COMMENTARY

Illegal Captive Lemurs in Madagascar: Comparing the Use of Online and In-Person Data Collection Methods

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Although it is illegal to capture, sell, and trade lemurs, the live capture of lemurs in Madagascar is ongoing and may have impacted over 28,000 lemurs between 2010 and 2013. Only one study has examined this trade and did so using in-person interviews in northern Madagascar. The current study sought to expand this existing dataset and examine the comparability of online surveys to more traditional on-location data collection methods. In this study, we collected data through a web-based survey resulting in 302 sightings of 685 captive lemurs. We also collected data from 171 hotel and 43 restaurant websites and social media profiles. Survey submissions included sightings of 30 species from 10 genera, nearly twice as many species as identified via the in-person interviews. *Lemur catta*, *Varecia variegata*, and *Eulemur fulvus* were the most common species sighted in captivity. Captive lemurs were reported in 19 of Madagascar's 22 administrative regions and most were seen in urban areas near their habitat ranges. This represents a wider geographic distribution of captive lemurs than previously found through in-person interviews. The online survey results were broadly similar to those of the in-person surveys though greater in species and geographic diversity demonstrating advantages to the use of online surveys. The online research methods were low in cost (USD $100) compared to on-location data collection (USD $12,000). Identified disadvantages included sample bias; most of the respondents to the online survey were researchers and many captive sightings were near study sites. The results illustrate the benefits of incorporating a social science approach using online surveys as a complement to traditional fieldwork. Am. J. Primatol.

Key words: lemurs; Madagascar; Africa; pet; trade; capture

INTRODUCTION

The capture of wildlife from remnant natural habitats can threaten biodiversity [Baillie et al., 2004]; commercial wildlife trafficking is the world's third largest illegal trade following drugs and arms sales [Giovanni, 2006]. Live capture affects at least 40,000 primates annually [Karesh et al., 2005] which are captured from the wild for multiple and overlapping reasons (for consumption, trade/sale, use in medicines, and as pets [Brashares et al., 2011; Nekaris et al., 2010; Shanee, 2012; Soulsbury et al., 2009]). Studies of primate pets have been conducted on all continents where they are endemic: Asia (e.g., [Nekaris et al., 2010; Nijman et al., 2008; Shepherd, 2010; Todd, 2008]), Africa (e.g., [Fa et al., 1995; Svensson & Friant, 2014]), and Central and South America (e.g., [Ceballos-Mago et al., 2010; Duarte-Quiroga & Estrada, 2003; Shanee, 2012]). Only two studies [Reuter & Schaefer in press; Reuter et al., 2015] have investigated the incidence of illegal captive primates in Madagascar.

Madagascar is a priority for primate conservation and a biodiversity hotspot [Myers et al., 2000]. The country has 100% endemism at family, genera, and species levels and is home to the highest number of threatened primate taxa in any one country [Mittermeier et al., 2010; Myers et al., 2000]. Although it is illegal to capture, sell, and trade lemurs, the live capture and ownership of lemurs is ongoing [Reuter et al., 2015]. Lemurs are kept in captivity, generally in sub-par conditions [Reuter & Schaefer in press] as personal pets and as a source of income (tourists will pay to take feed or take photographs with lemurs; hotels and restaurants often keep lemurs as a "value added" attraction for clients [Reuter et al., 2015; Schwitzer et al., 2013]).

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Through face-to-face interviews of 1,053 informants in northern and central Madagascar, Reuter et al. [2015] estimated that over 28,000 lemurs were illegally kept in captivity in urban areas of Madagascar from 2010 to mid-2013. The researchers also found that lemur ownership was widespread and affected a variety of taxa, though the study was not able to determine which species was most impacted. The live capture of lemurs was not highly organized; individuals tended to capture their own lemurs (46% of owners) though sample sizes were too small to determine how this varied by species or geographic area.

