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Article

Preprint: Piloting close-range remote sensing of endangered Borneo Pygmy Elephants using photographs ecotourists share via social media.

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Abstract:

This pilot study explores the potential of using a citizen science approach for sourcing volunteered geographic information via social media to research wildlife tourism interactions with endangered Borneo Pygmy Elephants on the lower Kinabatangan River in Sabah, Malaysia. Such information is critical if the lower Kinabatangan region is to achieve the United Nations Sustainable Development Goals through a sustainable tourism industry based around viewing the pygmy elephants. Guests and guides from the Sukau Rainforest Lodge were encouraged to become close-range remote sensors by sharing geotagged photographs of pygmy elephant sightings on Flickr. A ten week on-ground trail generated 247 photographs shared by 17 individual contributors with approximately two-thirds (65%) of photographs being georeferenced for the time and location of the elephant sighting. Plotting those sighting to explore the vegetation matrix (i.e. remnant forest or oil palm plantation) showed almost three-quarter (73%) of the sightings occurred within 1 km of an oil palm plantation. Of greater concern is that one in two sightings (50%) along the river occurred within the 500 m of an oil palm planation, which is inside the riparian buffer that the Sabah Government recommended for conservation of the elephants in their Lower Kinabatangan range. This study therefore demonstrates proof of concept for this research method and its further application at the nexus of wildlife conservation and sustainable ecotourism research.

Keywords: Crowdsourcing, Citizen Science, Flickr, Land Cover/Use, Social Media, Volunteered Geographic Information, Wildlife Tourism, Borneo Pygmy Elephant, Sabah, Malaysia, SDGs

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1. Introduction

Despite the practice of sourcing data from photographs being underutilized in tourism-based research [1], there is a growing acceptance and increased publication of ecological and tourism research based on photographs and other geographic data contributed by *citizen scientists* whilst engaging in ecotourism experiences (e.g. [2-10]). There remains, however, a perception that research based on photographs taken by tourists is heavily biased or "tainted" [1]. As such, some authors still question the validity ecological and tourism research that utilizes such data [11,12]. Those views are in stark contrast to the discipline of remote sensing, which was founded on the interpretation of photographic images and has embraced the concept of citizens contributing *volunteered geographic information* to generate research data [13-16]. This article describes our pilot project that recruited ecotourists as citizen scientists who became close-range remote sensors of the Borneo Pygmy Elephants they encountered while participating in wildlife tourism experiences in Sabah, Malaysia.

In the first two decades of the 21st-century, wildlife tourism has evolved as a global industry, driven by the inherent human desire to see and interact with wildlife in natural settings [17-19]. Wildlife interactions, which are widely considered to be a non-consumptive tourism activity, range from observing and/or feeding wildlife in regulated and unregulated experiences through to photographing wild animals in different environments (e.g. [19-23]). As the economic and social significance of wildlife tourism and ecotourism continue to grow, particularly for biodiverse, developing nations striving to achieve the United Nations Sustainable Development Gaols (SDGs), understanding the ecological interface of these experiences is critical for achieving long-term sustainability [22,24-29].

Effective management of wildlife tourism experiences should not only consider the views and perceptions of visitors [30,31], but ideally the circumstances under which wildlife is appreciated must also be monitored [2]. In the case of endangered wildlife, the conservation needs of the species must also be prioritised (e.g. [32-34]. In addition, protected areas are a key strategy for nature conservation that can provide opportunities for the human-wildlife interactions desired by ecotourists (e.g. [35-39]), which an approach is consistent with SDGs [24,26,28]. In turn, sustainable ecotourism can generate funding and political support for the ongoing management of the protected areas, which is also in alignment with SDGs [24,26,28,40]. However, delivering management that is both responsive and adaptive requires real-time information relating to human-wildlife interactions, especially in respect to the location and conditions under which wildlife is appreciated [2,41]. Such data is, however, often limited [6,22,34,42].

Traditionally, retrieving up-to-date information on how tourists interact with natural and protected areas has involved methods such as surveys and interviews, which can be laborious, time-consuming, and costly to deliver (e.g. [23,29,36,40,43-47]). Citizen science and crowdsourcing data from the public can provide an effective alternative to traditional centralised research methods, particularly when resources and funding are limited [48]. Collecting data in this way has been facilitated over the past two decades by the availability of smart devices equipped with Global Positioning System (GPS) services, high quality digital cameras, and access to the World Wide Web [48,49]. This has occurred in tandem with the exponential growth in *social media*, which is referred to more formally as social networking sites (SNSs) [50-53].

The emerging alternative of using widespread and readily available data uploaded to SNSs can provide a rapid and cost-effective way to explore nature-based tourist experiences and activities is being utilised with increasing frequency [29,40,43,47]. As seen in the ecological and tourism research literature, SNSs can also provide a novel source of biodiversity data, with users sharing images and associated metadata that include identification information and geographic references (e.g. [54-56]). One response to this trend has been the development of citizen science projects that utilise volunteered geographical information to generate data, such as occurrence records, for a broad range of flora and fauna taxa [54,57,58]. Many authors now report that data from SNSs holds the potential to assist with investigating environmental factors relating to wildlife tourism research (see [6,42,55,59-61].

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For this pilot study, the social media platform Flickr was used to explore the wildlife-centred dimensions of an ecotourism experience that focused on viewing wild Borneo Pygmy Elephants during riverboat tours along the lower Kinabatangan River, Sabah, Malaysia (see example in Figure 1). The critical importance of this region for nature conservation, coupled with the endangered status of the Borneo Pygmy Elephant [62], underpins the conservation significance of this research. As reported by Newsome et al. [31], viewing pygmy elephants is of high importance for ecotourists on the lower Kinabatangan River and a vital component of the overall wildlife-viewing tour, which further reinforces the significance of this study. This research utilizes photographs uploaded by tourists to pilot the collection of volunteered geographic information relating to where elephants are sighted. A further goal of this research was to explore the potential for implementing an innovative and low-cost data collection approach that can inform future management decisions pertaining to tourist viewing of Borneo Pygmy Elephants in Sabah, Malaysia.

Figure 1. Sighting of a Borneo Pygmy Elephant during a wildlife tourism riverboat cruise along the lower Kinabatangan River, Sabah, Borneo. Photo Credit Obelia Walker.

2. Scoping Literature Review

2.1 Borneo Pygmy Elephants in Sabah

The Borneo Pygmy Elephant (*Elephas maximus borneensis*), which is increasingly recognized as a sub-species of the Asian elephant (*Elephas maximus*), has been listed as an endangered species on the IUCN Red List of Threatened Species since 1986 [62-64]. Research on these elephants has, in the main, only occurred in the past fifteen years, with the first satellite tracking efforts undertaken by the World Wildlife Fund for Nature (WWF) in 2003 [65]. Despite their high conservation priority, there remains a degree of uncertainty about the size of the Borneo Pygmy Elephant population and its distribution [63]. The WWF [66] states that Borneo's elephants remain the "least-understood elephants in the world".

