Are Social Media Reports Useful For Assessing Small Ape Occurrence? A Pilot Study From Peninsular Malaysia

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NEW APPROACHES

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Are social media reports useful for assessing small ape occurrence? A pilot study from Peninsular Malaysia

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Abstract

Citizen science-based research has been used effectively to estimate animal abundance and breeding patterns, to monitor animal movement, and for biodiversity conservation and education. Here, we evaluate the feasibility of using social media observations to assess the distribution of small apes in Peninsular Malaysia. We searched for reports of small ape observations in Peninsular Malaysia on social media (e.g., blogs, Facebook, Instagram, Twitter, YouTube, iNaturalist, etc.), and also used online, radio, print messaging, and word of mouth to invite citizen scientists such as birders, amateur naturalists, hikers, and other members of the public to provide information about small ape observations made during their activities. These reports provided new information about the occurrence of all three species of small apes (*Hylobates agilis*, *Hylobates lar*, and *Symphalangus syndactylus*) in Peninsular Malaysia. Social media users reported observations of small apes in almost every state. Despite the fact that small apes are believed to occur primarily in the interior of large forested areas, most observations were from fairly small (<100 km^2) forests near areas of high traffic and high human population (roads and urban areas). This suggests that most outdoor enthusiasts primarily visit well-traveled and easily accessible areas, which results in biased sampling if only incidental observations reported on social media are used. A more targeted approach specifically soliciting reports from citizen scientists visiting large, less-accessible forests may result in better sampling in these habitats. Social media reports indicated the presence of small apes in at least six habitats where they had not been previously reported. We verified the reported data based on whether reports included a date, location, and uploaded photographs, videos and/or audio recordings. Well-publicized citizen science programs may also build awareness and enthusiasm about the conservation of vulnerable wildlife species.

KEYWORDS

gibbons, hylobatidae, passive citizen scientist, Peninsular Malaysia, small apes, social media

1 | INTRODUCTION

Research on the distribution of wild animals across large geographic areas that use direct observations by scientists can require enormous time and resource investments (Bonney et al., 2009). However, this problem can sometimes be worked around by enlisting members of the public to gather scientific information, a practice broadly referred to as "citizen science" (Bhattacharjee, 2005; Dickinson, Zuckerberg, &

Bonter, 2010; Horns, Adler, & Şekercioğlu, 2018a; Kullenberg & Kasperowski, 2016). The specific meaning, practice, and value of citizen science can differ significantly across academic disciplines. For example, one thread of citizen science research focuses on the democratization of science as an enterprise (Kullenberg & Kasperowski, 2016). In conservation biology, however, the emphasis has been on practical applications (Theobald et al., 2015) and here, citizen science is usually defined as activities that engage the public or stakeholders in research design, data collection, or interpretation together with scientists (Paul et al., 2018). Online citizen science research engages volunteers from various backgrounds in collecting data about species occurrence and ecology and reporting them online (Cooper, Dickinson, Phillips, & Bonney, 2007; Devictor, Whittaker, & Beltrame, 2010; Dickinson et al., 2010; Donnelly, Crowe, Regan, Begley, & Caffarra, 2014; Liberatore, Bowkett, MacLeod, Spurr, & Longnecker, 2018). This type of research can be effective in coordinating networks of local stakeholders, including members of the general public, to monitor biodiversity, leading to improved outcomes, and greater buy-in by local communities (Donnelly et al., 2014; McKinley et al., 2017).

Recent research suggests that data from citizen scientists can be used effectively for analyses of animal distribution. For example, Wang et al. (2018) used a combination of museum and online citizen science data to build reliable distribution maps for northern black widow spiders (*Latrodectus variolus*) and black purse-web spiders (*Sphodros niger*). Similarly, Schuttler et al. (2019) used camera trap data collected by children as young as 9 years old to obtain reliable mammal species occurrence data near schools in four countries. Horns et al. (2018a) determined that estimates of population trends derived from eBird (an online repository for bird count data contributed by amateur birders) records differed little from those based on formal surveys, particularly for widespread species (but see Fogarty, Wohlfeil, & Fleishman, 2018; Horns, Adler, & Şekercioğlu, 2018b).

Three species of small apes (Hylobatidae), occur in Peninsular Malaysia (*Hylobates agilis*, *Hylobates lar*, and *Symphalangus syndactylus*). All three are listed as Endangered in the IUCN Red List (Brockelman & Geissmann, 2008; Geissmann & Nijman, 2008; Nijman & Geissmann, 2008), but their current status, distribution, and abundance in Peninsular Malaysia are not well understood, which creates challenges in conservation planning (Geissmann, 2007; O'Brien, Kinnaird, Nurcahyo, Iqbal, & Rusmanto, 2004). Small apes prefer closed-canopy forests spanning a range of elevations from 0 to >2,000 m above sea level (O'Brien et al., 2004). *H. lar* (the white-handed gibbon or lar gibbon) is geographically distributed in two discrete regions in Peninsular Malaysia. It occurs in most of the south of Peninsular Malaysia and also in a small part of the northern peninsula, in Kedah and Perlis, and across the Thai border and beyond. Thus, *H. lar* occurs across almost all states in Peninsular Malaysia, except certain parts of Kedah and Kelantan (Brockelman & Geissmann, 2008). *H. agilis* (the agile gibbon or black-handed gibbon) is distributed in a band across the north of Peninsular Malaysia (most of Kedah and Kelantan), which separates the two distribution areas of *H. lar* (Geissmann & Nijman, 2008). *S. syndactylus* (the siamang) is sympatric with *H. lar* over much of Peninsular Malaysia (in small parts in Kelantan and Perak and most of Pahang, Terengganu, and Selangor; Nijman & Geissmann, 2008). There is little evidence of sympatry between the *S. syndactylus* and *H. agilis* (Gittins & Raemaekers, 1980), but their distributions may overlap in small parts of Royal Belum State Park and the Bintang Range (Geissmann & Nijman, 2008; Nijman & Geissmann, 2008).