While it is clear that there are other threats facing lemurs (e.g., habitat degradation, deforestation, and hunting [Mittermeier et al., 2010]), the evidence from Reuter et al. [2015] suggests that the illegal live capture of lemurs presents a larger threat than previously thought. Data are needed to inform conservation and policy initiatives, but they are prohibitive to collect on the ground without substantial resources. Therefore, we collected data remotely via an online survey and by examining hotel and restaurant websites and social media profiles. We present the results of our online data collection and discuss the costs/benefits of collecting sensitive data on the illegal ownership of lemurs online (in this study) versus in-person (in Reuter et al. [2015]). We aimed to increase understanding of: (objective 1) which species are most at risk and (objective 2) where they are most likely to be found. Where relevant, and to inform future data collection initiatives, we examined whether different survey respondents provided different types of information and compared online survey methods with field survey methods.

For the first objective, based on data indicating that diurnal lemurs living in groups are potentially more likely to be captured from the wild for illegal captivity [Reuter & Schaefer unpublished] we hypothesized that (1A) while many species could possibly be kept in captivity, a few species would be disproportionately affected. For the second objective, we hypothesized that (2A) lemur ownership would be reported across the country in at least half of the country's 22 regions, as seen in Reuter et al. [2015]. Due to the potential link between tourism and lemur ownership [Schwitzer et al., 2013] we hypothesized that (2B) more captive lemurs would be reported in popular tourist areas than in areas with fewer tourists. Based on Reuter et al. [2015], which found that more owners of captive lemurs were found in cities (100% of current or former owners) than in villages (0%) but that larger cities were not more likely than smaller cities to have captive lemurs, we hypothesized that (2C) most records of lemur ownership would be from urban areas but that (2D) the number of captive lemurs observed was not correlated with the population of a town. Finally, given that captive lemurs are rarely moved on public transport [Reuter et al., 2015] and with no anecdotal information to suggest otherwise, we hypothesized that (2E) lemurs would be observed most often in areas and towns near their habitat ranges.

METHODS

Online Survey

We collected data from the public (January–June 2015) via a web-based survey in compliance with the University of Utah's Institutional Review Board (IRB). This research adhered to the American Society of Primatologists principles for the ethical treatment of primates and followed all relevant legal requirements for the collection of information from adult populations. The survey contained 14 questions (see supplementary materials) asking for details about captive lemurs observed by respondents (e.g., when, where, how many seen, species identification, captive environment). Some response choices were provided, though respondents could elaborate via several open-ended questions. Surveys were available in English and French and were designed to take less than 5 min to complete. Surveys were not available in Malagasy because there are over 19 different Malagasy dialects and it would have been difficult to translate accurately questions into each dialect without changing the meaning of questions (subtle changes in the phrasing of a question can affect survey respondent interpretation, Bradburn & Sudman [1979]). Respondents could leave any question unanswered.

We used direct email recruitment to inform researchers and conservation managers about the project and listservs and social media to collect data from the public. We contacted researchers who had worked across Madagascar's 22 administrative regions to decrease geographic bias. More information about recruitment strategies can be found in the supplementary materials.

Websites and Social Media Profiles of Hotels and Restaurants

We viewed websites and social media profiles of 171 hotels (in 33 towns across 16 regions) and 43 restaurants (8 towns across 7 regions) across Madagascar (January–March 2015). The distribution of hotels and restaurants surveyed can be seen in Figure S1. More information regarding this online search can be found in the supplementary materials. From these websites and social media profiles, we recorded whether images of captive lemurs were shown and the number and species of lemur(s) pictured. Eligible pictures needed to show a restrained lemur (e.g., in a cage) or suggest that human-lemur contact would be possible at the

establishment. Photographs were excluded when captions indicated that the human-lemur contact was not taking place at the hotel.

Definition of a Captive Lemur

We aimed to examine a wide range of domestic, captive, and pet ownership settings of lemurs (referred to as "captive lemurs") including lemurs removed from natural habitats, relying on humans for food, or with an apparent human owner. Survey respondents were not provided with a definition for a captive lemur specifically to solicit a wide range of responses. We acknowledge that our definition includes lemurs that are kept for a variety of reasons, and that the primary motivation for ownership of these lemurs might not always be companionship. However, given that many lemurs in Madagascar are kept in a variety of captive conditions [Reuter & Schaefer in press] for multiple reasons that are not mutually exclusive [Reuter & Schaefer unpublished], and given that the respondents were not usually the owners of captive lemurs (and were therefore inferring the primary motivation for ownership), we did not disaggregate the data to differentiate between different types of owners.

