interference, affecting 64.5% of projects (Table 3). Respondents reporting that more than 1% of their images showed people were also more likely to have found their cameras damaged ($\chi^2 = 25.5$, $N = 223$, $p = 0.00$), suggesting that the problem of interference rose with the frequency with which people were photographed. There was no relationship between trap-days (number of traps deployed multiplied by the number of days they were deployed for) and the proportion of camera traps that were interacted with (Spearman's rho = 0.12, $N = 206$, $p = 0.10$), suggesting that it was not trapping intensity or duration, but the deployment of cameras where pictures of people were more likely to be captured, that generated most interference.

Qualitative responses suggest that in some cases people went to great lengths to interfere with camera traps. For example, one respondent answered that "once my camera, which was securely attached to a large tree, was burnt by a fire set deliberately to destroy it (only a 1m^2 area was burnt, exactly where the camera was)", whilst another respondent indicated that their cameras were "shot with shotguns". Other types of interaction reported by respondents included having SD cards/data stolen (7.7%) and having their cameras removed but left on the ground (2.6%). Nearly a quarter of respondents

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Table 3
The number and percentage of respondents who reported that people outside the project had interacted with their camera traps, and the form of that interaction (total answered=234)

	Never	Once	A few times	Often (more than ten times)
Damaged	157 (67.1%)	22 (9.4%)	47 (20.1%)	8 (3.4%)
Destroyed	173 (73.9%)	17 (5.5%)	39 (16.7%)	5 (2.1%)
Removed	83 (35.5%)	35 (15.0%)	92 (39.3%)	24 (10.3%)
Covered/blocked	179 (76.5%)	11 (4.7%)	41 (17.5%)	3 (1.3%)
Rendered unworkable in some other way	186 (79.5%)	8 (3.4%)	36 (15.4%)	4 (1.7%)
Other	213 (91.0%)	3 (1.3%)	12 (5.1%)	6 (2.6%)

(23.4%) reported that cameras were blocked or covered at least once in their projects. This behaviour is particularly interesting as it suggests concern with what the cameras might be seeing, rather than a desire to damage the cameras. Such behaviour cannot be dismissed as gratuitous violence.

Just over a tenth of respondents (11.9%) reported receiving objections to camera traps in ways that did not involve directly interacting with the cameras. These included verbal complaints (8.4%), official complaints (2.7%) and public protests (0.9%). There was no relationship between the number of trap-days and whether the project received objections (Mann-Whitney U, $N = 198$, $p = 0.94$). Looking at damaging interference with camera traps and objections to their use together, 75.3% of respondents reported one or both of these issues occurring.

In total, 76.8% of respondents who reported interactions and/or objections said in their qualitative answers that they had some idea of who had been involved. Again, the way these people were described reflects the attitude of camera trap operators to people in their study area. The most frequently mentioned category of person was 'poacher' (19.1% of respondents answering these questions). Other common categories were 'people doing illegal things other than hunting' (12.2%), 'children or teenagers' (7.9%), and 'armed groups' (2.0%).

Many respondents were conscious that those interfering with cameras were motivated by concern over surveillance. The most frequent reason respondents gave for why they thought people had interfered with their camera traps was 'fear/concern of what might be done with the images' (66.5% of respondents). Respondents often said that they thought this fear derived either from general privacy concerns or from not wanting to be caught carrying out illegal activities, e.g. "since hunting is illegal in Brazil, hunters usually are concerned with might be done with the images". Qualitative answers show that the presence of camera traps can produce intense feelings of fear amongst affected people (e.g. "once we found a woman on the field near a camera trap, and she complained because she thought that we were trying to take pictures of children to steal them later"), as well as instigate conflict between local groups (e.g.: "Other ranch owners complained about those that agreed to collaborate, they became "traitors"").

However, not all interference was attributed to concern about surveillance. Other reasons given for interference with camera traps included desire to sell or re-use the cameras (53.9%), gratuitous vandalism (28.7%), and objections to technology in a 'wild' area (3.6%). Some respondents thought that interference and objections stemmed from issues other than the camera traps themselves, for example distrust of the government (even in cases where the government was not involved in the camera trap project), or dislike of wild species, such as pumas (*Puma concolor*), perceived to be supported by those deploying the cameras.

What are the conservation implications of the collection of human images by camera traps?