Small apes live in small family groups (2–6 individuals) and are highly arboreal and territorial (Bartlett, 2011; Cheyne, Capilla, Cahyaningrum, & Smith, 2019; Chivers, 2005). They tend to flee from human observers, which makes direct observational surveys of small apes difficult. However, small apes produce loud and distinctive calls, which can be detected from ≥1 km away in the forest (Brockelman & Ali, 1987; Buckley, Nekaris, & Husson, 2006; Gittins & Raemaekers, 1980). Therefore, either direct visual observations or detection of their vocalizations can be used to establish the presence of small apes in a landscape. Different species of small apes produce songs that can be readily distinguished by experienced observers. Therefore, it is often easier to identify species using vocalizations than during typically brief visual observations of fleeing animals.

In a long-term research project of which this study is a part of, our team has initiated field surveys in several forest reserves and protected areas in Peninsular Malaysia in 2017 to assess the current population status of small apes through vocal surveys and passive acoustic monitoring. However, given the size of the area and the very large number of habitat fragments in Peninsular Malaysia, it is not possible to directly survey each forest patch, and little scientific literature about the recent (since 1981) distribution of small apes in Peninsular Malaysia is available (see Marsh & Wilson, 1981). Therefore, we concurrently initiated a social media survey to identify locations where small apes have been recently sighted to add to our sketch of the current distribution of small apes in Peninsular Malaysia. We used reports sent to us directly in response to our solicitations, as well as information posted on social media by users that may have been unaware of our research. Using the data from these reports, we sought to confirm the occurrence of small apes in forest fragments that we are unable to directly survey because of resource limitations and to identify priority areas for future field surveys.

Gray literature reports from citizen scientists have been effectively deployed to assess the distribution of territorial hornbills in Malaysia (Yeap & Perumal, 2017), but the utility of this method for arboreal mammals, including primates, has yet to be demonstrated. There is reason for caution in applying this method to other taxa, as the quality of data may differ across taxa (Zhang, 2019). "Birding" is a popular pastime in many countries (Callaghan et al., 2018; Steven, Morrison, & Castley, 2014), including Malaysia (Orenstein et al., 2010), and there is a robust birding culture that promotes the sharing of information among birders (and competition among birders may take the form of posting of photographs of rare species). There does not appear to be an equivalent cohesive global "mammaling" or "primating" community (but see https://www.mammalwatching.com/ and https://www.primatewatching.com/). Nonetheless, Malaysia is home to networks of naturalists, birders,

hikers, and outdoor enthusiasts, many of whom routinely report their observations of wildlife that they find interesting, including primates, on social media platforms. Many of these reports include documentation in the form of high-quality photographs or video/audio recordings with the date, place, and circumstances of the sightings. Local social media groups, such as the Malaysian Nature Society (MNS) Selangor Branch Mammal Group (https://www.facebook.com/groups/MammalGroup), and MNS Selangor Branch Bird Group (https://www.facebook.com/groups/sbbgbirdgroup), promote this kind of information sharing, and facilitate communication among members. Therefore, while the observers posting this information are motivated primarily by their desire to share their experiences with like-minded peers or to document their travel experiences, this material can also be viewed as a variant of citizen science. In this case, the observers (who we will subsequently refer to as "reporters") are enlisted as participants in the research only after making their initial reports.

TABLE 1 Small ape location reports by online platform

Online platforms	All reports	All reliable Reports
Online search (public uploads):		
(1) Blogs, travel websites, and nature and photography websites	69	36
(2) Facebook	28	24
(3) YouTube	12	11
(4) iNaturalist	46	42
Solicited Reports:		
(5) Personal messages on Facebook	20	4
(6) Emails to the authors	5	4
Total reports (nonredundant)	181[a]	121[a]

[a]One report included evidence of both *Symphalangus syndactylus* and *Hylobates lar*, so it was counted twice.

2 | DESCRIPTION OF APPROACH

To determine whether this type of passive citizen science is useful in mapping the distribution of small apes in Peninsular Malaysia, we searched from June 2017 to September 2019 for spontaneously generated social media posts. We examined the information presented in these posts, or elicited in follow-up communication with the reporter, to determine whether these reports are adequate in number, quality, and spatial coverage to form a useful supplement to planned surveys. We also sought to identify gaps and deficiencies in the use of this method to map small ape distributions in Peninsular Malaysia and to identify potential solutions for these problems. Starting in November 2017, we also actively solicited reports of small ape observations from citizen scientists to augment our sample, and to determine whether solicitations would result in additional reporting or higher report quality or coverage.

