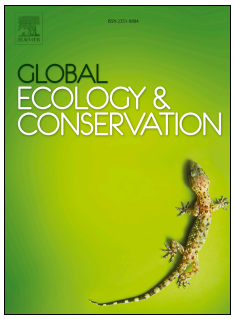

Scaling up local ecological knowledge to prioritise areas for protection: determining Philippine pangolin distribution, status and threats

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Scaling up local ecological knowledge to prioritise areas for protection: determining Philippine pangolin distribution, status and threats

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Local ecological knowledge (LEK) can provide cost-effective baseline ecological data across large geographical areas, and is increasingly seen as an important source of information for rare and cryptic species. However, to date its use as a practical tool for prioritising conservation action is limited. Pangolins are the world's most heavily trafficked wild mammals and all species are in decline. The Philippine pangolin (*Manis culionensis*) is Critically Endangered but conservation efforts are hindered by a lack of knowledge on where populations still exist and where *in situ* action should be prioritised. We conducted the first range-wide systematic survey for the species using household interviews (n=1,296) to provide new data on pangolin distribution, status and threats, and to assess the use of LEK for highlighting priority areas for conservation. LEK about pangolins was high (87% of respondents recognised pangolins and provided further information), with evidence of pangolin occurrence in 17 of the 18 municipalities surveyed. The majority (70%) of respondents had seen a pangolin, but most (72%) perceived pangolins to be 'rare' or 'very rare', and local use of pangolins was reported across the species' range. Spatial differences in sighting frequencies, perceived abundance and reported population trends were observed, providing an important baseline to identify priority sites for targeted research and community-based pangolin conservation.

Keywords: Local Ecological Knowledge; Palawan; Pangolins; Philippines; Population baselines; Spatial prioritisation

1. Introduction

The importance of robust data to inform conservation management is widely recognised by conservation practitioners (Sutherland et al., 2020; Yoccoz et al., 2001). An evidence-based approach allows changes in wildlife populations to be tracked and can identify key areas that are in need of protection, helping to direct limited resources to where they are most needed (Collen et al., 2013; Loh et al., 2005; Pereira and Cooper, 2006). However, obtaining comprehensive data on rare and threatened species to enable conservation action can be difficult, with efforts often confounded by low detection probability (Kéry and Schmidt, 2008; Martin et al., 2007; Thompson, 2004). For some species, this can result in a paucity of basic data, with baseline knowledge of their distribution,

status, or threats limited or non-existent (Willcox et al., 2019). This leaves a void of information, prevents conservation action, and hinders the development of monitoring efforts. Baseline assessments are thus an important first step to help inform conservation planning before in-depth monitoring methods can be developed in areas shown to contain species of conservation concern (Knight et al., 2006).

Taking conservation action with limited knowledge of a system can result in conservation efforts of little value, and can be problematic when designating areas for protection. Aichi Target 11 of the 2010 Convention of Biological Diversity aims for >17% of terrestrial land to be protected by 2020. However, many countries lack the data needed to guide effective expansion of their protected areas, with up-to-date information on key species, ecosystems and threats often absent, insufficient or unavailable at a scale that can be used to make decisions at national or international levels (Minin and Toivonen, 2015). Much has been written on the shortcomings of conservation areas (Butchart et al., 2015; Mora and Sale, 2011; Pressey et al., 2015; Rife et al., 2013), which can often fail to adequately represent threatened species (Joppa and Pfaff, 2009; Rodrigues et al., 2006; Venter et al., 2017) and/or integrate social and political considerations (Brockington and Igoe, 2006; Brockington and Wilkie, 2015; Brosius, 2004; West et al., 2006). Effective designation of protected areas therefore requires identification and employment of cost-effective data sources that capture relevant ecological and socio-cultural baselines, and practical yet socially-just solutions are needed to assist conservation practitioners when faced with limited data.