From what is known, the distribution of the pygmy elephants is restricted to approximately 5% of the island of Borneo [67]. The elephants are primarily located in the northeast of the island, within

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five highly managed ranges located in the eastern portion of the Malaysian state of Sabah [63,67,68]. Those ranges are the Lower Kinabatangan (~400km²), North Kinabatangan (~1,400km²), Central Sabah (~7,900km²), Tabin (1,200km²), and Ulu Kalumpang (~510km²). The presence of elephants in North Kalimantan, Indonesia occurs as part of the Central Sabah range, with the number of individuals in Kalimantan estimated to be less than 20 elephants in 2011 [69].

A decade has passed since Alfred et al. [68] surveyed the elephant population in Sabah using a systematic line transect approach and long-term monitoring of dung decay rates. That survey estimated the total Sabahan population to be 2040 elephants, with a lower and upper bound (95% confidence interval (CI)) of 1,184 to 3,652 elephants. Alfred et al. [68] estimated the population in the Lower Kinabatangan range, which is the locale for this study, to be 298 elephants (95%CI 152-581). The Lower Kinabatangan range is isolated from both the North Kinabatangan range and from the Central Sabah range by oil palm plantations and a public highway [70]. In respect to habitat selection, the elephants show preference for low-lying areas, avoiding steep-slopes and mountainous terrain that hinder movement [69]. Forested areas close to rivers that provide plenty of food and shelter, into which elephants can retreat during the heat of the day, are features that have also been identified as synonymous with Borneo Pygmy Elephant habitat [69].

For those reasons, the major threats facing the Borneo Pygmy Elephant are habitat loss and the fragmentation of the remnant forest [67,70,71,72]. Habitat loss in the Lower Kinabatangan region has occurred through the conversion of existing forests to agriculture and human settlement [71]. It is therefore of concern that in the last 50 years an estimated 80% of the indigenous forest in the Lower Kinabatangan region has been converted for agriculture and settlement [67,71].

The lack of connectivity between elephant ranges and ongoing habitat loss has increased elephant densities in forest remnants, which is contributing to an increase in the occurrence of human-elephant conflict. As local people and elephants continue to compete for space and resources, there are costs to both sides in the form of economic losses from crop raiding and damage to infrastructure with resulting retaliative actions towards the elephants sometimes causing serious injury or death [73]. Historically, poaching has not posed a serious threat to the elephants [70], however, reports of illegal killing (shooting and poisoning) have occurred, typically because of the elephants entering oil palm plantations [73,74]. Those attacks on elephants and the associated deaths come despite the elephants being listed as a Totally Protected Species under the Sabah Wildlife Conservation Enactment 1997 [73]. Any person found guilty of killing or hunting an elephant can receive a fine of RM 50,000 and/or a jail sentence of up to five years [70].

2.2 Kinabatangan - Corridor of Life

Dubbed the "Kinabatangan - Corridor of Life" [75], the Lower Kinabatangan region is located on the Kinabatangan River in southeast Sabah, Malaysia (see location map [31]. This region is dominated by a river system that flows 560 km eastwards towards the Sulu Sea, with the catchment covering approximately 23% of the total land area of Sabah [76]. The catchment of the lower Kinabatangan contains a matrix of fragmented forest ecosystems that includes riparian vegetation, limestone forests, freshwater swamps, mangroves, oxbow lakes, and dryland Dipterocarp forests [31,77-79]. At present, however, only 4% of the Kinabatangan River catchment comprises remnant forest, approximately two-thirds of which is protected through the establishment of forest reserves and wildlife sanctuaries such as the Kinabatangan Wildlife Sanctuary [31,80]. The dominant land use matrix outside of these remnant forest fragments includes extensive oil palm plantations, processing mills, roads, human settlements, and small food-crop farms [80].

The Kinabatangan Wildlife Sanctuary was created in 2005 by the Sabah State Government under the Wildlife Conservation Enactment [78,79]. The sanctuary covers approximately 29,000 hectares [31] and consists of blocks of land linking pockets of forest reserves with mangrove forests near the coast to provide a habitat corridor through the Kinabatangan region [78,81]. Protected areas located close to the headwaters of the river are significantly smaller and sparser than those located further downstream [31,82]. These reserves play a critical role in maintaining wildlife habitats and ecosystem processes along the Kinabatangan River [78,82]. As with the rest of Sabah however, they exist within

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a severely fragmented landscape that is dominated by oil palm plantations and logged forested areas [78,80,82]. Existing oil palm plantings and any future expansion of that industry pose an on-going threat to the ecological values of the Kinabatangan Wildlife Sanctuary [31].

2.3 Significance of Kinabatangan Wildlife Sanctuary

Despite high levels of habitat degradation and fragmentation, the Kinabatangan River is one of the most important wetland ecosystems in Malaysia for indigenous biodiversity [82,83]. By encompassing a range of wildlife habitats (and variation within those habitats), the Kinabatangan Wildlife Sanctuary supports a very high level of biological diversity [77,84,85]. The sanctuary contains over 250 species of birds, 90 species of mammals, 90 species of freshwater fish, 20 species of reptiles, and 15 species of amphibians [79,81]. Iconic and rare wildlife, such as the endangered Borneo Pygmy Elephant, inhabit and migrate through the forests of the sanctuary providing a significant drawcard for tourists to the region [31,85]. It is also one of only two sites in the world (the other being Danum Valley - also located in Sabah) where ten species of primates occur together, with four of these being endemic to Borneo [31,78,81].

It has been two decades since the Sabah Tourism Masterplan [86] identified the Sandakan–Kinabatangan region for tourism development but cautioned that the Kinabatangan offered "top quality wildlife viewing under threat from surrounding development" [86] (p. 181). The promotion of the Lower Kinabatangan region for nature-based tourism activities has attracted long haul tourist markets, such as those sourced in Europe and North America, to the region [31,87] with estimated tourist arrivals at around 17,000 in 2015 [31]. Wildlife tourism experiences are facilitated through the numerous ecolodges found along the river, often providing their own knowledgeable and experienced tour guides, many of whom are local to the area. Riverboat cruises are the primary ecotourism activity, which provide a unique and alternative way of viewing wildlife under natural conditions [31,88].