2.1 | Online search for social media reports

We searched for small ape sightings in online reports in social media platforms (Table 1) using keywords in English including the formal (and where different, common) names of forested areas in Peninsular Malaysia, including forest reserves, virgin jungle reserves, wildlife reserves, national parks, and state parks, together with the scientific or common names of the three small ape species found in Peninsular Malaysia. For example, for general searches, we used search terms "gibbon," "*Hylobates*," "siamang," and "*Symphalangus*." To search for small ape sightings in specific locations, such as Bukit Larut (or Maxwell's Hill, the English common name), we used the search terms: "Bukit Larut" + "gibbon" or "Maxwell's Hill" + "gibbon" or "Bukit Larut" + "*Hylobates agilis*." While Bahasa Malaysia is the national language of Malaysia, many languages are routinely used in online communication, including English, Bahasa Malaysia, several dialects of Chinese, and Tamil. We were not able to search exhaustively in each of these languages. However, the word "siamang" is identical in Bahasa Malaysia and English, and searches of the word "ungka" (the name for small apes in the form of Bahasa Malaysia commonly used in Peninsular Malaysia; small apes are also called "owa owa" and other terms in Sabah and Sarawak) only generated posts about captive or rehabilitant animals or posts from our own research team, which were not included in this study. We also did not include information from scientific journals, other published articles or online materials designed to promote tourism. We included all posts dating back to 2010.

We classified all reports as either "reliable" or "unreliable" (Table 1). We considered reports to be reliable only if they included all three of the following criteria: (a) information about the actual or approximate date of the observation or posting date; (b) location information (i.e., global positioning system [GPS] coordinates or a detailed description of the location); and (c) a photograph, audio recording, or video that allowed us to confirm the species identification. Where the location information provided was in the form of description rather than GPS coordinates, we used Google Earth to estimate the latitude and longitude. Where confirmation of the species identification was provided, but date or location information was missing, we attempted to contact the reporter to obtain this information. If this information was subsequently provided, we classified the report as a reliable report. Similarly, if a photograph or video showed an animal that was probably a small ape, but did not allow for definitive identification, we contacted the reporter and asked them if they could provide additional photographs, video, or audio recordings that would allow us to conclusively identify the taxon. When additional information was provided satisfying each of the criteria above, we classified the report as reliable. All other reports were classified as unreliable.

2.2 | Solicitation through public outreach

In addition to public social media uploads, we also solicited observations from birders, hikers, naturalists, or fieldworkers studying

other organisms in the forest (Table 1). These solicitations were made via a posting on our Facebook page (https://www.facebook.com/GibbonsOfMalaysia), an article in the print publication *Malaysian Naturalist* (Lappan et al., 2018), and in-person during conservation outreach events, including ca. 20 public lectures and outreach events and one local radio show (https://www.bfm.my/gibbon-a-chance). In these solicitations, we described our citizen science-based research and our survey work and invited readers and listeners to help by submitting their own sightings via email, posting them on iNaturalist under our project (https://www.inaturalist.org/projects/gibbons-of-peninsular-malaysia), tagging our project or team members on social media posts, or using private messages.

2.3 | Mapping small ape location records

We mapped the locations of all publicly uploaded and solicited small ape observations that we deemed reliable for each species in ESRI® ArcMap 10.3.1. We used a land cover map (ESA Climate Change Initiative—Land Cover led by UCLouvain, 2017) and DIVA-GIS maps of road locations (Hijmans et al., 2004) for further spatial analysis to examine the distribution of small ape sightings in different habitat types.

To determine whether the reports offered important new information about the distribution of small apes in Peninsular Malaysia, we performed two additional steps. First, we evaluated all scientific literature that we could locate (searching in English and Bahasa Malaysia) for records of small ape presence in each forest fragment reported in this study. Second, for areas where there were no previous reports of small ape presence in the scientific literature, we conducted an additional search using the name of the taxon and the name of the area as search terms to locate any species lists published by wildlife management authorities and tourism professionals to establish whether the presence of the species is common local knowledge that is readily accessible to scientists, despite the absence of formal scientific reports. Where we found no previous records of the taxon at a site where we received a reliable report, we designated that report as new information about the presence of the taxon in the site. Where we found previous records of a taxon at a site, but that record was from surveys conducted in or before 1999 (20 years before the current study period), we considered the report as new information about the persistence of the taxon in a landscape (but not a new report of its presence).

This approach may not adequately document the prior knowledge of local communities or the relevant wildlife authorities (e.g., the Department of Wildlife and National Parks Peninsular Malaysia [PERHILITAN] and the Forestry Department Peninsular Malaysia), but as the authorities do not share wildlife data with external researchers without a written application and a complex preapproval process necessitated by local protections, the use of social media to establish presence in these fragments provides a much less time-intensive (for researchers) and labor-intensive (for researchers and wildlife authorities) method for estimating species presence.

2.4 | Ethical statement

PERHILITAN granted us permission to conduct research on small apes in Peninsular Malaysia, and all research reported here was conducted in compliance with the laws of Malaysia and following the ASP Principles for Ethical Treatment of Non-Human Primates. During our outreach efforts, we cautioned citizen scientists to avoid exposing precise locations of small ape individuals or groups in communications visible to the public due to the vulnerability of small apes to poaching. We were careful to protect the privacy of reporters that contributed to the project. For these reasons, we have not deposited our raw data with links to specific posts or geographic information in a public repository, but summarized data with general locations can be made available upon reasonable request.