Analysis

Individuals are treated as replicates when data are presented as percentages. In statistical tests, either individuals or towns ($n = 52$) are used as replicates, depending on sample size. Means show averages with $\pm 95\%$ confidence intervals.

To determine which species were most common in captivity, we summed the number of individuals observed by species. In many cases, respondents provided common and/or scientific names. We did not assign a species identification to a record if the information was not provided by the respondent (e.g., a photograph or scientific/common name). We classified all lemurs identified by respondents as "common brown lemurs" as *Eulemur fulvus* and all lemurs identified by respondents as "brown lemurs" as *Eulemur spp*. (i.e., in the *Eulemur* genus but without a species identification). "Common brown lemur" is sometimes used interchangeably to denote the *Eulemur* genus more broadly (e.g., Primate Info Net Primate Factsheet *Eulemur* [2013]), so some *E. fulvus* observations may actually have been of other *Eulemur sp*. A Pearson χ^2 Test was used to test hypothesis whether different types of respondents differed in their to ability to provide the scientific or common name for the lemur observed.

To determine whether lemur ownership was geographically widespread, we examined the number of lemurs seen in each region of Madagascar. We aggregated data to protect anonymity by summing the number of lemurs reported in each region; data are not scaled or presented in relative terms. We made efforts to sample evenly across Madagascar (see Supplementary Materials). We used linear regressions and a Mixed Effects Model (with regions as a random effect) to test hypothesis (2B). Data for the number of hotel rooms as well as the total number of hotels per province were taken from Christie & Cromption [2003]; these were treated as a proxy for the popularity of a province with tourists.

To determine whether lemurs were seen in urban or rural areas, we analyzed the location data provided by web-based respondents. All towns named by respondents had been classified as urban in the ILO Project [2003] census. In contrast, some respondents stated that captive lemurs were seen in "rural" or "small villages"; we classified these records as rural. We used linear regressions to test hypothesis (2D). We used a Pearson χ^2 Test to test hypothesis (2E).

It is possible that double counting occurred (e.g., see results for Hypothesis 2D). For example: (i) three records (of 302 sightings of lemurs) involved reports of the same species of lemur at the same hotel, however they were reported for different years (time periods of 9, 11, and 14 months between the different observations); and (ii) one respondent reported seeing lemurs at a hotel which was also included in our search of hotel websites (and the hotel did feature images of captive lemurs on its website). In all cases where double counting could have occurred, there was not enough information to be certain that the same individual lemur was recorded twice in our dataset. Therefore, and given that this affected few records, we did not delete these records from our dataset and did not otherwise compensate for double counting. Undercounting may also have occurred, as respondents may not have observed all of the captive lemurs in one location and hotel websites may not have shown all lemurs kept in captivity.

RESULTS

Sampling

Web-based survey

Data were collected via an online survey (www.petlemur.com); ~229 individuals (199 unique IP addresses; ~30 via email) submitted information to the study. We received information about 685 individual lemurs kept in captivity from 302 different sightings (respondents often reported several lemurs being kept captive by one owner and specified the number of individuals from different taxa that were seen; when this was not specified, we assumed one lemur per species was seen). Four submissions were excluded for providing general information rather than a specific sighting of a captive lemur.

The 302 sightings of captive lemurs in Madagascar were reported by researchers (40% of the time), people

who lived in Madagascar full-time or were Malagasy (28%), tourists (8%), business travelers (5%), and foreign exchange students (4%). Most sightings of captive lemurs were reported by people who had spent more than 1 year in the country (55%, including Malagasy people), though some respondents had spent between 3 and 12 months (15%), 1–3 months (13%), and less than 1 month (7%) in the country. The proportion of lemur sightings reported by respondents living in Madagascar differed across the six provinces of Madagascar (Regression, $n = 52, R^2 = 0.27, P = 0.01$, towns as replicates) while the proportion of sightings submitted by researchers did not (Regression, $n = 52$, $R^2 = 0.16$, $P = 0.14$, towns as replicates).

Hotels and restaurants

Out of 171 hotels (across 16 regions), 25 hotels ($15 \pm 13\%$) (regions as replicates) depicted captive lemurs on their websites or social media pages in such a way that insinuated ownership. None of the 43 restaurants (7 regions) did so. The 25 hotels showed images of 55 captive lemurs; we identified lemurs as being different individuals when they were of different species and/or when multiple individuals of the same species were featured in one photograph. Therefore, this is likely a conservative estimate.