Being a world premier ecotourism destination [83], tourism in the Lower Kinabatangan provides significant socioeconomic benefits and plays an import role in achieving SDGs for the region [31]. Delivering a sustainable tourism industry is directly dependent on the wildlife that the Kinabatangan River and fringing forests supports, making those natural assets a primary focus for conservation. For those reasons, the Kinabatangan-Corridor of Life Tourism Operators Association (KiTA) was established by local tour operators and WWF Malaysia as an advocacy group for tourism focused on delivering the SDGs [89]. The mission of KiTA is to "promote and implement a globally recognized sustainable tourism industry" through good environmental management practices, providing opportunities to local people/ businesses, and preserving a balance whereby agriculture, people, and nature can co-exist [31,89]. To ensure the long-term sustainability of the Lower Kinabatangan region as an ecotourism destination, it is essential that further environmental degradation is prevented through the implementation of effective government planning and law enforcement [83]. Chan, Newsome, Teo and others [30,31,83,85] report that unless wildlife conservation is made a priority, the foundation of nature-based tourism in this region will continue to be threatened by surrounding agriculture and other development.

2.4 Consolidation of Research Method

To implement this close-range remote sensing pilot study, it was first necessary to understand the characteristics of image-based SNSs in order to determine which would be most appropriate to answer the research questions (see Section 3.2). The selection of SNSs would then guide the development of the research method based on the characteristics and features of the selected SNS(s). The three photo-sharing social media platforms most commonly utilized for such research (Table 1) are Facebook, Instagram, and Flickr [9,42,55]. To effectively capture the close-range data shared by the ecotourism citizen scientists, it was critical that the selected platform(s) could support the upload of geotagged photographs, were easy for tourists to access/use, and would allow for efficient remote searching and filtering of content by the researcher.

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2.5 Selection of Remote Sensing Platform

There is citizen science based studies that have utilized Facebook in the collection of photos for research on wildlife [58,90]. For privacy reasons, Facebook does, however, remove much of the useful Exchangeable Image File (EXIF) data during the photograph uploading process [58]. The EXIF contain information such as the time and geographic coordinates for when and where the photograph was taken. In addition, Facebook is not solely an image-sharing platform, meaning it can be difficult to filter through the many text-based posts acquire the desired photographic data.

Instagram allows users to capture and instantly share real-time experiences through a mobile application and has been used in several studies on nature tourism [48]. Instagram has been used to research tourist preferences for nature-based experiences and for visitor monitoring in parks and protected areas [40,43,47]. The geotagging feature on Instagram allows users to manually add a location, landmark, or public place to posts, but, like Facebook, Instagram removes all EXIF data from photographs uploaded to the service [91]. This means it is not possible to pinpoint the exact location of where a photograph was taken using metadata accessed remotely.

Table 1. Comparison of three image-sharing SNSs (adapted from Di Minin et al., [48]). Statistics regarding number of monthly active users sourced from Cowling [92].

Name of Platform	Description	Available Search Parameters	Retains EXIF Location Data	Monthly Active Users
Facebook	Popular social networking site. Allows sharing of statuses/ photos/ videos and links with friends. Supports interactive online discussion.	User, page, event, group, place	No	15,000,000
Instagram	Sharing of photos and short videos via mobile application. Captions often include hashtags to organise/ categorize photo content and to connect users around a subject.	User, location (selected by user), keyword, tags, followers, photos, popular items, comments. likes	No	9,000,000
Flickr	Image/video hosting and storing website. Popular amongst photographers.	User, location (latitude/longitude), photo photographs, keyword, tags, people, groups, galleries, favourites, contacts, comments, places	Yes	480,000

Flickr was not the most popular of the three image-sharing platforms in terms of the number of active users (Table 1). However, the literature reports it to be the preferred of the three platforms in terms of capturing data for ecological, geographic, and tourism research based on volunteered geographical information [93]. This can be attributed to the distinction that Flickr, unlike the other two platforms, does not wipe the EXIF data when photographs are uploaded. Flickr also supports an easily accessible Application Programming Interface (API), which allows software developers to write code that can then be used by researchers to retrieve relevant metadata for shared photograph. Traditionally, Flickr has been more targeted towards photographers uploading high resolution pictures taken with professional cameras [40]. In 2012, however, Flickr responded to growing

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competition in the field of image-sharing platforms, particularly from Instagram, by developing a new and updated Flickr application for iOS and Android mobile devices [94]. The application also includes the ability to edit, add filters, leave comments, and attach a geo-location manually or from a coupled GPS device (such as the GPS receiver built into most smartphones). Flickr also supports the ability to tag photographs with keywords or hashtags, allowing for simple and effective searching of content. This longitudinal development of Flickr reflects the changing nature of photography, with smartphones being amongst the most common devices now used to capture and share images on Flickr [95].

The versatility of the Flickr upgrade and the enhanced capabilities added by the API has seen it utilized in multiple of conservation research projects in the past few years (e.g. [54,56-58,90,96]). Barve [54] provided a proof of concept assessment for the use of Flickr in collecting primary biodiversity data. Barve [54] described Flickr as a suitable SNS to document species occurrence in time and space, as the platform hosts many users sharing images of wildlife and associated metadata. Stafford et al. [58] also explored the citizen science potential of Flickr to study bee distribution across the United Kingdom. The BeeID project, as it was named, was setup as a special interest group on Flickr to keep the project focused within the framework of a SNS [57,58].

In respect to our remoting sensing pilot study, the preceding studies confirmed that Flickr provided the necessary features to support the upload of accurately geotagged photographs of elephant sightings along the lower Kinabatangan River. We therefore decided that Flickr would be the most suitable platform for our pilot investigation. In the early planning of this study, we considered creating a specialized and dedicated group, like the approach used in the BeeID project. Eventually we decided, however, that to maximize involvement and for ease of use by the participants, it would be more appropriate to track posts using a unique hashtag (see Section 3.3)

3. Materials and Methods

3.1 Study Location

This pilot study was conducted on the Kinabatangan River in lower Kinabatangan region of Sabah, Malaysia (see location map provided in Newsome et al. [31]. As previously mentioned, that region is a premier ecotourism destination and one of the foremost wildlife viewing locations in Southeast Asia [31,93]. As such, the lower Kinabatangan River provided an excellent location to explore the close-range remote sensing of endangered wildlife using geotagged photographs that ecotourist citizen scientists share online.

3.2 Aim, Objectives, and Ethics Approval

This pilot study explores how tourist-generated photographs sourced through existing SNSs could be used in wildlife tourism and conservation research. The conceptual framework for the study, shown in Figure 2, illustrates the SNS used, the type of data collected, and the over-arching objective. The literature that informed the design of this study is reported in publications by Simpson, Walker, and others [6,9,55,59] and is summarized in the previous section. This research was undertaken with approvals obtained from the Murdoch University Human Research Ethics Committee (2017/161) and the Murdoch University Animal Ethics Committee (O2961/17).