3 | EXAMPLE OF OUTCOMES

During the 27-month search period, we found 181 reports of small ape sightings from Peninsular Malaysia on social media, including 121 reports that we classified as reliable (Table 2). Since we started soliciting reports, we have received 25 additional direct reports from birders, amateur naturalists, and other citizen scientists via our project email, private emails to team members, and as Facebook private messages; however, 17 of these reports did not include audiovisual evidence and were therefore not classified as reliable or included in the subsequent analyses. All but three of the unreliable reports sent via email or personal messages were sent by reporters that had also produced ≥1 reliable report, demonstrating their ability to correctly identify gibbons. We, therefore, believe that these reports are likely to indicate the presence of small apes at the reported locations, although we followed our original criteria and classified them as unreliable here.

Social media reports included sightings of all three small ape species found in Peninsular Malaysia (Figure 1). The distribution of small ape sightings by citizen scientists spans much of the reported

TABLE 2 Small ape location reports by species

Small ape species	All reports	Reliable reports
Symphalangus syndactylus	62	57
Hylobates lar	65	42
Hylobates agilis	34	22
Species could not be identified	20	0
Total	181[a]	122

[a]One report included evidence of both *S. syndactylus* and *H. lar*, so it was counted twice.

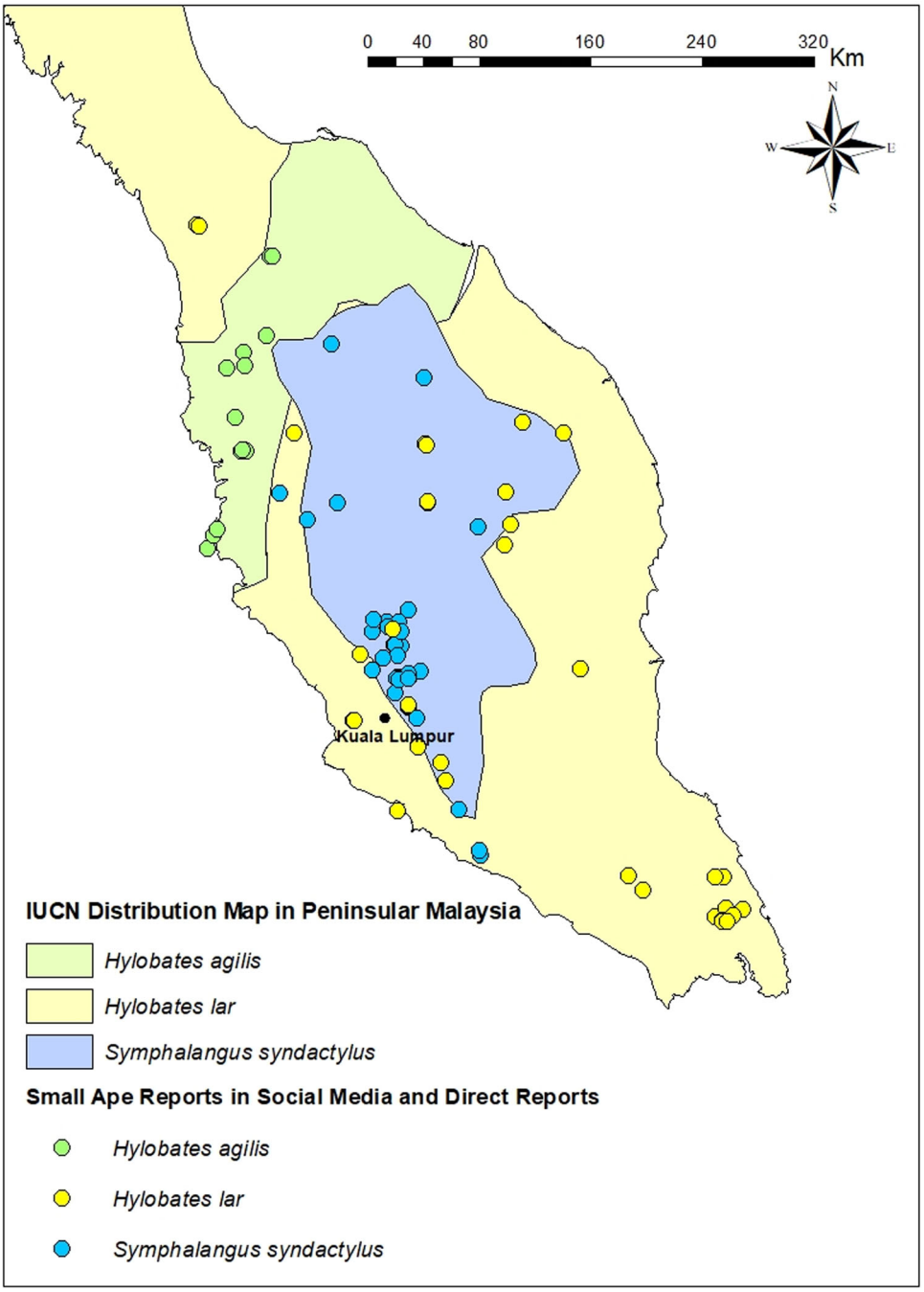

FIGURE 1 Small ape sightings reported in social media and solicited from citizen scientists mapped onto the estimated distribution maps for each taxon. Estimated distribution maps for each taxon were downloaded as shapefiles from the IUCN (https://www.iucnredlist.org/; Brockelman & Geissmann, 2008; Geissmann & Nijman, 2008; Nijman & Geissmann, 2008). A few observations by citizen scientists for *Symphalangus syndactylus* and *Hylobates agilis* were outside of the IUCN estimated distribution ranges. It is unclear whether these inconsistencies indicate location errors in the citizen science reports, or inaccuracies in the distribution maps