Lemur Species Kept in Captivity

Of the 302 sightings of captive lemurs reported by web-based respondents, 257 records (85%) could be identified to genus; we cross-referenced 75 of these records with images/videos provided by the respondent. Except for one instance, the species identification provided by the respondent matched with the species pictured. These 257 records described 584 individual lemurs and spanned 10 genera and 30 species. One respondent reported seeing a hybrid (likely a cross between *E. rufifrons* and *E. albifrons* based on a photograph). The 25 hotels kept species from 6 genera and 14 species (100% of individuals were identified to the genus). One hotel appeared to keep a hybrid lemur (likely a cross of *E. macaco* with another *Eulemur sp.*). In support of hypothesis (1A), a wide range of species were seen in captivity though a few species were disproportionately affected (Table I). The top three species of lemurs reported in the web-based survey were *Lemur catta*, *Varecia variegata*, and *E. fulvus*, while the top three in hotels were *E. macaco*, *E. coronatus*, and *Propithecus verreauxi*. Researchers were more likely (93% of the time) than other respondents (80% of the time) to provide some kind of species identification (Pearson χ^2 Test, $n = 302$, DF = 1, $P = 0.0025$).

Geographic/Regional Distribution

In accordance with hypothesis (2A), lemur ownership was geographically widespread across Madagascar (Fig. 1). Captive lemurs were reported by survey respondents in 19 of the 22 regions in all 6 provinces. There was mixed support for hypothesis (2B). The total number of lemurs seen did not differ by province (Regression, $n = 52$, $R^2 = 0.10$, $P = 0.41$, towns as replicates) nor did the total number of different reports of captive lemur sightings (Regression, $n = 52$, $R^2 = 0.13$, $P = 0.25$, towns as replicates). In contrast with hypothesis (2B), the total number of lemurs seen in a province did not differ by the number of hotel rooms (Mixed Effects Model, $n = 51$, $R^2 = -0.11$, $P = 0.92$, regions as a random effect, towns as replicates) or the total number of hotels (Mixed Effects Model, $n = 51$, $R^2 = -0.09$, $P = 0.87$, regions as a random effect, towns as replicates) in the province, nor did the number of reports of lemur sightings (number of hotel rooms: $R^2 = -0.05$, $P = 0.80$; number of hotels: $R^2 = -0.04$, $P = 0.74$). The top three regions in which captive lemurs were reported were Atsimo-Andrefana (20% of the 740 lemurs reported by survey respondents and on hotel websites), Alaotra-Mangoro (14%), and Diana (12%).

In accordance with hypothesis (2C), most captive lemurs were seen in urban areas (65% of $N = 302$ records). These urban areas included 52 towns with human populations ranging from 3,000 to 1,054,649 people [ILO Project, 2003]. Few lemurs (8%) were reported from rural areas. Remaining records ($N = 82$) did not provide enough information to determine whether the lemur was seen in urban or rural areas. There was mixed support for hypothesis (2D); among urban towns, the total number of individual lemurs seen by respondents did not differ by the human population size (Regression, $n = 48$, $R^2 = 0.03$, $P = 0.2258$) though the number of reports increased as the size of a town increased (Regression, $n = 48$, $R^2 = 0.09$, $P = 0.0352$).

In accordance with hypothesis (2E), all of the species most commonly observed (top three in the web-based survey and in hotels) were kept in captivity near their natural habitat ranges (Fig. S2). However, in contrast to hypothesis (2E) there is evidence that these species also were moved considerable distances from their natural habitat ranges (Fig. 2). Four of the six species were found in regions that did not overlap with their habitat ranges: *E. fulvus*, *E. macaco*, *L. catta*, and *V. variegata* were found in six, one, six, and two regions, respectively that did not overlap with their habitat ranges, (Fig. S2). These species differed in the proportion of individuals that were reported in regions inside versus outside their range (Pearson χ^2 Test, $n = 226$, df = 3, $P < 0.0001$); 53% of *E. fulvus* were seen in regions that did not overlap with their habitat ranges (less than 20% for the other three species).