Local people can often provide crucial knowledge on rare species utilising the same environments, and in particular on species that are difficult to detect using standard ecological monitoring methods. This type of knowledge is known as Local Ecological Knowledge (LEK) and represents first-hand information derived through an individual's observations of their environment (Newing, 2011). To date, LEK data have been used as a conservation aid to clarify species' distributions (Mahmood et al., 2020; Trageser et al., 2017; Turvey et al., 2015; Zanvo et al., 2020), provide insights into the status of threatened species (Anadon et al., 2009; Nash et al., 2016; Turvey et al., 2015, 2014), generate quantitative occupancy estimates (Brittain et al., 2018; Zeller et al., 2011), inform fisheries management (Beaudreau and Levin, 2014; Drew and Henne, 2006; Thurstan et al., 2016), and provide information on local threats and social considerations such as uses of wildlife (Nash et al., 2016). However, although LEK data collection can represent a cost-effective method of obtaining conservation-relevant data across wide geographical areas (Anadón et al., 2010; Nash et al., 2016), its use as a practical tool to aid terrestrial conservation planning directly is still limited.

As with any monitoring method, there are biases associated with LEK data collection, and potential limitations of using such data to inform conservation. Certain species, notably large-bodied, charismatic vertebrates and/or species with cultural or economic value, may be better-represented within LEK than others (Karst and Turner, 2011; Nyhus et al., 2003; Parry and Peres, 2015), and

respondent knowledge levels may differ or be influenced by socio-demographic parameters (Beaudreau and Levin, 2014; Iniesta-Arandia et al., 2014; Papworth et al., 2009). This presents challenges when working across large geographical areas, as random respondent selection is needed to achieve adequate sample sizes for analysis, complicating efforts to ensure respondent knowledge levels are comparable across study areas. Further, whereas LEK data can determine species' presence or absence, they cannot determine absolute abundance, an important metric in spatial prioritisation of conservation effort; LEK data might instead be restricted to providing broad-level insights and relative abundance patterns, and are limited spatially to areas subject to human use that may coincide with anthropogenic threats but not necessarily with areas of high species abundance. However, uncertainty and bias can be reduced through appropriate data collection and critical analysis that accounts for socio-demographic variation within datasets. For example, inclusion of additional "control species" within survey design permits comparison of between-species relative abundance patterns, and assessment of whether data variation is likely to reflect underlying ecological patterns or instead variation in respondent knowledge or experience (Turvey et al., 2015). The use of interspecies comparisons has been used elsewhere to provide insights into species distributions and relative abundance patterns for other rare and cryptic species (Turvey et al., 2015) and increases the likelihood of respondents reporting potentially sensitive information on the target species, alongside reducing social desirability bias by removing the focus from the species of interest (Newing, 2011).

Here, we explore the use of LEK to help identify priority areas for community-based conservation using the Philippine pangolin (*Manis culionensis*) as a case study. Endemic to Palawan Province (mainland Palawan and associated islands) in the Philippines, this species is classified as Critically Endangered on the IUCN Red List (Schoppe et al., 2019), and is an example of a rare mammal which, like other pangolin species, is rarely detected through general biodiversity surveys (Ichu et al., 2017; Schoppe et al., 2020; Willcox et al., 2019). Few studies on the species exist in the scientific literature, and whilst research efforts have been increasing in recent years (Lagrada, 2012; Marler, 2016; Schoppe and Cruz, 2009), including research on the use of pangolins by indigenous peoples (Schoppe et al., 2020), range-wide studies remain lacking. Thought to be the most heavily trafficked wild mammals, all eight pangolin species are threatened with extinction and have experienced large declines (Challender and O Criodain, 2020; Heinrich et al., 2017). Establishing robust ecological baselines on distribution, abundance, trends and threats for these species is therefore urgently needed to help develop monitoring methods and inform conservation efforts (Ingram et al., 2019; Willcox et al., 2019).