While it might be expected from the literature on conservation surveillance that conservation managers would see the increased surveillance potential of camera trap deployment as helpful, there were mixed views amongst respondents about whether the ability of camera traps to take images of people had a positive or negative effect on conservation. 34% of respondents answered that they had a positive influence, whereas 24% thought they could increase the risk of negative conservation outcomes. Among positive implications, respondents highlighted the conservation value of pictures of people in providing information on human activity patterns and impacts on wildlife (11.9% of total respondents), helping law enforcement (4.7%) and deterring damaging activities (3.0%). Such 'positive' impacts might, of course, have been regarded as negative by those observed, or by other people living in the area.

When asked if in their experience the deployment of camera traps to record images of people could increase the risk of negative conservation outcomes, 4.9% of respondents mentioned in their qualitative answers that this could happen if they fostered antagonistic relationships with people outside the project team. A small number of respondents (1.6%) noted that there could be negative repercussions for conservation if people conflated their project with law enforcement, by thinking that the camera traps were there to monitor illegal activities. Some of these respondents emphasised that maintaining a good relationship with local people was crucial to the project's success. Other researchers noted that human interactions with camera traps resulted in a waste of time, equipment and data, or limited the areas where data on wildlife could be collected.

Are the conservation implications of camera traps discussed by researchers?

Despite the awareness of our respondents of the role of camera trap deployment in terms of surveillance, or the social

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impacts of that surveillance, our search of published camera trap papers suggested that there is little formal analysis or discussion by researchers of these issues. Our analysis of papers revealed very limited engagement with terms we considered relevant to the impact of camera traps on people (e.g. two papers made relevant mention of the words 'privacy' and 'surveillance'; Table 4). In contrast, there was considerably greater engagement with terms we considered relevant to the impact of people on camera traps (Table 4). This suggests that while researchers saw the damage or loss of equipment (and data) as a problem worthy of discussion, they did not see the social impacts of surveillance as worthy of systematic analysis (even though our survey shows that the problem was relatively widely recognised).

What approaches are used to maximise positive and minimise negative outcomes for people and are they effective?

Unsurprisingly, given the awareness of reactions to camera trap deployment among our respondents, a number took steps to minimise negative outcomes, either for their projects or for those photographed (or both). In total, 65.3% of survey respondents took steps to reduce interference with camera traps and 33.7% of respondents took steps to reduce objections. 70.7% said they took steps to reduce one or both of these issues. A variety of strategies was used, including using physical defences, avoiding deploying the cameras where the risk of human interaction was too high, and explicitly reassuring local people that the cameras would not be used against them. 59.2% of respondents said they told local people about their project, with a further 12.0% answering that there were no people present to tell. 37.0% of the respondents who said they had informed local people about their projects also specified that they involved them in the project (for example by engaging them in the deployment of camera traps), and 12.3% said they asked for permission from local people before deploying the traps.

Respondents who reported more interference with their cameras by people outside the project were more likely to report trying to reduce these events ($\chi^2 = 40.8$, $N = 222$, $p = 0.00$). Similarly, respondents who said they received objections were more likely to have reported attempting to reduce objections ($\chi^2 = 37.41$, $N = 175$, $p = 0.00$). However, informing local people about trap deployment did not seem to reduce either the level of interference with traps ($\chi^2 = 5.12$, $N = 205$, $p = 0.28$), or the level of objection to projects ($\chi^2 = 1.92$, $N = 198$, $p = 0.17$). This suggests that simply informing people about traps is not an effective way of reducing conflict.

Camera traps are deployed in very different social contexts around the world, and as described above in Section 3.1 we found that the frequency of human images captured varied by continent. It might be expected that wealthier people might be more willing or able to complain about camera traps, while poorer people might be more likely to be negatively affected by the use of camera traps. In this respect, we found no relationship between the incidence of poverty at the country level (measured by World Bank development status category of the country where the cameras were deployed) and the level of interference with traps ($\chi^2 = 14.89$, $N = 217$, $p = 0.25$) or the number of objections to projects ($\chi^2 = 1.06$, $N = 209$, $p = 0.78$).

DISCUSSION

This study provides the first global perspective on the social and conservation implications of 'human bycatch' from camera traps. Remarkably, over 90% of camera trap projects we surveyed took pictures of people, and in 22.9% of projects the proportion of pictures featuring people was one in ten or greater. In most cases these images were accidental human

Table 4

Number of camera trap papers in which various terms appeared in a context relevant to human bycatch, and the number of instances across all papers for each term. Percentages represent the proportion of documents and instances that appeared in a context relevant to human bycatch from the total number of documents and instances for that particular term