TABLE I. Lemur Species Kept in Captivity as Seen by Respondents (Web-Based Survey) and as Observed on Hotel Websites and Social Media Pages

	Web-based survey		Hotels		
	N	*%N*	*N*	*%N*	*%H*
Eulemur spp.	218	37	33	60	5 ± 5
E. albifrons	19	3			
E. cinereiceps	3	<1			
E. collaris	11	2			
E. coronatus	32	5	8	15	<1 ± 1
E. flavifrons	2	<1	3	5	<1 ± <1
E. fulvus	59	10	2	4	<1 ± 1
E. macaco	9	2	12	22	<1 ± 2
E. mongoz	1	<1			
E. rubriventer	3	<1			
E. rufifrons	4	<1	3	5	1 ± 2
E. rufus	12	2	1	2	<1 ± 1
E. sanfordi	4	<1	4	7	<1 ± <1
Unidentified *Eulemur* spp.	59	10			
Cheirogaleus spp.					
Unidentified *Cheirogaleus* spp.	9	2			
Hapalemur spp.	53	9	2	4	<1 ± <1
H. alaotrensis	4	<1			
H. griseus	11	2	2	4	<1 ± <1
H. meridionalis	1	<1			
H. occidentalis	2	<1			
Unidentified *Hapalemur* spp.	35	6			
Indri indri	12	2			
Lemur catta	165	28	4	7	2 ± 2
Lepilemur spp.	4	<1			
L. ankarenensis	1	<1			
Unidentified *Lepilemur* spp.	3	<1			
Microcebus spp.	31	5	1	2	<1 ± <1
M. murinus	1	<1			
M. myoxinus	3	<1			
Unidentified *Microcebus* spp.	27	5			
Prolemur simus	1	<1			
Propithecus spp.	24	4	9	16	8 ± 12
P. coronatus			1	2	<1 ± 1
P. coquereli	2	<1	1	2	
P. deckenii			1	2	<1 ± 1
P. diadema	2	<1			
P. verreauxi			6	11	7 ± 12
Unidentified *Propithecus* spp.	20	3			
Varecia spp.	66	11	5	9	<1 ± 1
V. rubra	1	<1			
V. variegata	60	10	5	9	<1 ± 1
Unidentified *Varecia* spp.	5	<1			
All individuals identified to the genus	584	—	55	—	15 ± 13

N, sample size; *%N*, percent of individuals seen of that species; *%H*, percent of hotels keeping species in captivity, regions as replicates.

DISCUSSION

Comparison of Findings

The results of the online survey are largely in agreement Reuter et al. [2015]. First, in the current study, 30 species were reported in captivity (10 genera, four out of five families represented), including all species reported in Reuter et al. [2015] (14 species from 8 genera except *Avahi laniger*). In addition, some species (e.g., *Lepilemur dorsalis*; *Daubentonia madagascarensis*) were not reported in either study. Second, both studies suggest that a few species are disproportionately impacted by illegal captivity in Madagascar. Although 30 species of lemurs were observed in captivity, six species comprised almost half of the individuals kept in captivity (*E. coronatus*, *E. fulvus*, *E. macaco*, *L. catta*, *P. verreauxi*, and *V. variegata*) and five of these six species were in the family Lemuridae, supporting the anecdotal results in Reuter et al. [2015]. Third, both