In this study, we use a multi-species LEK survey in communities living close to natural areas to provide a rapid assessment of status and threats to the Philippine pangolin, to better understand knowledge levels, interactions, and local use of pangolins, and provide the first large-scale range-

wide assessment for the species. We also investigate local values and willingness to be involved in conservation to better understand local attitudes towards conservation. Such baselines can help design tailored interventions and help prioritise conservation action to areas with local support, where conservation activities are more likely to be successful in the long-term (Bennett and Dearden, 2014; Berkes, 2007). We use these baselines to explore the use of LEK for prioritising community-based conservation areas for the Philippine pangolin. By investigating the extent to which LEK data can be used as a practical community-based conservation tool, our findings also provide wider conservation lessons about how to use LEK to guide spatial conservation planning for other rare and cryptic species.

2. *Materials and Methods*

A large-scale household survey using a standardised questionnaire was conducted across Palawan Province between January and June 2019. All mainland Palawan municipalities (n=13), the city of Puerto Princesa, and the island municipalities of Araceli, Busuanga, Coron, Culion and Linapacan were surveyed (figure 1). Balabac and villages in southernmost Bataraza and Rizal were excluded due to safety and security concerns. The island municipalities of Agutaya, Cagayancillo, Cuyo, Kalayaan and Magsaysay were not surveyed as available historical records showed no evidence of local pangolin occurrence, and logistical considerations prevented the inclusion of these remote island municipalities.

In total, 211 neighbourhoods across 72 villages were targeted to provide wide geographical coverage across the province. Villages were selected at random using QGIS version 3.8.0 (QGIS Development Team 2018), with the number of villages per municipality weighted depending upon the geographical area of each municipality. Specific neighbourhoods were chosen through discussion with village officials who recommended areas with high human-wildlife interactions, thereby targeting areas where respondent knowledge levels were thought to be highest. Eighteen households per village were interviewed and were randomly selected by walking through each neighbourhood and targeting every fifth household.