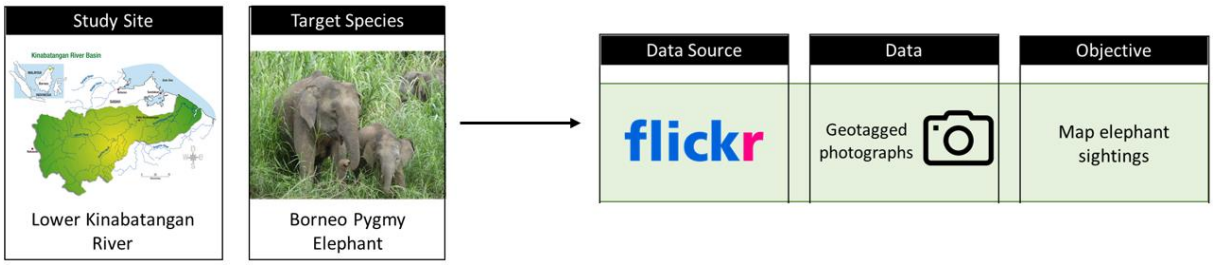

Figure 2. Logical framework of study outlining the wildlife-centred research application of the study.

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Specifically, this study pilots the use of geotagged photographs to gather information about the endangered Borneo Pygmy Elephant in the context of riverboat tours along the lower Kinabatangan River, Sabah, Malaysia (see Figure 1 and Newsome et al. [31]). On that basis, this pilot study was designed to provide proof of concept for the use of the Flickr SNS as a tool for remote sensing the ecological elements of a wildlife tourism experience. To achieve this, the objectives of this ecotourism-based wildlife-centred research were to:

1. Map sightings of Borneo Pygmy Elephants along the lower Kinabatangan River using geotagged photographs that citizen scientist ecotourists uploaded to Flickr.
2. Investigate the landscape matrix in the proximity of Borneo Pygmy Elephant sightings along the lower Kinabatangan River.
3. Consider the feasibility of extending the technique of using geotagged tourist photographs shared online to supplement the long-term monitoring of Borneo Pygmy Elephants.

3.3 Borneo Based Fieldwork

To explore the on-ground implications of coordinating the citizen science approach adopted for this pilot study, marketing materials were designed to engage ecotourists and promote their involvement in the project. Collaboration with the marketing department of our industry research partner Borneo Eco Tours (BET) produced an information poster (Figure 3) and brochures targeted to guests staying at the Sukau Rainforest Lodge (SRL), a sister company of BET [97]. The project was also promoted through social media, via the Facebook and Instagram profiles of BET, SRL, BEST Society (not-for-profit sustainable community development organization in Sabah allied to BET and SRL), Murdoch University [98], and the researchers. The project was also picked up and profiles through traditional media in Australia and Malaysia [99,100] and on several conservation and international study blogs [101-103]. That online and social media exposure was designed to generate public interest and allowed guests to hear about the pilot project online before their arrival at SRL.

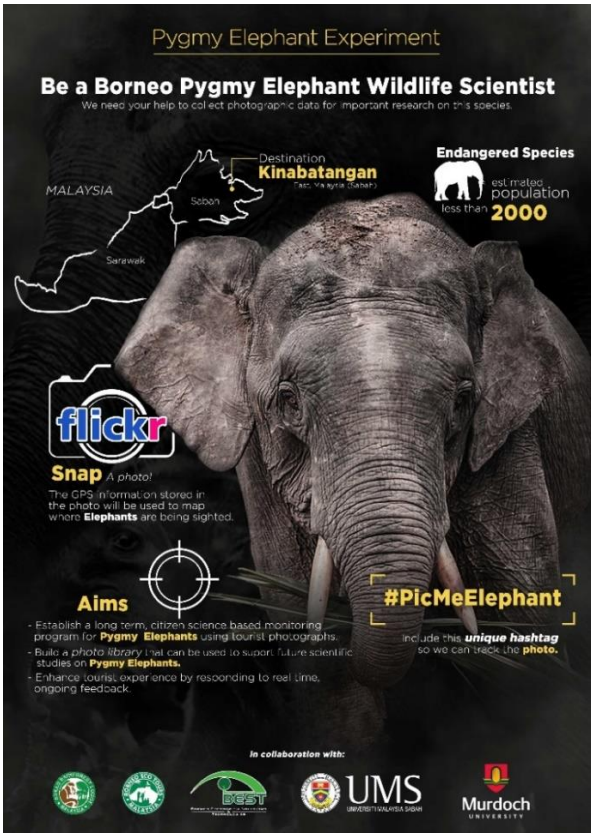

Figure 3. Poster informing ecotourist at Sukau Rainforest Lodge about the project and to engage them as citizen scientists and contribute geotagged photographs as close-range remote sensors.

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On shifting the Sabah based fieldwork to SRL, lodge staff and tour guides were informed of the logistics of this pilot study, why such research was important and valuable for tourism operators in the lower Kinabatangan region, and suggestions to optimize the education and inclusion of guests in the project. Guests arriving at the lodge would receive a welcome briefing and were provided with a short overview about the project and how to participate by contributing geotagged photographs of the elephants. The information brochures that highlighted key details were also be handed out at this time.

Becoming a citizen scientist and participating in the pilot project as a close-range remote sensor of pygmy elephant sightings/interactions required guests to:

1. Switch on the location services of their smartphone or GPS enabled camera device; and
2. If they did encounter and photograph elephants during a riverboat cruise, to upload those photographs to Flickr.

Almost all smartphones, and some high specification digital cameras, feature a built-in GPS receiver that draws location data from a network of geostationary satellites [104]. Photographs of elephant sighting taken with the location services switched on during tours on the lower Kinabatangan River (where internet connection is not guaranteed) would then retain the location information for the photograph in the image EXIF. Step by step guidance on how to do this was provided at the lodge and, on request, was emailed to guests.

In that way, all photographs uploaded to Flickr, at any time in the future, retained the geolocation of where the photograph was taken and not from where it was uploaded. Hence, guests were able to upload photographs at any time during their stay, or weeks later after returning home and gaining access to a potentially more stable internet connection, and the coordinates were fixed to the location of where the photograph was taken. In addition, that delay in uploading the georeferenced images provided an added level of protection by reducing the potential for the elephants to be targeted by disgruntled local land holders or poachers.