Term/string	Number of relevant documents	Number of relevant instances
A. Impacts of Camera Traps on people		
Social	0* (0%)	0* (0%)
Ethic (e, g, ethics, ethical)	0 (0%)	0 (0%)
People	0* (0%)	0* (0%)
Privacy	2 (50%)	2 (40%)
Surveillance	2 (2.2%)	2 (0.87%)
Deleted (i.e. camera data cards)	0 (0%)	0 (0%)
Protest	0 (0%)	0 (0%)
B. Impacts of People on Camera Traps		
'Vandali' (e.g. 'vandalism', 'vandalisation')	28 (96.6%)	37 (92.5%)
Illegal	8 (5%)	15 (41.7%)
Poach (e.g. 'poacher')	19 (8.4%)	45 (3.6%)
Steal	1 (1.3%)	3 (2.4%)
Stole	38 (80.9%)	46 (82.1%)
Theft	83 (93.3%)	106 (75.7%)
Sabotage	2 (100%)	2 (100%)

*Assessment of whether instances were relevant was stopped if none of the first 50 instances was relevant

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bycatch. If anything, this may be an underestimate of the true occurrence of this phenomenon, because 1) our sample targeted researchers rather than conservation practitioners, and it seems likely that practitioners would be more likely to deliberately take pictures of people given their potential application in law enforcement; 2) cameras taking more images of people were more likely to be damaged, which could result in respondents being unaware of images taken by damaged equipment. The frequency with which camera traps take pictures of people suggests that potential positive or negative implications of this phenomenon need to be taken seriously.

From the narrow point of view of biodiversity conservation outcomes, our results suggest that our respondents thought camera trap images of people could have value as a conservation tool (Hossain et al. 2016), for example by enabling people breaking conservation regulations to be arrested (Snow Leopard Trust 2017). Camera traps are therefore recognised as significant surveillance tools, contributing to the power of conservation actors to promote or enforce conservation regulations and behaviour (c.f. Agrawal 2005, Fletcher 2010). However, some camera trap users saw positive social impacts from camera deployment. For example, in some cases images were shared with local people (including those photographed) to generate goodwill, a practice that has also had some success among those using drones for research purposes (Duffy et al. 2017).

The very usefulness of camera trap surveillance as a tool for the management of people and the enforcement of conservation regulations generates potential negative outcomes, both for the people observed and (in as much as those people object) for conservation projects. Our study cannot provide an in-depth assessment of the social impacts of camera traps on local people, as we did not collect data directly from those affected. However, our results provide strong circumstantial evidence that camera traps can have negative implications for the wellbeing of local people in several ways.

Firstly, cameras frequently capture pictures of people who would not wish to be photographed, raising questions about infringements of privacy, and whether there are circumstances under which camera traps should not be used for this reason. These questions echo wider debates about the privacy implications of other surveillance technologies, such as drones used in public spaces (Finn and Wright 2012, 2016) or for conservation (Sandbrook 2015). Secondly, camera traps (along with other surveillance devices) are being deployed to enforce conservation regulations, whether or not collecting images of people was initially intended. Surveillance is central to the militarised strategies being developed to counter threats such as poaching (Duffy 2014; Büscher and Ramutsindela 2015). In circumstances where governance and systems of justice are weak or arbitrary, it is problematic to assume that images of people apparently breaking the law will be used wisely and fairly. Thirdly, camera traps can cause fear, as in the case of the mother who thought the traps were part of a plot to steal her children, and they can instigate conflict between different groups, as in the case of local people who had sided with researchers being labelled as "traitors". Similarly, Shrestha and Lapeyre (2018) note that a major factor in camera trap vandalism in the Terai-Arc Landscape in Nepal was the fear resulting from lack of information in the local community about what the traps were for, and how images of illegal activities (such as firewood or fodder collection) would be treated. Unfortunately, our results suggest that simply telling people about camera traps in advance does not reduce levels of interference, perhaps demonstrating a lack of trust regarding the claimed rationale for camera trap deployment. Fourthly, people resist being photographed by camera traps, either by hiding from them or seeking to damage, block or remove the cameras themselves. It seems reasonable to assume that they would not do so if they were comfortable with being photographed. Subversive acts such as urinating on the cameras can be interpreted as 'weapons of the weak' (Scott 1985) – a tool of resistance available to people without the power to directly challenge the authority of those deploying camera traps.

Many leading international conservation organisations have adopted the Conservation Initiative on Human Rights, which reflects the aspirations of the UN Universal Declaration of Human Rights in 1948 (Springer et al 2011). The provision that "human beings shall enjoy freedom of speech and belief and freedom from fear and want" (Preamble) and "No one shall be subjected to arbitrary interference with his (*sic*) privacy, family, home or correspondence" (Article 12; UN General Assembly 1948) suggest the need for further consideration of the human rights dimensions of camera trap deployment and the management of images of people.