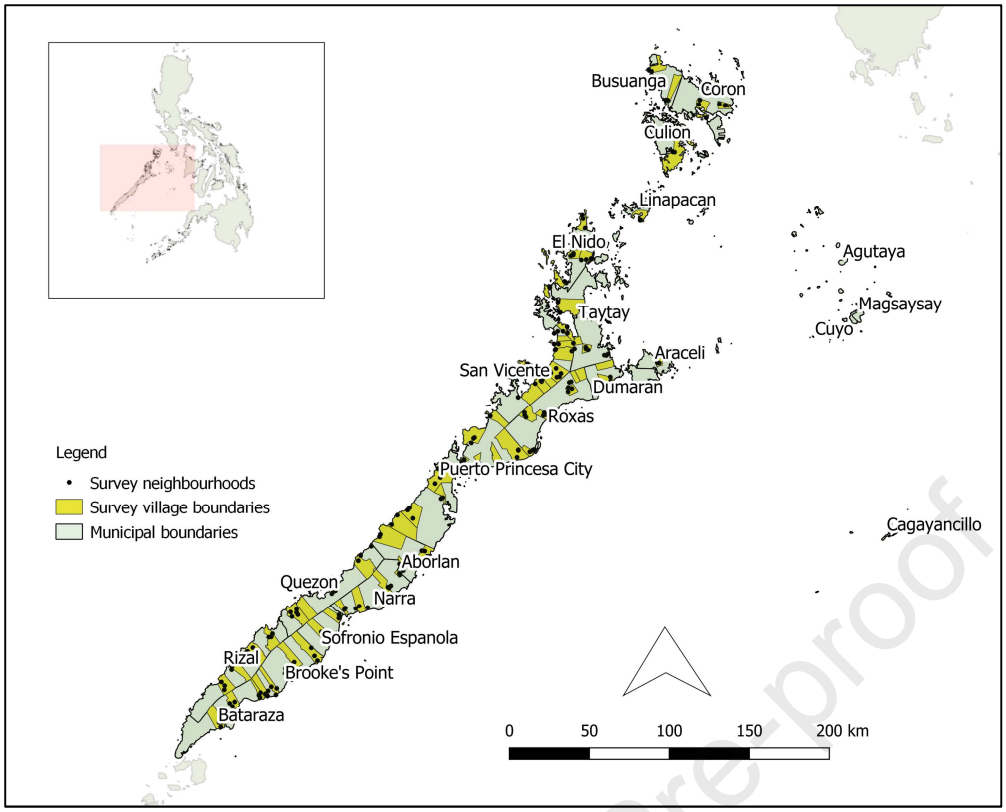


Figure 1. Map of Palawan Province, indicating surveyed neighbourhoods (n=211; black points) and surveyed villages (n=72; village administrative boundaries highlighted in yellow). Municipal and city boundaries represented with black lines (n=18).

Permission was sought from each municipal or city mayor and village captain prior to conducting research, and all surveys were conducted in villages outside of areas with a certificate of ancestral domain title. The purpose of our research was explained to respondents prior to every interview and free prior informed consent was sought verbally. All responses were anonymous. Participants could stop the interview at any time and could remove their data from the survey by contacting their village captain. Only adults aged 18 or above were interviewed, and interviews were limited to one person per household to increase independence of responses. Interviews were conducted in Filipino, Cuyonon or Bisayan languages by interviewers local to Palawan Province to ensure appropriate positionality and minimise social desirability bias (Newing, 2011). Interviewers received a week's training, followed by two rounds of pilot surveys to trial and reformat question structure and wording.

Questionnaires consisted of both closed and open-ended questions, took up to 35 minutes to complete (Appendix 1), and were completed on android tablets using the software Open Data Kit (Hartung et al., 2010). Data on respondent attributes and socio-demographics were collected, followed by questions focussed on the respondent's LEK in relation to five species (Table 1).

155

156 *Table 1. Species included in questionnaire, detailing their conservation status and reasons for inclusion.*

Species	IUCN Red List Status	Endemic to Palawan?	Population trend	Used locally or traded?	Notes on inclusion
Palawan stink badger (*Mydaus marchei*)	Least Concern	Yes	Stable	Yes	Common species that respondents should be familiar with. Presented first to put respondents at ease and encourage discussion.
Giant anteater (*Myrmecophaga tridactyla*)	Vulnerable	No, native to South and Central America	NA	NA	Negative control to check for respondent accuracy. Interviews where respondents reported seeing giant anteater were excluded from analysis.
Philippine pangolin (*Manis culionensis*)	Critically Endangered	Yes	Declining	Yes	Focal study species. Declining and threatened Palawan endemic.
Palawan porcupine (*Hystrix pumila*)	Vulnerable	Yes	Declining	Yes	Declining and threatened Palawan endemic. Easily identifiable.
Palawan hornbill (*Anthracoceros marchei*)	Vulnerable	Yes	Declining	Yes	Declining and threatened Palawan endemic. Easily identifiable.

157

158 Questions on the pangolin, porcupine and hornbill were randomised to remove any potential order
159 bias. Photographs (sourced locally or from www.arkive.org) were used to present each animal and
160 engage respondents in the interview process (Nash et al., 2016). Follow-up questions asked
161 respondents if they recognised each species, and if so, whether they had seen it, the calendar year
162 of their last sighting, last-sighting location (within or outside village boundaries, habitat types, and
163 specific habitat characteristics), frequency of sightings, and perceptions on the conservation status
164 and population trends (covering the past ten years) for each species. Open-ended questions on
165 cultural values and local uses of wildlife were also included, providing respondents with the
166 opportunity to discuss personal or local beliefs and uses of pangolins. Respondents were also
167 asked their opinions on conservation importance and willingness to be involved in conservation
168 efforts. Research was authorised by the Palawan Council for Sustainable Development (Gratuitous
169 permit 2018-23), with official endorsement from each local government unit. Project design was
170 approved by the ZSL Human Ethics Committee (Reference: I-FM12).