3.4 Collection and Analysis of Citizen Science Data

The process of sourcing photographs of elephant sightings to extract remote sensing data was made possible by using a unique hashtag created for this project. Guests were asked to include *#picmeelephant* in their posts to Flickr, so that it was possible to quickly find their photographs and consolidate the necessary information into the remote sensing dataset. Location information was then extracted from the geotagged photographs using the *flickr.photos.getInfo* application made publicly available through the *Flickr App Garden* [105]. This application was created using the open API in Flickr, which allows users and developers to write their own programs to present publicly accessible Flickr data. The latitude and longitude coordinates for each geotagged photograph were plotted onto a map using the *Google My Maps* [106] application. Photographs were grouped as a single sighting if they took place on the same day, during the same riverboat trip, and within 100 m of each other.

Several riverboat tours were available at SRL. Using time, date, and location information recorded in the EXIF, it was possible to determine the type of tour upon which elephants were encountered. The sightseeing riverboat cruise options were the Morning Cruise, the Afternoon Cruise, and the late afternoon Elephant Search. Arrival and departure cruises from and to Sandakan were also included in this analysis, as they provided additional opportunities for elephant sightings.

Mapping the elephant sightings onto a satellite-view in Google My Maps, made it was possible to view and interpret the landscape matrix in which elephants were being encountered. When displayed on the satellite-view map, agricultural areas could be identified as distinct patches of primarily oil palm monoculture. Familiarity with the fragmented landscape matrix was acquired on-ground for the Lower Kinabatangan/Sukau section of the Kinabatangan Wildlife Sanctuary where the field researcher experienced firsthand the clear distinction between primary/secondary tropical forest and oil palm plantations. The distance from each sighting to the nearest oil palm plantation was measured to the nearest 10 m using the Google Maps *Measure distance* tool.

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4. Results

4.1 Sabah Fieldwork

The on-ground element of this project was conducted at SRL from August to October 2017 and was promoted to both guests and staff as a citizen science pilot project for the remote sensing of spatial and temporal information relating to the Borneo Pygmy Elephants, particularly where and when the animals were being seen by tourists on tours. Concurrent with the ten week on-ground research phase of this project, a total of 207 photographs featuring the project-specific hashtag (#picmeelephant) were uploaded to Flickr (equivalent to almost three photographs added per day). Of those, 135 photographs (65% of the 207 images) were georeferenced, with 96% of those geotagged photographs were taken using mobile smartphones. Following the on-ground project implementation, an additional 40 photographs of the elephants were uploaded to Flickr between October 2017 and December 2017 that were tagged #picmeelephant. That produced a dataset 247 photographs shared from 17 individual contributors.

4.2 Remote Sensing Data Capture and Analysis

4.2.1 Mapping elephant sightings

The latitude and longitude coordinates for each of the geotagged photographs on Flickr featuring #picmeelephant were extracted from the associated EXIF information. After grouping photographs taken on the same day, during the same riverboat trip, and within 100 m of each other as a single interaction, 22 separate sighting were recorded during the ten weeks that the project was promoted on-ground at SRL. The location of those sightings, the relevant tour type, and approximate times are displayed in Figure 4.

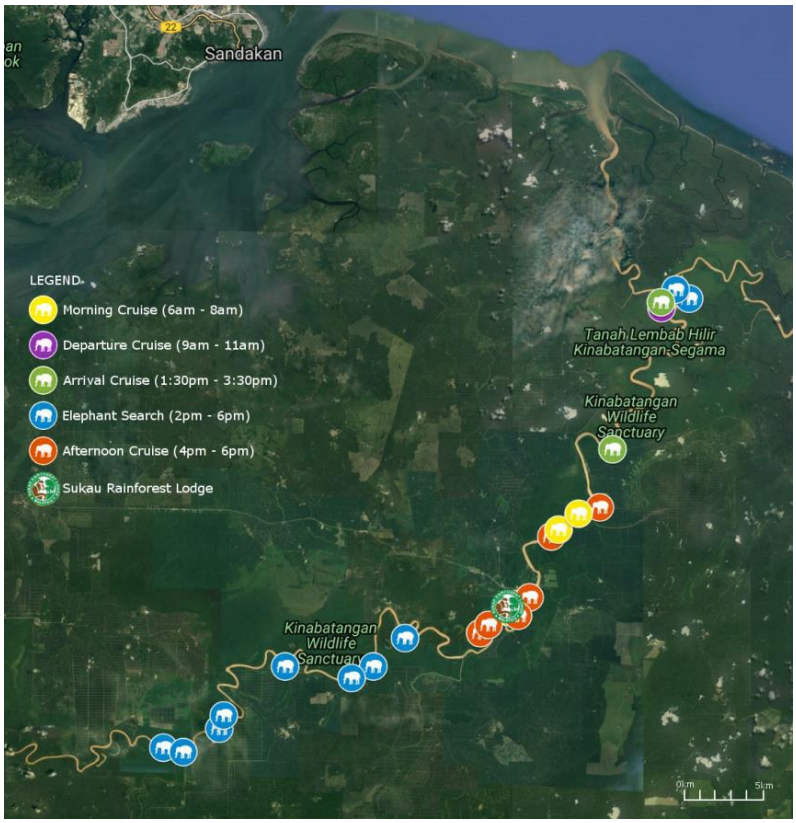

Figure 4. Mapping of Borneo Pygmy Elephant sightings during riverboat cruises on the lower Kinabatangan River between August and October 2017. Coordinates sourced from geotagged photographs ecotourist citizen scientists and professional guides uploaded to Flickr.

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The photographs shared to Flickr and tagged #picmeelephant were taken during riverboat cruises along approximately 100 km of the lower Kinabatangan River from Batu Puteh to Abai, Sabah, Malaysia. Of the 22 sightings reported from riverboat tours, three were recorded during Morning Cruises, six during Afternoon Cruises, and ten sightings were from designated Elephant Search tours. A further two sightings were recorded during the afternoon arrival riverboat trips from Sandakan to SRL and one sighting was recorded during a morning departure trip when returning to Sandakan along the river.

4.2.2 Assessment of landscape matrix

From visual inspection of the My Google Maps satellite-view (Figure 4), it was possible to identify different vegetation patches occurring within two distinct landscape matrices of cleared agricultural matrix and remnant forest cover (terms *matrix* and *patch* defined in Newsome et al. [19] and Forman [107]). An example of the juxtaposition between the continuous remnant forest areas and the distinct blocks of oil palm monoculture is shown in Figure 5. Measured to the nearest 10 m, the average distance of an elephant sighting to the nearest oil palm plantation was found to be 1.2 ± 0.7 km (± 95%CI). Almost three quarters (73%) of the 22 recorded sightings occurred within 1 km of the agricultural matrix (Figure 6). Of more concern is the fact that a half of all the sightings (50%) were closer to the agricultural matrix than the aspirational 500m riparian vegetation buffer recommended by the Sabah Government for the conservation of elephants [70] (p. 19).