distribution range for *H. agilis*, *H. lar*, and *S. syndactylus*, with few reports falling outside of the expected ranges.

There were only a few reports from three large protected areas known to contain small apes, Royal Belum State Park ($N = 2$), Pahang National Park ($N = 2$), and Endau-Rompin National Park ($N = 3$), and only one of these reports, from Pahang, was reliable. No sighting was reported from Krau Wildlife Reserve, where small apes also persist, although there was one report from an adjacent forest reserve. Small ape sightings were heavily concentrated around areas of high human use or population (roads and urban areas) and were sparse in rural areas (Figure 2). Some *S. syndactylus* and *H. lar* observations were reported in tiny (<2 km^2) forest fragments near agricultural landscapes (Figure 3). Some sightings also originated from small (<20 km^2) forests near urban areas, including Ipoh and Kuala Lumpur.

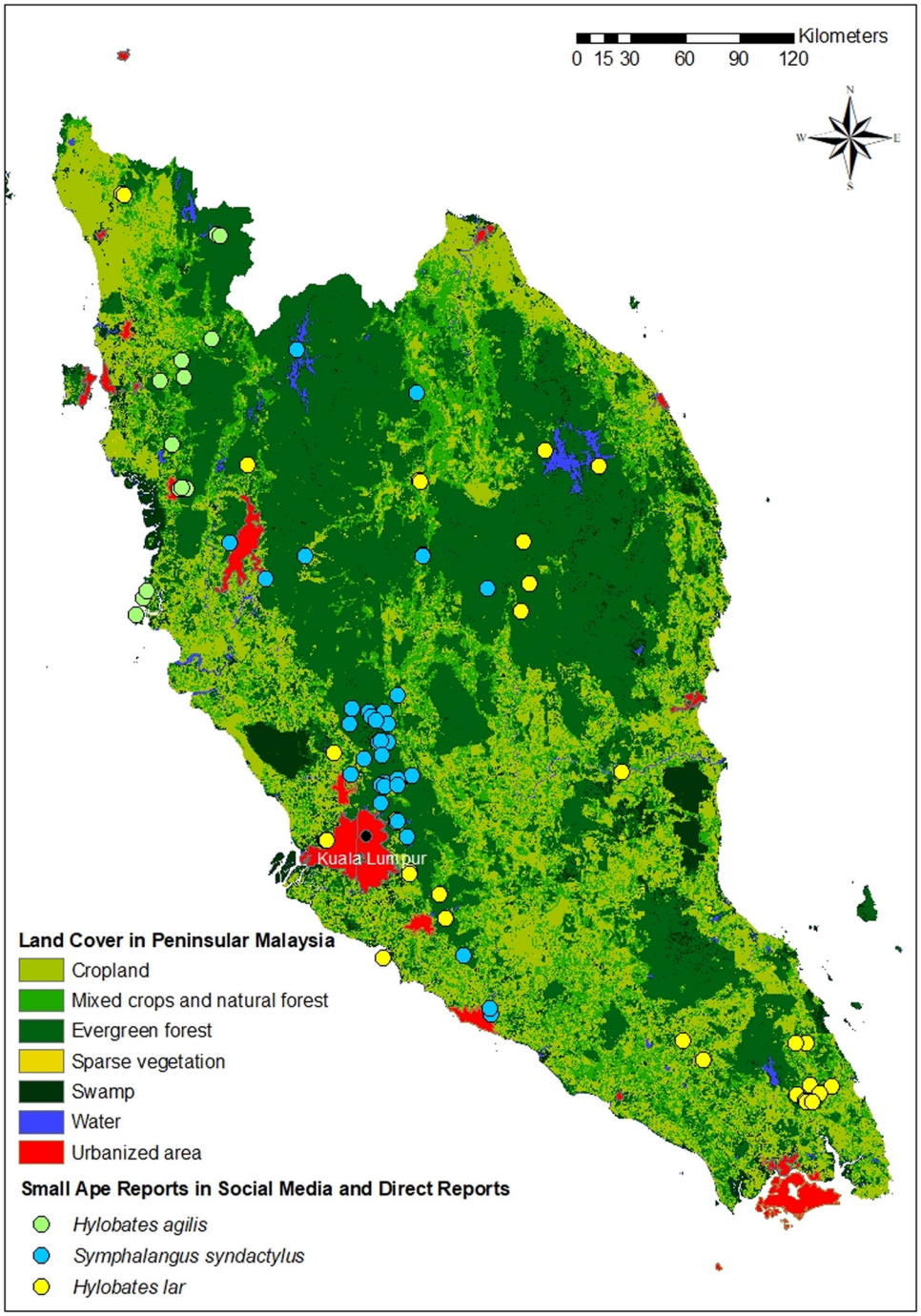

FIGURE 2 Land cover with small ape observations reported in social media or submitted directly by citizen scientists. Most sightings were inside forested areas near to roads for all three species of small apes

Furthermore, despite the fact that larger forest fragments and protected areas can support larger small ape populations, most reports represented sightings in small (<100 km^2) fragments, rather than larger (≥100 km^2) areas (Figure 3).