171 *2.1 Quantitative analysis*

172 Interview data were translated into English by D.B. Corona in August 2019. Data were analysed
173 using R version 3.5.1 (R Development Core Team, 2018). Variables influencing whether
174 respondents recognised or had seen each species were investigated using generalised linear mixed
175 models (GLMMs) using a binomial error structure, as the response variables are binary (yes/no).

The R package “glmmTMB” was used for analysis. Variables influencing how a respondent: i) perceived species population changes, ii) perceived species abundance, iii) perceived the importance of conservation, and iv) reported their willingness to help monitor wildlife were investigated using ordinal logistic regression models using the R package “ordinal”. Models were fitted using the “clmm” function to allow for the inclusion of random effects. Ordinal logistic regression models were also used to investigate factors influencing perceived abundance and trend scores across all species. Variables for inclusion were selected *a priori* (Appendix 2, Table 1). Post-hoc tests using the R package ‘emmeans’ were conducted to compare between groups. Chi-squared tests were used to test for associations between respondent recognition, sightings and perceptions of pangolins and respondent recognition, sightings, and perceptions of other Palawan endemic species, using the subset of respondents who could recognise all four species.

3. Results

A total of 1,296 interviews were completed during the survey. Two respondents reported sightings of giant anteater, so were excluded from analysis. Most respondents (82%, n=1067) had lived in their current village since birth, with <1% (n=12) of respondents immigrating to Palawan post-2010. Respondent demographic characteristics are shown in Table 2.

Table 2: Demographic characteristics of respondents.

Demographic characteristics		Number of respondents
Sex	Female	877
	Male	419
Age	Mean age (range)	44 (18-87)
Occupation	Farmer	705
	Private employment	264
	Fisher	212
	Shop owner or trader	55
	Other	58
Frequency of visits to natural places	Daily or weekly	870
	Monthly	261
	Yearly/biannually	97
	Less than yearly	36
	Other/no longer visit	30
Ethnolinguistic group	Palaweno (Cuyunen, Agutayen, Kagayanen, Pala'wan, Tagbanua)	572
	Visayan (Cebuano, Ilonggo)	473
	Luzon (Ilocano, Bicolano)	204
	Moro	42
	Other	3

3.1. Pangolin status and threats

Pangolin recognition and knowledge across Palawan province was high, with 87% (n=1123) of respondents able to recognise and provide further information on pangolins and 70% (n=902) of respondents reporting pangolin sightings. Local names for pangolin were provided by 86% (n=1114) of respondents: 'balinton' (40%, n=444), 'balintong' (40%, n=442), 'balikon' (10%, n=117), 'tanggiling' (10%, n=107) and 'buey' (<1%, n=4). Municipality influenced respondent recognition of pangolins (GLMM, X^2=71.644, df=17, p<0.001) and respondent sightings of pangolins (GLMM, X^2=69.557, df=16, p<0.001), with significantly lower pangolin recognition and zero sightings reported by respondents in Linapacan (Figure 2). Respondents in Bataraza had significantly lower sighting reports compared to respondents in Roxas, San Vicente, Taytay and Puerto Princesa, and respondents in Brooke's Point reported significantly lower sightings than respondents in Aborlan,

Busuanga, Coron, El Nido, Puerto Princesa, Roxas, San Vicente and Taytay. Last sightings were reported from a variety of habitat types; secondary growth forest was most frequently reported (54%, n=490), followed by virgin forest (14%, n=125). 'Other' was the third most frequently reported habitat described (13%, n=120), with descriptions of 'other' related to captured pangolins observed by respondents in people's possession or in houses.