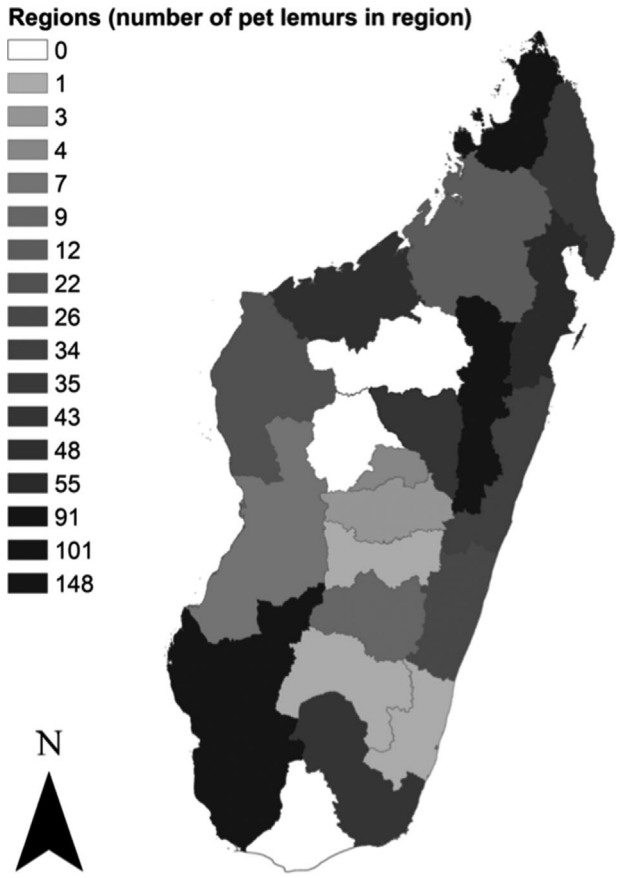

Fig. 1. Regions in which captive lemurs were seen, showing data from survey respondents and from hotel websites and social media sites. Numbers of captive lemurs per region are the summed numbers of individual lemurs seen in web-based surveys and in hotels; numbers are not scaled. Data are aggregated to the 22 regions in Madagascar.

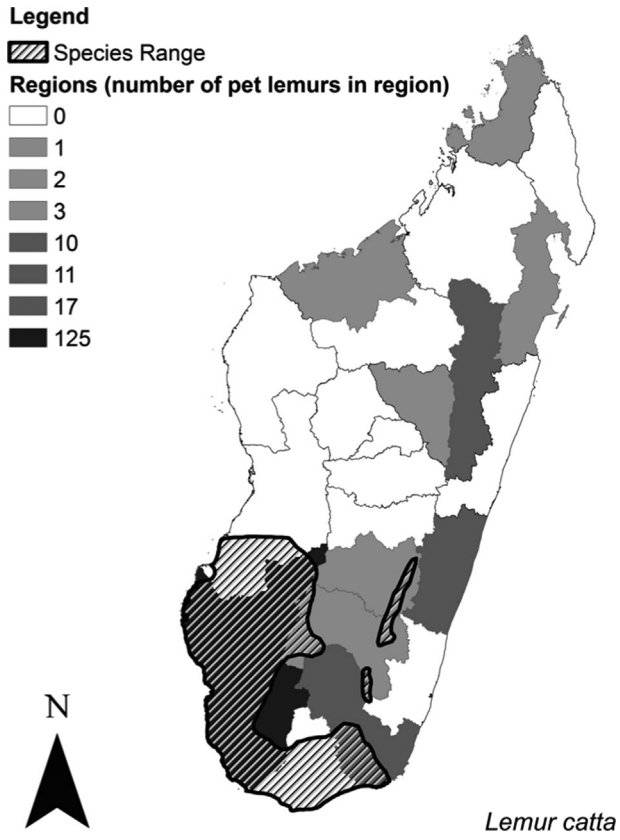

Fig. 2. Map of the regions in which *Lemur catta* were seen by respondents. Species ranges are indicate by black hash marks. Regions in which *L. catta* was observed in captivity are shaded in gray with darker gray indicating a higher number of individuals observed in captivity. Similar maps for other commonly observed species can be found in Figure S2.

studies show that illegal captive ownership of lemurs occurs across the country. Combining the data presented here and in Reuter et al. [2015], there are only two regions in Madagascar where no captive lemur observations were recorded (Bongolava and Androy). Finally, as found by Reuter et al. [2015], most lemurs reported by web-based respondents were in urban areas.

This current study moves beyond the Reuter et al. [2015] in several important ways. First, it is the first to estimate the proportion of hotels keeping lemurs in captivity. We found that $15 \pm 13\%$ of hotels kept captive lemurs though additional research is needed to understand how this varies by region, by hotel clientele (e.g., foreign vs. domestic visitors), and across hotels without an online presence. Second, this study estimated the relative impact of the illegal ownership of lemurs for the first time, with *Lemur catta* mentioned in 28% of all reported sightings. Third, this is the first nation-wide study of illegal captive lemurs and provides insight into which regions could be considered "hotspots" for illegal captive lemurs.