As well as being undesirable in themselves, social impacts of camera traps could have knock on impacts on long term conservation effectiveness. The most obvious negative conservation outcome identified in our study was the damage that people inflicted on camera traps, which incurs financial costs on researchers as well as causing loss of data through damaged or removed cameras and reductions in data quality and completeness due to suboptimal sampling in less visible locations. Importantly, the most frequently mentioned reason why researchers thought that their cameras had been interfered with was 'Fear/concern of what might be done with the images', strongly suggesting that much of this cost to conservation can be directly attributed to the ability of camera traps to capture images of humans.

Beyond these direct costs, the opposition to camera traps described above can create conditions of conflict that may undermine conservation success (Redpath et al 2015). For example, one respondent said that "conservation is only successful if local people are on your side - if you place cameras to watch them, they feel that you are against them and will do more to harm wildlife…just to get back at you". Almost a quarter of our respondents felt that taking pictures of people with camera traps could increase the risk of negative conservation outcomes, and over a third of them took steps to reduce objections to their camera traps. Considering that our respondents were people who themselves deploy camera traps

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and might therefore be expected to have an optimistic view of their value, this level of concern seems remarkably high.

Many respondents took steps to mitigate potential conflict with people, using physical means to protect their camera traps (which protects cameras from people, but not vice versa) or through communication. Our study was not designed to provide clear answers to questions about what works and what doesn't in this regard, and further research would be valuable. However, it is interesting to note that levels of interaction with camera traps were higher in projects that sought to mitigate conflict. This apparently counter-intuitive result might make sense if efforts to mitigate conflict are undertaken only in response to experience of such conflict. In any case, it suggests that telling local people about trap deployment does not necessarily reduce opposition: nearly 60% of our respondents said they had told local people about their project (and in a further 12% of cases there were no local people to tell). It is also important to note that damage to camera traps may be motivated by wider issues, with the camera traps acting as a lightning rod for quite different concerns such as a grievance over land rights or mistreatment by a government authority. As a result, approaches to reducing conflict around camera traps may be more effective if they are placed in a broader context rather than just focusing on responses to the cameras themselves.

An important final point is that there seems some evidence of evolution in practice with respect to 'human bycatch'. Our data show that that the number of projects that made use of images of people was far greater than the number that set out to do so. It seems that once they exist, images find uses that were in most instances not envisaged, in management, enforcement or in work with resident human populations. Accidental 'bycatch' is therefore being harvested as if it were a deliberate 'catch', and it would be interesting to know how the availability of these images comes to influence later camera trap deployment campaigns. Both the use of traps to capture images of people, and the responses of people to them are likely to change over time, especially if human imaging develops as part of standard conservation practice.

CONCLUSION

Camera traps and related surveillance technologies are widely heralded as game-changers for conservation research and practice, yet the critical literature on surveillance and conservation calls attention to various ways in which they might have negative social and political consequences. There is no doubt that surveillance technologies have great technical advantages for researchers and conservation managers needing data on the presence or numbers of animal species of concern. However, our results demonstrate empirically that they also have a powerful role in the surveillance of people, including both those going about their normal and lawful business, and those breaking the law. This does indeed have both negative and positive social and political consequences, although not always in the ways anticipated by previous theoretical studies on these issues. In the light of the importance of camera trap surveillance that we reveal in this study, we identify four conclusions.

First, our results suggest that camera trap users are aware that their devices regularly take pictures of people, and that their deployment is recognised implicitly and sometimes explicitly as a contribution to conservation governance. Camera traps can provide the basis for a surveillance regime that can allow the analysis of human distribution and behaviour (where people go and why) and can contribute to the restriction or prevention of behaviours judged by managers to be detrimental to conservation outcomes. Camera trap surveillance therefore contributes to the development of conservation environmentalities (Fletcher 2010, 2017). It increases the power of conservation governance by providing evidence of apparent law breaking and it helps mark and enforce the distinction between spaces for nature and spaces for people (c.f. Bluwstein and Lund 2018). Where (as is commonly the case) cameras are deployed by non-state actors such as researchers or non-governmental organisations), they extend authority in environmental governance beyond the state. Interestingly, our results suggest that while camera trap images are used as a tool to shape environmental subjects, this is not always intended from the outset, and can be the result of unexpected images being captured in an ecology project. This somewhat challenges the straightforward extension of the environmentality framework to these cases, as work using this concept tends to assume a conscious and strategic choice on the part of those actors who are seeking to create environmental subjects (Fletcher 2010). While some uses we identified were certainly deliberate, others might be better characterised as (diverse forms of) 'opportunistic environmentality'.