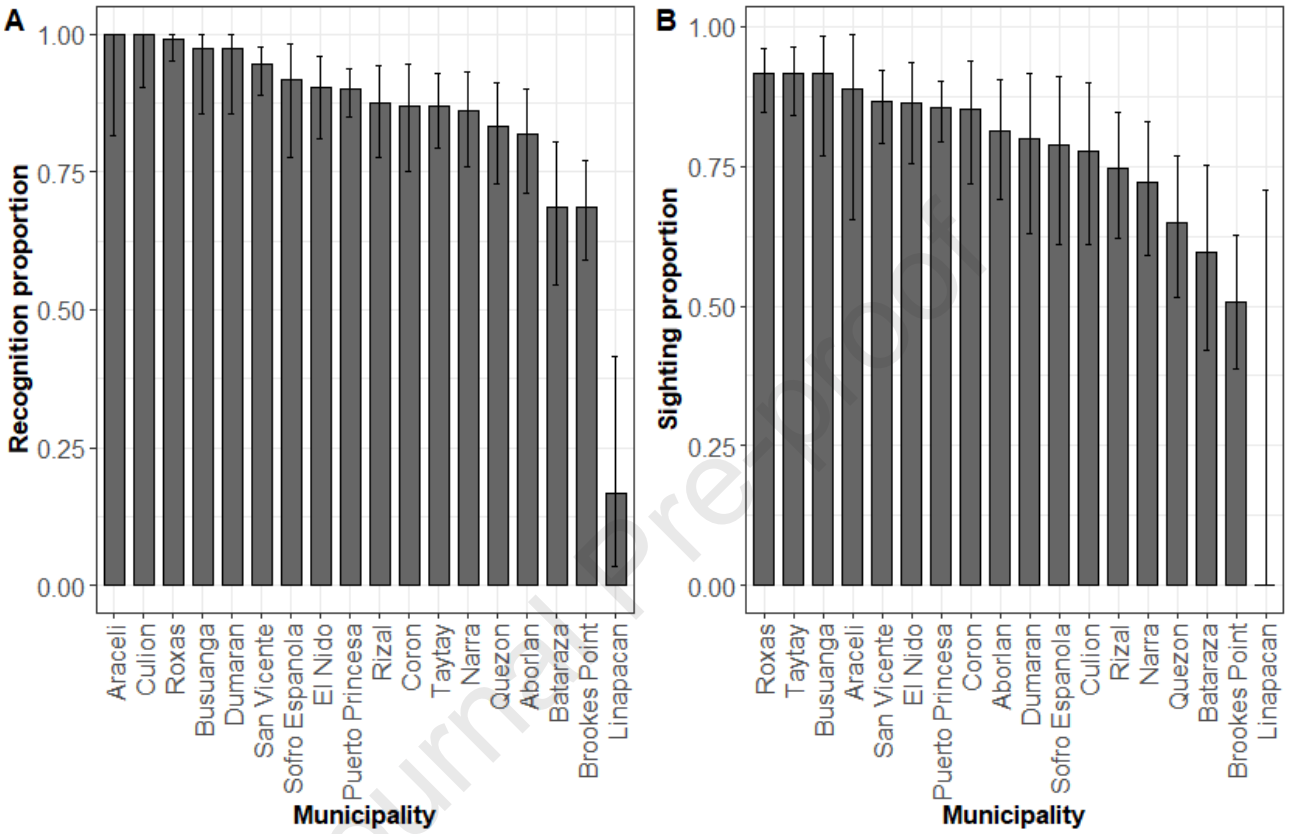


Figure 2. a) Proportion of respondents who could recognise a pangolin per municipality. b) Proportion of respondents reporting pangolin sightings per municipality (representing subset of respondents who could recognise a pangolin). Error bars show 95% confidence intervals, with non-overlapping error bars indicating the municipalities that significantly differed in: i) respondent levels of pangolin recognition, ii) respondent sightings of pangolins.