Comparison of Methods

Both in-person and web-based data collection can achieve relatively high sample sizes across a wide geographic region (Table II). Reuter et al. [2015] used face-to-face interviews to sample 1,093 Malagasy households in 10 cities and seven villages across three regions in northern and central Madagascar; 305 of these households had seen a captive lemur across 18 regions. Via the web-based survey, we collected data from 229 individuals (typically long-term visitors to Madagascar) who had seen lemurs in 52 cities and several villages across 19 regions.

There are advantages and disadvantages of taking a virtual approach to data collection. First, the geographic boundaries imposed on in-person data collection due to resource limitations make online data collection useful when geographically widespread data need to be collected (captive lemurs are found across the country, Fig. 1). We were interested in understanding whether there were regions in Madagascar where the ownership of captive lemurs was proportionally more common and our online approach was successful in providing

TABLE II. Comparison of Resources Required and Data That Was Successfully Collected by Method (in Person vs. Web-Based Data Collection)

	In-person data collection [Reuter et al., 2015]	Web-based data collection (this study)
Resources required		
Time for data collection (months)	3	6
Number of people directly collecting data	8	2
Cost for data collection (US$)	12,000	100
Data collected		
Number of sightings of captive lemurs	305	229
Number of species observed (out of ~106)	14	30
Number of regions in which lemurs observed (out of 22)	18	19

a preliminary answer to this question (Fig. 1). In comparison, while Reuter et al. [2015] evidenced that captive lemur ownership was a nation-wide issue (Table II), the emphasis on data collection in northern Madagascar precluded understanding the relative popularity of captive lemurs in different regions of the country. Based on data from Reuter et al. [2015] one would conclude that captive lemurs are most common in the north, whereas based on the nation-wide sample it is clear that there are several "hotspots" across the country where lemurs are most often kept as pets (Fig. 1).

Second, online sampling can help target key informants (individuals with firsthand knowledge or expertise; see Methods and Supplementary Materials) while the on-site survey protocols used in Reuter et al. [2015] make it difficult to a priori identify these individuals (especially given the illegal nature of captive lemur ownership). For example, in part because our online sampling targeted both researchers and the public, twice as many species were identified as in Reuter et al. [2015] where respondents (heads of households, randomly selected) could not typically identify the species that they had seen (Table II). The lack of respondent ability to identify captive lemurs to the species meant that Reuter et al. [2015] could not ascertain the proportional threat of illegal ownership for different species. For example, while the few respondents in Reuter et al. [2015] who could identify a lemur ($N = 19$) to the species most often reported *L. catta* (58%, perhaps because it is such a recognizable species), in the current study, we show that 28% of all observations of lemurs submitted via the web-based survey identified this species. The ability to understand which species are proportionately more affected than others is important for targeting future studies and management actions; in this case, targeting surveys at researchers as well as the general public facilitated collection of data that could inform conservation initiatives.

Third, the costs and speed of data collection differ between the two data collection methods. Costs for online data collection were substantially lower than costs for in-person data collection though, depending on recruitment methodologies, online data collection may not lead to results as quickly as the face-to-face interview process (Table II). Data collection through the website is on-going (www.petlemur.com) but responses have slowed substantially following the website's launch (78% of data were collected in first 3 months of the online project). Therefore, after 6 months of data collection, our original goal of surveying the same number of people as interviewed by Reuter et al. [2015] had not been realized. This highlights one the disadvantage of the online surveys: the need to recruit people without face-to-face interaction, which may not be as effective.

Fourth, in the context of collecting data about the illegal ownership of lemurs, online data collection initiatives provide a level of anonymity that face-to-face surveys lack. Respondents may be reluctant to provide accurate information when surveyed face-to-face regarding illegal activities [Nuno et al., 2013]. Innovative methods to decrease respondent discomfort have had mixed success. For example, the use of a randomized response technique to collect data on illegal bushmeat consumption in Madagascar confused many participants and ~16% of surveys were later excluded [Razafimanahaka et al., 2012]. In contrast, anonymous online surveys can increase respondent comfort by: (i) allowing respondents to provide data in a way that does not identify them as a participant (e.g., they are not seen talking to researchers); (ii) decreasing bias introduced by researchers who might consciously or subconsciously send verbal and non-verbal cues to respondents; (iii) and providing respondents with greater flexibility to participate at a time and place of their choosing. Regarding the collection of data from business websites and social media pages: this is a cost-effective (but perhaps incomplete) method for surveying hundreds of establishments that might not disclose their ownership of captive lemurs if approached in-person.