Figure 5. Close up image of two elephant sightings that clearly shows the remnant forest matrix of the Kinabatangan Wildlife Sanctuary on the north side of the lower Kinabatangan River and the oil palm plantation dominated agricultural matrix south of the river. Note how the agricultural matrix extends to the riverbank, despite the recommendation of the Sabah Government [Borneo Pygmy] Elephant Action Plan 2012-2016 for a "moratorium on new oil palm development within 500m on both sides of the Kinabatangan River" [70] (p. 19).

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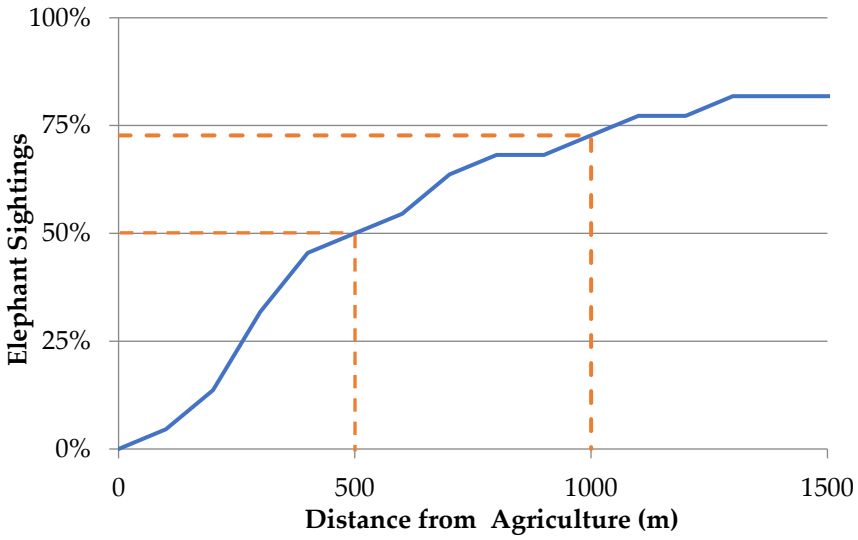

Figure 6. Cumulative distribution for the proximity of Borneo Pygmy Elephant sightings to the palm oil plantation dominated agricultural matrix the measured to nearest 10m. Almost three quarters (73%) of sightings made during riverboat cruises on the lower Kinabatangan River between August and October 2017 occurred within 1 km of a plantation. One in two (50%) of those sighting occurred within 500m of the agricultural matrix, despite a Sabah Government recommendation for a 500m remnant vegetation buffer along both banks of the river [70] (p. 19).

5. Discussion

From a sustainable ecotourism perspective, the Borneo Pygmy Elephant is one of the "Borneo Big 5". This phrase is used by tour operators in the promotion and marketing of their wildlife viewing tour packages [42,88,108]. Other than pygmy elephants, the four other most iconic wild species found in Borneo are the Orangutan, the Proboscis Monkey, the Rhinoceros Hornbill, and the Estuarine/Saltwater Crocodile [88,108]. Being a keystone species for both the long-term sustainability of the Bornean forest ecosystems [109] and the Sabah tourism industry [30,31,86] justifies the selection of the Borneo Pygmy Elephant as the focus of this pilot study. In addition, Newsome et al. [31] report that visitors to the lower Kinabatangan River had a strong desire to see the wild elephants, but they were not satisfied with that aspect of their visit. To both improve visitor satisfaction and ensure the long-term sustainability of an elephant-viewing based tourism industry aligned to the SDGs, it is important to understand where and under what conditions the elephants are being sighted.

Alfred et al. [65,110] report the difficulty of visually tracking pygmy elephants through the dense forests of Sabah, with the tracking small groups and lone adult males being particularly problematic. Whilst remotely tracking elephants via satellite collaring is an option that has been utilized, that method has been shown to have limitations. The process of tranquilizing and fitting collars to the elephants is invasive and there have also been reports of collars fitted to elephants in Sabah not providing reliable data, failing to transmit any data, and/or falling off the elephants [65].

Given the breadth of the increasingly dated population estimates of Alfred et al. [68], there is an urgent need for further research to improve and update our understanding of the population size and distribution of the elephants in Sabah. The premise for this pilot study was that engaging ecotourists as citizen scientists to develop a non-invasive and cost-effective alternative to supplement traditional ecological research could lead to a photo-identification library that would utilize pattern recognition to identify individual elephants and trace their movements. Ardovini et al. [111] employed such an approach for wild African elephants by developing a reference system based on shape comparisons of distinct folds, nicks, notches along the edges of the earflaps of individual elephants. Close-range remote sensing of elephants through photo-identification should be capable

of dealing with lower resolution images taken in the wild [111]. While beyond the scope of this pilot study, the quality of photographs taken by tourists during riverboat tours using modern smartphone cameras should provide images that allow the identification of individual elephants, providing that the photographs are taken from a suitable distance to the elephant and clearly shows the ear outline.

5.1 Remote Sensing Tourist-Elephant Encounters

By crowdsourcing geotagged photographs from Flickr that featured the project specific hashtag, #picmeelephant, it was possible to extract information about where and when the elephants were being sighted on riverboat tours along the lower Kinabatangan River. Whilst the sampling period for this study was limited to just over ten weeks, given more time it should be possible to detect elephant-viewing hotspots over this stretch of the river. Being a source of dynamic and continuously evolving data, such information would be particularly valuable both for tour operators seeking to optimize elephant viewing opportunities and for informing species monitoring and protected area management [40]. This pilot study provides an example of how close-range remote sensing data generated by citizen scientists can provide pertinent information regarding pygmy elephant utilization of modified and remnant habitat along the lower Kinabatangan River.

5.2 Landscape Context of Elephant Sightings

We believe that the most significant analysis reported in this study is the examination of the landscape matrix in which elephants were sighted. The finding that three out of every four elephant sightings occurred within 1 km of an oil palm plantation is an indication of the fragmented landscape in which this tourism activity occurs. In addition, this finding provides quantitative evidence that ground truths the finding and recommendations of the visitor satisfaction survey research reported in Newsome et al. [31].

As mentioned previously, human-elephant conflict alongside habitat loss and fragmentation has been identified as an increasing threat to the Borneo Pygmy Elephant populations in Sabah [73]. This pilot study also provides insight into the increased exposure of the elephants to human disturbance and changing land use along the lower Kinabatangan River. Damage to crops and subsequent economic losses, because of elephants entering crops and oil palm plantation, has led to extreme incidents of elephants being killed or severely injured [73,74]. A more comprehensive remote sensing dataset would be needed to make informed management decisions regarding the need to mitigate human-elephant conflict in Sabah. This study does, however, provide support for the findings of Othman et al. [73] and for the 500 m riparian buffer recommended by the Sabah Government [70] in the Elephant Action Plan 2012-2016.