Despite high overall knowledge levels and sightings, just 19% (n=248) of respondents had seen a pangolin recently (in 2018 or 2019). As with overall sightings, municipality significantly influenced whether respondents had seen a pangolin recently (GLMM, X^2=36.360, df=16, p=0.003), with model-predicted probabilities of recent sightings highest in Busuanga and Coron (Figure 3). Post hoc tests indicate that respondents in Aborlan, Busuanga, Coron, Culion, El Nido, Roxas and Taytay had significantly higher sighting probabilities compared to Brooke's Point and Bataraza; Busuanga had significant higher sighting probabilities compared to Dumaran, Narra, Puerto Princesa, Quezon, Rizal, Roxas, San Vicente and Sofronio Espanola; Coron had significantly higher

sighting probabilities than Dumaran, Narra, Puerto Princesa, Rizal, Roxas, San Vicente, Brooke's Point and Bataraza; and Taytay had significantly higher sighting probabilities than Dumaran, San Vicente and Puerto Princesa, Bataraza and Brooke's Point.

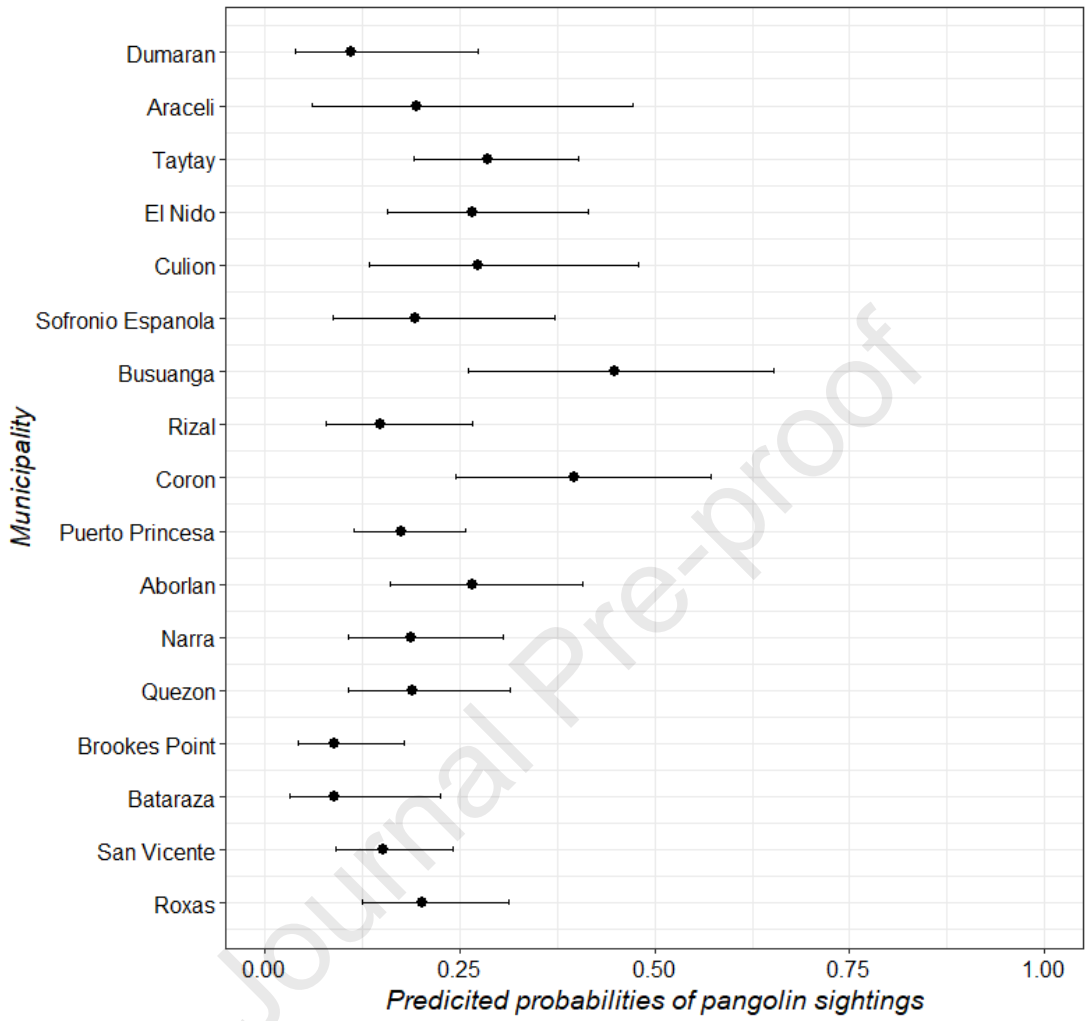


Figure 3. Model-predicted probabilities of recent pangolin sightings across municipalities, covering the period January 2018–July 2019 and using the subset of respondents who could recognise a pangolin. Error bars show 95% confidence intervals.

Older respondents (GLMM, X^2=23.236, df=1, p<0.001) and male respondents (GLMM, odds ratio 1.84±CI 1.15–2.95, df=1, p=0.011) were more likely to recognise pangolins. Although recognition of pangolins was not explained by respondent education levels, respondent occupation did influence the probability of recognising a pangolin (GLMM, X^2=10.244, df=4, p=0.037), with fishers (odds ratio 0.56±CI 0.32–0.98) and those in private employment (odds ratio 0.51±CI 0.32–0.83) less likely to recognise a pangolin compared to farmers. Ethnicity was also significant (GLMM, X^2=21.235, df=7, p=0.003), with respondents of Bisayan, Cuyunen and Pala'wan ethnolinguistic groups more likely to recognise a pangolin than respondents of the Luzon ethnolinguistic groups.