Social media reports documented the presence of small apes in at least six forests where their presence had not been previously reported by scientists (Figure 2). Social media reports also confirmed small ape presence in six sites where their presence was last reported at least 20 years ago (three sites in 1969, one in 1981, one in 1992, and one in 1999).

4 | COMPARISON AND CRITIQUE

Previous studies of other organisms have found that research using data from citizen scientists produced results that were comparable

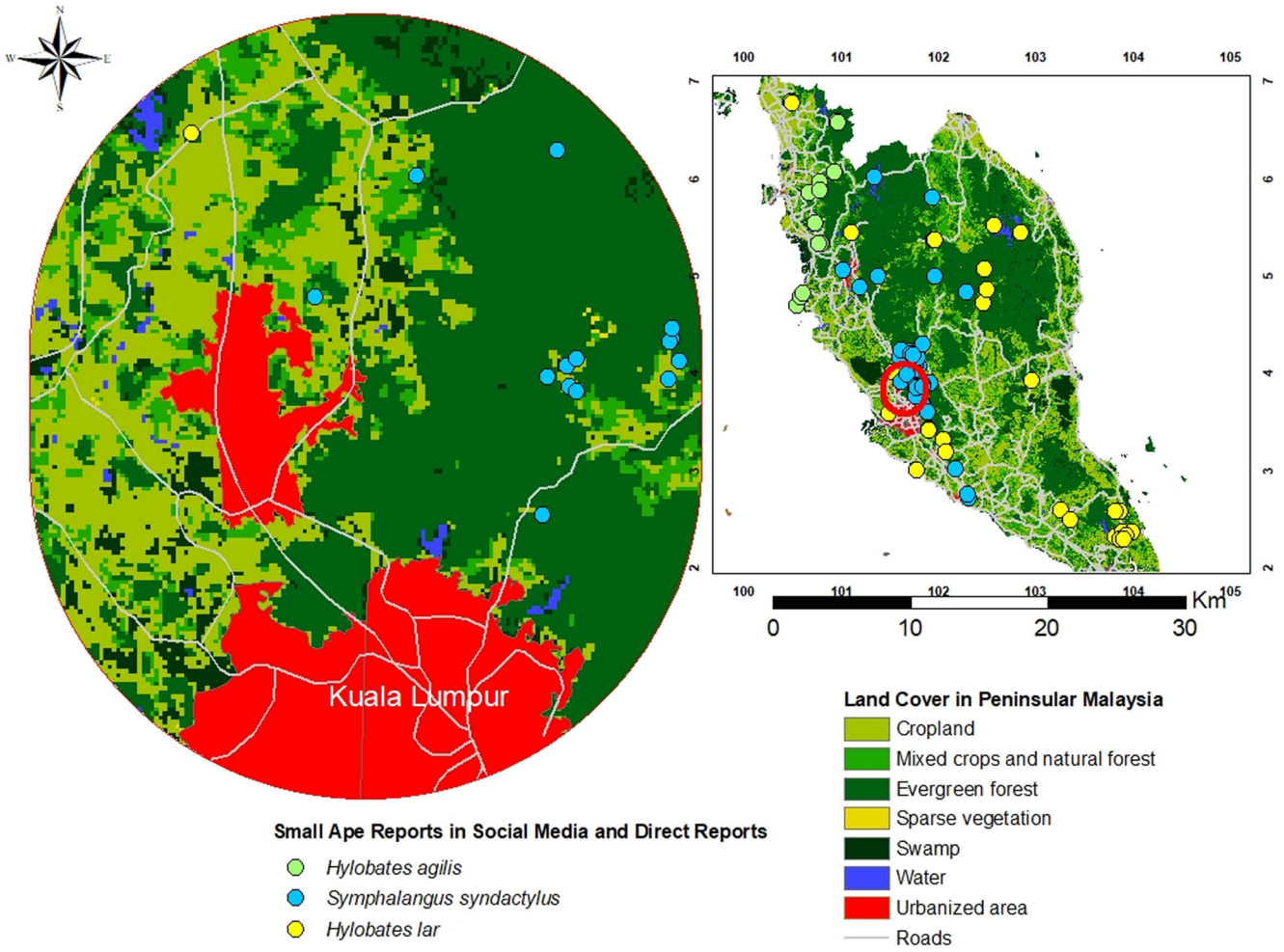

FIGURE 3 Location of *Symphalangus syndactylus* in small fragmented forest areas. A few reports from social media and citizen scientists showed *S. syndactylus* occurring outside of large forested areas. Upon closer examination, we found that these sightings occurred in very small forest fragments in a matrix of croplands, natural forest and urban area

with researcher-generated data (Aceves-Bueno et al., 2017; Horns et al., 2018a, 2018b; Schuttler et al., 2019). Small apes typically travel in the middle or upper forest canopy, and most small apes in Malaysia have a dark pelage, making them quite difficult to photograph. Small ape songs are conspicuous and relatively easy to record, but few nonspecialists have a routine practice of recording animal vocalizations. Untrained observers may not be able to distinguish species-specific calls, especially for *H. agilis* and *H. lar*, and even when citizen scientists record sections of gibbon songs, they may not record song elements that are useful in distinguishing between closely related species. Despite the limitations of this method, we found 121 reliable recent reports that included either images or recordings of sufficient quality to verify the reporter's identification of the species.