In line with United Nation SDG 15: Life on Land [24,26,28] and the Elephant Action Plan 2012-2016 [70] was created with the objective of addressing issues associated with human-elephant conflict, as well as targeting underlying threats to the elephants from habitat loss and fragmentation, disruption to migration routes, and poor genetic diversity. That plan proposed site-specific management actions, including the institution of a "moratorium on new oil palm development within 500 m on both sides of the Kinabatangan River" [70] (p. 19). Enforcement and revegetation of that conservation buffer in the riparian zone of the river is critical for re-establishing habitat connectivity and improving the natural setting in which the elephants are viewed and appreciated. In addition, the research of Horton et al. [112] demonstrates that in addition to the ecological benefits of conserving and restoring tropical riparian buffer zones, that approach also provides economic benefit by increasing the productivity of adjoining oil palm plantations. Hence conservation and restoration of the buffer zone promoted in the Elephant Action Plan would deliver benefits under multiple SDGs.

The findings of this pilot study highlight concerns and questions about the long-term sustainability of elephant-viewing tourism in the Lower Kinabatangan region. In line with the SDGs [24,26,28], attention must be given to restoration of degraded land and improvement of wildlife corridors [67,71,113]. Management plans should be regularly revised and updated as necessary [31,114]. Ecotourism and conservation in this region are inter-dependent [31,78,85] and the prospect of further unsustainable agricultural development will have serious implications for the long-term

viability of tourism based on elephant-viewing along the lower Kinabatangan River. As promoted by the BEST Society [115,116] and the Sukau Ecotourism Research Centre [117], efforts should be made to increase the involvement of local people in tourism as a sustainable livelihood option and to reduce the need for further clearing of privately-owned remnant forest for oil palm cultivation. Informed by the SDGs, a shift towards ecotourism as the principal industry of the region could help to ensure sustained wildlife conservation along the lower Kinabatangan River [26,31,78,85,118].

5.3 Feasibility of SNSs for Long-Term Monitoring

This pilot study explores the potential of engaging ecotourists as citizen scientists and gathering photographic volunteered geographical information via an image-sharing SNS for remote sensing ecological data relating to the endangered Borneo Pygmy Elephant. The ecotourism-based approach established and implemented in this pilot study provided proof of concept, on a small scale, for the potential to map elephant sightings using geotagged photographs that tourists and guides shared via the Flickr SNS. Given that the Borneo based fieldwork and data generation ran for a relatively short time (10 weeks) and was focused to a single lodge, the number of photographs (n = 207) collected in that time was relatively large and comparable to other published citizen science projects using Flickr. The BeeID project, which was spread across all of the United Kingdom, acquired an almost equal number of photographs (n = 206) over the same period [58]. Similarly, 59% of the photographs uploaded for the BeeID project [58] featured geographical information compared to the 65% collected in this study. This comparison provides evidence to support the success of the brochures, information poster, instructional guides, and one-on-one interaction with guests to educate about how to correctly upload geotagged photographs to Flickr. These findings illustrate the potential to upscale and expand this approach over time. For example, if scaled up to the period of one year, over a thousand photographs could be generated at the pilot study upload rate of approximately three photographs per day. This leads to the question of how these large photographic datasets can be applied to species monitoring?

Development of this pilot study was informed by the innovative photo-identification of Whale Sharks (*Rhincodon typus*) using publicly sourced images to implement a mark-recapture approach to studying population dynamics and migration routes [96,119-121]. Geographically disparate and temporally rich monitoring of Whale Sharks has been made possible through a robust citizen science data collection program that utilizes photographs sourced from the public (tourists, ecotourism operators and residents) and researchers [96,121]. The natural spot and stripe patterns present on the flanks of each Whale Shark can be used to identify individuals. These natural markings are analysed by the public domain pattern-recognition software I3S (Interactive Individual Identification System) to look for matches that longitudinally links individual Whale Sharks to sites and track movement patterns [119].

As previously mentioned, elephants can also be identified through their distinguishing features, which in the case of elephants, are the unique folds, nicks, and notches that characterize their earflaps [111]. Ardovini et al. [111] proposed a semi-automated method for wild elephant photo-identification by performing shape comparison of the earflap nick curvature using a matching algorithm. They found that approach was capable of dealing with low resolution photographs with cluttered backgrounds, which would be a requirement when analysing publicly sourced photographs taken on a wildlife tours in a tropical forest setting.

The dedicated online platform, *Wildbook for Whale Sharks* (https://www.whaleshark.org/), is a mark-recapture database that provides the basis for geotagged photograph collection and identification in the Whale Shark research program [121]. The *Wildbook for Whale Sharks* database is operated by the not-for-profit scientific organisation, *Wild Me* (http://www.wildme.org/). Looking forward, adapting the methods of this pilot for remote sensing the location and movement of Borneo Pygmy Elephants in the Lower Kinabatangan range by integrating a dedicated platform such as the Wildbook/Wild Me photo-collection and identification software warrants further exploration. Long term, such collaboration may assist in improving the focus, validity, and security of information

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gathered this citizen science approach of crowd sourcing volunteered geographical information that could be utilised in monitoring the remaining Borneo Pygmy Elephants throughout eastern Sabah.

Photo-identification offers a non-invasive and cost-effective method of tracking Borneo Pygmy Elephants, with the potential for this data to supplement and enhance current research that utilizes satellite tracking of Borneo Pygmy Elephant movements [65,73,113]. A real-world example of such complementary research is the Southern Tanzania Elephant Program in East Africa [122]. That program monitors elephants in Ruaha National Park through the development of an elephant identification database that can be used to assess trends in elephant density, map elephant distribution, and evaluate the impacts of human-elephant conflict [122]. The program involves regular vehicle and aerial transects, camera trapping, and citizen science contributions of sighting data, particularly from Ruaha tour guides. The Southern Tanzania Elephant Program, therefore, demonstrates the adoption of combined approaches to data collection and monitoring to improve understanding and optimize protection of these elephants. The Southern Tanzania Elephant Program demonstrates that combining close-range remote sensing data from an expanded citizen science program that engages ecotourists and guides with data generated by dedicated researcher could provide the enhanced understanding of the Lower Kinabatangan pygmy elephant population.