Secondly, we identify a gap in debates within conservation about camera traps. It is notable that although many of our respondents were aware of the potential social impacts of camera trap surveillance, the formal research literature makes almost no reference to these issues. Some studies have mentioned negative effects of people on camera traps (e.g. through vandalism (e.g. Bernard et al. 2014; Clare et al. 2015) but very few mention the inverse: the negative effects of camera traps on people (Rupf et al. 2011; Villaseñor et al. 2014; Table 4). A similar situation applies to the literature on conservation drones (Sandbrook 2015). It is interesting to consider why this might be. Perhaps researchers see such impacts as just a fieldwork challenge of little interest to journal readers? Or perhaps the social implications of surveillance by camera traps are simply not considered an appropriate issue for natural science-based conservation journals? In either case we would disagree: camera trap deployment, and wider conservation surveillance, are important, and urgently need broad discussion.

Thirdly, we note that at present there is no widely recognised set of standards for taking and handling camera trap images of people, and most of our respondents had no specific plan in place for dealing with such images. Our results suggest the need for such a protocol, informed by the experience of camera

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trap users, social scientists, rights-based NGOs and people who live with camera traps. Guidelines for good practice might address the need for ethical review of project proposals, standards for using, sharing and storing images of people, and arrangements for prior informed consent. Recently published WWF guidelines for users of camera traps offer a very positive step in this direction (Wearn and Glover-Kapfer 2017). One specific possibility is using automated image classification (Swinnen et al. 2014; Price Tack et al. 2016) to delete or blur accidental images of people, which has already been used to select images of people believed to be breaking the law (Betts 2015). Rather than being developed in isolation, guidelines and protocols for camera trap use may have synergies with those under development for other technologies used by conservation, such as drones.

Fourthly, we note the need for further research on the social dimensions of camera traps. In particular, we suggest two areas for further work. First, in-depth qualitative studies with communities in zones where traps are installed would be valuable to explore the 'view from below', which our survey does not let us address. Such studies should consider the range of social and ecological environments in which camera traps are employed, and how these shape their effects. Second, we see potential for in-depth qualitative research with those deploying camera traps to allow analysis of the discursive frames woven around camera use and the management of pictures of people in the context of conservation governance and the wider conservation imagination about nature and local society.

The human bycatch of camera traps is a significant and largely unrecognised issue in conservation. The implications of camera traps, along with other forms of conservation surveillance, urgently need to be addressed and included in future debates about conservation governance and the rights and interests of people living with conservation practice.

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NOTES

1. Our search criteria excluded the use of time-lapse cameras. We have subsequently learned that some investigators are now using time-lapse triggering for detection of wildlife to compensate for detection issues in camera trap studies. This may have led to a small number of relevant studies and authors being excluded from our database.
2. The methods used in this study were approved by the University of Cambridge Department of Geography ethical review board on January 18, 2017.
3. We received the largest number of responses about camera trap projects in North America (73 cases, 31%). As respondents may have given answers relating to a different project from the one covered by the published work from which we drew their email address, we cannot tell whether there was any geographical response bias.
4. We recognise that 'local people' functions as a closed category in our survey and our interpretation of the data. This choice was in part informed by our expectation that our respondents would find this category meaningful, helping them to respond to the survey. Further research on the issues raised in this paper could seek to open up this category to reveal the diverse people and practices implicated in and affected by the use of camera traps.

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APPENDICES

Appendix 1: Details of the search terms and criteria used for the systematic literature review

a) Web of Science search string

camera trap* OR infrared triggered camera* OR trail camera* OR automatic camera* OR photo trap* OR remotely triggered camera* OR remote camera*

b) Web of Science categories:

Biodiversity conservation, Behavioural sciences, Biology, Ecology, Environmental sciences, Environmental studies, Evolutionary biology, Fisheries, Forestry, Marine freshwater biology, Oceanography, Ornithology, Plant sciences, Veterinary sciences, Zoology.

Table A1
Inclusion/exclusion criteria for camera trap papers included in this study

Inclusion	**Exclusion**
Papers testing camera traps	Underwater cameras
Papers for which camera traps were deployed by someone other than the authors (e.g. citizen scientists)	Literature reviews
	Book chapters
Nest video cameras that were remotely-triggered (if from the title and abstract it was not clear that the cameras were remotely-triggered, the article was excluded)	Camera traps placed on the animals themselves, or mobile in any other way.
Editorial material, as long as it was clearly reporting the outcome of a camera trap-based project	Time-lapse cameras