Our results indicate that visitors to Malaysian forests notice small apes and that at least some of them value these encounters enough to post them on social media when they occur. Encouragingly, we found reliable reports of small ape sightings by citizen scientists in almost all states in Peninsular Malaysia, and the reports spanned most of the reported geographic distribution for each small ape taxon. Our results show that reliable reports from citizen scientists are useful in determining that small apes are present in habitats from which no published information is available. The presence-only data generated by citizen scientists could potentially also be used in analyses of habitat preferences, although further study will be required to validate this method (Velde et al., 2016).

Our results, however, also suggest that caution is warranted in using spontaneously generated citizen science data to estimate distributions for small apes (Table 3). Some GPS coordinates reported on social media indicated implausible locations. For example, one *H. agilis* sighting had coordinates offshore and four *S. syndactylus* sightings were reported outside of their expected range. Three of these reports, one for *H. agilis* and two for *S. syndactylus*, were from iNaturalist. iNaturalist automatically obscures coordinates (±10 km) provided for threatened species (classified as Vulnerable and above by the IUCN) so as not to reveal locations to potential poachers. By participating in our project, some observers permitted us to access the "private" location data, but not all participants had these permissions set, so some location data from iNaturalist include

TABLE 3 Summary of strengths and limitation of the approach and recommendations for future researchers using online citizen science

Advantages	Disadvantages	Recommendations
Online citizen science reports are easily accessible, and many reporters provide information of adequate quality to verify the species, site, and approximate time of the observation	*Data quality is variable*. Citizen scientists may misidentify species or make errors in documenting locations. Reporters may also deliberately produce false reports for their own purposes	*Establish standards* for verifying species identification and location to the degree of precision required to meet the research goals
		Data verification must be based on information provided by reporters, and not on prior assumptions about which species occur in a particular landscape
		Do not rely heavily on any single report or reporter
Social media reports are available from many sites. Scientific research is concentrated in relatively few sites, usually in protected areas less affected by human presence (Bezanson & McNamara, 2019), so citizen scientist reports may provide useful supplementary data	*Reports are biased toward more accessible sites near urban areas*	*Clearly identify the geographic scope of the research question*. Social media surveys are only likely to yield useful data from sites with relatively high human traffic unless additional efforts are made to enlist and educate visitors who are planning to visit more remote areas
Recruitment activities and community engagement with online citizen science-based research can enhance scientific literacy and engagement in conservation among participants (Cooper et al., 2007; Dickinson et al., 2010)	*Recruiting and educating potential reporters may involve substantial time and energy costs*	*Develop a recruitment strategy* to identify and educate potential reporters, especially among frequent visitors to target sites. Recruitment programs should be designed to communicate key information about the importance and conservation needs of the target species to diverse audiences through, for example, workshops, school programs, media materials, and so forth, to maximize benefits in terms of raised conservation awareness among participants
		When unsolicited reports are found on social media, contacting the reporter may lead to ongoing engagement
	Some reporters may wish not to be identified	*Protect reporter privacy*. Do not publish or disseminate the names or identities of any reporters without their affirmative consent
	Online reports may place vulnerable animals at risk of poaching by drawing attention to their presence at a given location	*Emphasize the importance of appropriate protections of location data in all outreach activities*
		Offer reporters a private means for communicating location information, and model responsible communication by only requesting location information through private channels
		Obscure sensitive location information
Online reports provide recent information about small apes indicating their occurrence or persistence in many landscapes, including sites from which there have been no previous reports	*Online citizen science reports do not provide information about abundance, demography, or social organization*	*Use online citizen science primarily to guide and complement field research*

substantial but intended error. In at least two cases, this likely explains the discrepancy, as the locations are very near to expected locations. We contacted the reporter for the final anomalous report on iNaturalist and confirmed the location, which is also just outside of the known distribution range for *S. syndactylus*. Two other reports from other sources were independent reports of *S. syndactylus* sightings by different reporters from the same location, which is close to but outside of the reported distribution range for the species. These reports may represent reporter error, but given the locations, it seems at least as likely that these reports may indicate errors in the IUCN distribution map. In some cases, errors may also have occurred because of the use of mobile phones instead of more accurate GPS devices. Other locality errors may reflect the positions where citizen scientists heard the small apes instead of the actual coordinates of the small apes (which may be ≥1 km away, in the case of auditory observations). Some reporters also misidentified *H. lar* and *H. agilis*, as

these two species only differ slightly in hand color and face mask shape, although we were able to correct for this where audiovisual evidence was provided. Therefore, careful validation of location and species data is essential.