Finally, recruitment methods can bias results [Szolnoki & Hoffmann, 2013] but reporting

aggregated demographic information can help highlight where bias might exist. For example, 40% of the respondents to the online survey were (often foreign) researchers (see Supplementary Materials) while all of the respondents in the Reuter et al. [2015] face-to-face interviews were members of the Malagasy general public. This demographic information provides context for the results; in this study, it clearly explains why a broader range of species were identified in captivity than in Reuter et al. [2015]. However, this is likely to have resulted in areas near study sites (such as national parks) being overrepresented (the three top regions in which 44% of captive lemurs were observed are home to three of the five most-visited national parks [Christie & Cromption, 2003]). Of course the online survey has the potential of underrepresenting rural areas where access to the Internet may be limited; this is a clear strength of on-location fieldwork. Rural or less affluent areas were underrepresented in the current study because our survey did not offer a Malagasy-language option. Future studies in Madagascar should consider how to best collect data using the various Malagasy dialects, given that the level of "intelligibility" of Official Malagasy can vary from 0% to 73.8% in rural and non-centralized urban areas [Bouwer, 2007].

Future Directions

Svensson & Friant [2014] observed that the peer-reviewed literature on the hunting and capture of African lorises did not accurately reflect the magnitude and scope of the trade (compared to information collected from researchers in the field). Similarly, virtually nothing regarding the captive lemur trade in Madagascar can be found in the literature (although lemurs have been kept in captivity since the 1960s if not earlier [Reuter et al., 2015]). Many observations of captive lemurs are not reported, perhaps because they are too anecdotal; hundreds of researchers reported captive lemurs that they had seen via our survey, but only a few publications mention captive lemurs. This may be part of the reason why the pet trade in Madagascar has been described as not being a threat to lemurs [Mittermeier et al., 2010]. In the future, an increased level of reporting, even of anecdotal information and the expansion of both online and in person surveys, could substantially improve our understanding of this issue and result in increased funding for conservation programming.

Increased reporting could fill several gaps in knowledge about the illegal ownership of lemurs in Madagascar. Research is needed to understand how large the threat of illegal captivity is compared to deforestation or climate change (e.g., [Brown & Yoder, 2015; Mittermeier et al., 2010]). Four of the six lemur species commonly kept in captivity are predicted to experience range contractions due to climate change within the next 70 years (losing 46.7–99.6% of their habitat; [Brown & Yoder, 2015]) and all have decreasing population sizes [IUCN, 2013]. This is especially critical for ring-tailed lemurs—the most commonly observed species of captive lemur—as they are considered a flagship species in Madagascar. Research on whether juveniles or reproducing females are preferentially removed from the wild is needed. In other countries, infant primates are commonly found in wildlife markets, where mothers are typically killed to obtain the infant [Nekaris et al., 2010; Nijman, 2005; Nijman et al., 2008; Shanee, 2012; Shepherd, 2010; Shepherd et al., 2005; Todd, 2008; Webber & Nekaris, 2004]. Such targeted extraction, if also present for captive lemurs, has consequences for the viability of threatened populations (removal of primates from the wild can disrupt the age and sex structure of wild populations (e.g., [Ceballos-Mago et al., 2010]) and implications for reintroduction programs. In addition, the motivations of captive lemur ownership are unclear though captive lemurs have been observed as both personal pets and at commercial establishments.

Future studies could more directly compare the trade-offs between the data collection methods by simultaneously undertaking both types of data collection. Alternatively, hybrid approaches (e.g., where on-the-ground outreach is used to recruit participants into an online survey) could also be tested. It is notable that the online data collection could, conceivably, allow for more cost-effective longitudinal studies over time, though this would likely require significant investments in ongoing recruitment strategies. There is space in more traditional data collection protocols for online surveys and we found that a wide range of people felt comfortable providing detailed information, anonymously, about illegal activities online. Both data collection methods had advantages and therefore complemented each other in terms of cross-validating findings and filling methodological gaps.

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