5.4 Limitations of the Research

As reported by Walden-Schreiner et al. [41], there are inherent limitations when using data crowdsourced from SNSs, particularly in respect to sampling bias. We are aware that not all guests who participated on the riverboat tours chose to take photographs and not all those who did take photographs uploaded them to Flickr. In this sense, the geotagged photographs uploaded to Flickr may not be representative of all elephant sightings along the lower Kinabatangan River, as this approach is only likely to be capturing data from a limited number of content producers [123,124]. Furthermore, with Flickr being a less popular social media platform (Table 1), many guests would have to first download the application and create a Flickr account to be able to contribute, which can pose a significant barrier to participation.

There are also spatial and temporal biases in respect to photographs only being taken of elephants when they were present on the riverbank and sighted during scheduled cruises along a logistically restricted section of the lower Kinabatangan River. As such, elephant sightings could only occur in the riparian zone and were limited to when and where riverboat tours operate. As such no information could be gathered regarding elephant behaviors, numbers, or movements within the landscape more broadly,

Concerns regarding these biases are partly ameliorated by the fact that the section of the Kinabatangan River covered under this pilot study was bordered by Lots 1-7 of the lower portion of the Kinabatangan Wildlife Sanctuary, which covers 82% of the total river length from the villages of Abai to Batu Puteh [71]. The village of Abai (located 40 km from Sandakan harbor) features a vast mangrove forest that restricts elephant movement past that point. Similarly, the Kinabatangan River continues above Batu Puteh village, but elephant movement upstream is restricted by a major highway and settlement in this area [71]. Further, increasing participation amongst guests and guides at SRL and engaging guests and guides from other ecolodges located on the lower Kinabatangan River, would be beneficial in increasing sampling effort and number of captured sightings. A larger sample size would improve the quality and ecological value of the demographic and spatial information remotely sourced from that the ecotourist citizen scientists and professional guides via a social media or a dedicated data capture platform.

To overcome perceived issues [41] regarding the crowdsourcing of location information from amateur close-range remote sensors (i.e. ecotourists and guides), GPS data was automatically rather than manually attached to the shared photographs to improve the precision of mapped sightings. As mentioned in the Methods, this was achieved by sourcing the location coordinates for each photograph via the GPS receivers built into the smart devices used to capture the images. In addition, geotagged photographs shared contemporaneously with elephant sightings were plotted on a map and shown to SRL tour guides to verify the locations where the elephant(s) were encountered.

While all possible measures were taken to optimize data quality for this pilot study, the relatively small sample size and short sampling period means interpretation of the results is more a hypothesis setting rather than a hypothesis testing exercise [125]. Accumulating a larger dataset over an extended period would enhance future research based on the remote sensing methods piloted in this study. The findings of this pilot study do, however, provide proof of concept for using geotagged photographs that ecotourist or guides share on SNSs or dedicated platforms for close-range remote sensing of Borneo Pygmy Elephants and the landscape within which those wild tourism experiences occur.

5.5 Future Research

We hope that this pilot study stimulates further research that explores and validates the use of social media for conservation research aligned to ecotourism experiences. The application of volunteered geographic information shared by ecotourist citizen scientists to generate remote sensing data for ecological and tourism research that was explored in this pilot study revealed that further research is required. That research should focus on improving the quality and efficiency of data collection based on crowdsourcing geotagged tourist photographs from online platforms and the interpretation of such data within a wildlife tourism context. Furthermore, there is a pressing need to ground truth data sourced from online platforms against more traditional field data to assess the validity and reliability of the methods piloted in this study as an alternative supplementary approach for wildlife conservation research.

As reported above, this pilot study does, however, demonstrate proof of concept. It is evident that there is significant potential for future research that utilises close-range remote sensing and photo-identification techniques to answer questions about the Borneo Pygmy Elephant, particularly in respect to population sizes, the interactions both between elephants and with humans, and movement patterns of the elephants.

Despite using the Flickr API service, the process of manually extracting relevant data and storing it within a Microsoft Excel spreadsheet was found to be relatively time-consuming and labour intensive, even for the limited dataset produced by this pilot study. While automated data striping/scraping routines exist [126], the process of recording date, time, and location data from individual photographs could be made more efficient through the establishment of a dedicated platform, such as those developed by the Wildbook/Wild Me collaborations and administrated and operated by researchers. Furthermore, capturing data on a secure dedicated platform (as opposed to publicly accessible social media platforms) would overcome concerns regarding the sharing of target species location information online [127]. Whilst the risk associated with uploading georeferenced photographs of Borneo Pygmy Elephants was deemed to be acceptably low in this pilot project, going forward, it would be responsible to adopt the precautionary approach to ensure that the sharing of such information does not put the target species at risk. It is our recommendation that appropriate cybersecurity for shared data should be considered by future projects using social media or other online platform to remotely sense real-time location data on flora and fauna that may be targeted by poachers.

6. Conclusions

This pilot study explored how remote sensing via tourist-generated photographs sourced from the image-sharing Flickr SNS can be applied in wildlife tourism research. We conclude that while this emerging field of tourism-based research is in its infancy, social media platforms have potential as a dynamic and largely untapped source for remotely sensing ecological and tourism data arising from human-wildlife interactions in natural and modified landscapes.

This study demonstrated the feasibility of using tourist-generated geotagged photographs to map elephant sightings and interpret the landscape matrix in which those encounters occur along the lower Kinabatangan River, Sabah, Malaysia. We postulate that extending this citizen science approach has significant potential to supplement current monitoring of the endangered Borneo Pygmy Elephant population in the Lower Kinabatangan range. In addition, we believe that such an

approach could also be used to provide a relatively low-cost method for benchmarking conditions in Sabah against several the United Nations Sustainable Development Goals and for remote sensing future performance against those goals.

To ensure the long-term success of wildlife monitoring based on this approach, consideration should be given to developing a dedicated platform for capturing photographs and automated methods of elephant identification should be explored. Further, the on-ground presence of a/some committed individual(s) to educate and promote such projects is important for optimizing the engagement of ecotourists as citizen scientists and close-range remote sensors, particularly during the foundation stage of such projects.

Going forward, while recognizing the challenges of the emerging techniques piloted in this study, the availability of social media data provides opportunities to study wildlife in innovative ways. The findings of this pilot study demonstrate the potential of crowdsourcing close-range remote sensing data from photographs tourist share on social media to support and compliment traditional field-based data collection methods used to inform management strategies, protect natural resources, and enhance the long-term sustainability of a wildlife tourism product.

Author Contributions:

The first listed authors (O.W. and T.D.) contributed equally to the writing of this manuscript and as such are Co-First Authors; Conceptualization, primary supervision, project administration, and writing—review and editing, G.S.; Methodology, O.W. and G.S. Investigation, data curation, formal analysis, and writing—original thesis preparation, O.W.; Writing—original draft preparation, review, and editing, T.D.; Funding acquisition, resources, supervision, review and editing, J.K.L.C, A.C.K.T, and D.N.

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