The concentration of small ape reports from forests near urban areas suggests that most outdoor enthusiasts primarily visit well-traveled areas that are easily accessible by road. This resulted in very uneven sampling, with many replicate sightings from the most popular areas (e.g., Fraser's Hill), few replicate sightings from others, and few or no sightings at all from some large areas where small apes are known to occur, such as Krau Wildlife Reserve, Pahang National Park, Endau Rompin National Park, and Royal Belum State Park (Snäll, Kindvall, Nilsson, & Pärt, 2011). Visitors entering state and national parks and wildlife sanctuaries in Malaysia must register and pay a small fee before entering, which may be an additional barrier to access in some cases.

Education and familiarity with social media may be another reason that more observations were reported from urban areas compared with rural areas as well as generally better internet access and cell phone coverage in more developed areas. The pattern of observations found here is opposite the usual pattern of research by primate specialists (Bezanson & McNamara, 2019), whose efforts are focused in a relatively small number of sites, usually in large protected areas, which suggests that social media reports may be a useful complement to research by specialists.

To produce a more fine-grained analysis of small ape distributions using citizen scientist data, we would need a larger sample of reports of small ape sightings from citizen scientists, and especially a sample that includes more reports from rural areas far from major roads. Whether it is feasible to obtain such a sample remains to be determined.

Social media surveys produce presence-only data, and therefore cannot be used for studies of small ape abundance or demography. Photographs and video may document the presence of >1 individual and recordings of duet songs document the presence at least two distinct individuals and verify the existence of a pair bond. Therefore, reliable social media reports could conceivably be used to estimate a minimum number of individuals at a site, to verify the presence of at least one mated pair (through photos or videos of pairs, or audio recordings of vocal duets), or to determine whether a population is breeding (if photographs include infants). However, only the adult pair duets, so infants and juveniles will not be recorded, and photographs and videos of small ape groups may not include all group members. Therefore, this information will not be comparable across sites, and is unlikely to be adequate to allow researchers to draw inferences about the characteristics of a population in the vast majority of cases.

After we initiated public outreach to solicit reports of small ape sightings, we started to receive direct reports from citizen scientists via Facebook (either through direct messaging or tags on small ape-related posts) and email. Several spontaneous reporters who we contacted to seek clarifying information commented that they were happy to contribute to the project, and some have also subsequently tagged us on additional social media posts, including posts by other reporters that they encountered. In these cases, passive citizen scientists became active research participants. These results show that there is enthusiasm for participation in primate-related research among people who participate in nature-related social media and suggest that social media may be an appropriate means for recruiting participants in future citizen science research projects.

A few key informants that are very active naturalists or researchers focusing on other taxa have started regularly submitting sightings from locations that are further off the beaten track. These promising developments suggest that more intensive outreach to specific communities, including field researchers, very active birders concentrating in the target areas, and tourists and hikers entering large forested areas (perhaps through signage or materials placed at park entrances), may result in improved sampling from rural areas and areas with limited road access. For this study, we used site descriptions to estimate the approximate locations of observations without GPS coordinates on Google Earth, but citizen science research programs that use more focused outreach and education to enlist public support may generate more reports, more reliable reports, and higher-quality reports by increasing public familiarity with small apes (or other target species) and creating greater standardization of observational methods. It is crucial that researchers requesting location data should provide a private means for communicating this information, and reporters should be urged to avoid revealing on social media sensitive information like exact locations for threatened animal taxa that are vulnerable to poaching.

Despite these limitations, our results indicate the potential utility of online research using both spontaneously generated and solicited reports from nonscientists, especially for initial assessments of animal distributions and to guide decisions about site selection for focused field research (Table 3). As Malaysia has many green spaces near or adjacent to major urban areas (Karuppannan, Baharuddin, Sivam, & Daniels, 2014), citizen science may be particularly useful in monitoring specific small ape populations in these areas. This approach is being used effectively by The Raffles' Banded Langur Working Group in Singapore (A. Ang, personal communication; https://www.nss.org.sg/nss_group.aspx?news_id=YZJVxnGiwDs=&group_id=oAuELzkrPVQ=)

This approach also has broader implications with regard to conservation education and outreach. While many Malaysians have some familiarity with small apes, there is little public awareness that small apes are endangered or about their unique conservation needs. By participating in research, citizen scientists may learn more about small apes and become more invested in their conservation (Bonney et al., 2009). Furthermore, because of their unique position in the social media landscape, online advocates have the potential to initiate a positive snowball effect, reaching a much wider audience than traditional science communication outlets. This sort of public engagement not only improves awareness about endangered small apes in Peninsular Malaysia but may encourage wider participation in any related citizen science projects strengthening conservation efforts for local wildlife.

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DATA AVAILABILITY STATEMENT

The Malaysian wildlife authorities (PERHILITAN) granted us permission to conduct research on small apes in Malaysia, and all research reported here was conducted in compliance with the laws of Malaysia and following the ASP Principles for Ethical Treatment of Non-Human Primates. During our outreach efforts, we cautioned citizen scientists to avoid exposing precise locations of gibbon individuals or groups in communications visible to the public due to the vulnerability of gibbons to poaching. We were careful to protect the privacy of reporters that contributed to the project. For this reason, we have not deposited our raw data with links to specific posts or geographic information in a public repository, but summarized data with general locations can be made available upon reasonable request.

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