241 Male respondents were almost twice as likely to report pangolin sightings compared to female
242 respondents (GLMM, odds ratio 1.92±CI 1.29–2.86, df=1, p=0.001), and the odds of having seen a
243 pangolin increased with age (GLMM, odds ratio 1.02±CI 1.01–1.03, df=1, p=0.001). Respondent
244 occupation also influenced the probability of seeing a pangolin (GLMM, X^2=18.950, df=4, p<0.001),
245 with those in private employment (GLMM, odds ratio 0.47±CI 0.31–0.71, df=4, p=<0.001) or 'other'
246 occupations (GLMM, odds ratio 0.30±CI 0.14–0.66, df=4, p=0.002) having lower odds of reporting
247 sightings compared to farmers. Ethnicity did not influence sightings. Recent sightings were
248 significantly predicted by gender (GLMM, odds ratio 1.95±CI 1.43–2.66, df=1, p<0.001), with male
249 respondents almost twice as likely to have seen pangolins recently compared to female
250 respondents. Age, occupation and ethnicity did not influence recent pangolin sightings.

251 *3.2. Species comparisons*

252 There was no significant difference between pangolin and stink badger recognition (X^2=3.364, df=1,
253 p=0.07), but there was a significant difference between pangolin and porcupine recognition
254 (X^2=201.4, df=1, p<0.001) and pangolin and hornbill recognition (X^2=85.044, df=1, p<0.001), with
255 pangolins significantly more likely to be recognised (Figure 4). There were also significant
256 differences when comparing both overall sightings and recent (2018-2019) sightings of pangolins to
257 the other three species. Overall there were significantly fewer pangolin sightings than stink badger
258 sightings (X^2=34.688, df=1, p<0.001), but significantly more pangolin sightings than porcupine
259 sightings (X^2=117.39, df=1, p<0.001) or hornbill sightings (X^2=49.62, df=1, p<0.001). There were
260 significantly fewer recent pangolin sightings than recent sightings of stink badger (X^2=4.624, df=1,
261 p<0.032), porcupine (X^2=84.611, df=1, p<0.001) or hornbill (X^2=14.38, df=1, p<0.001, Figure 4).

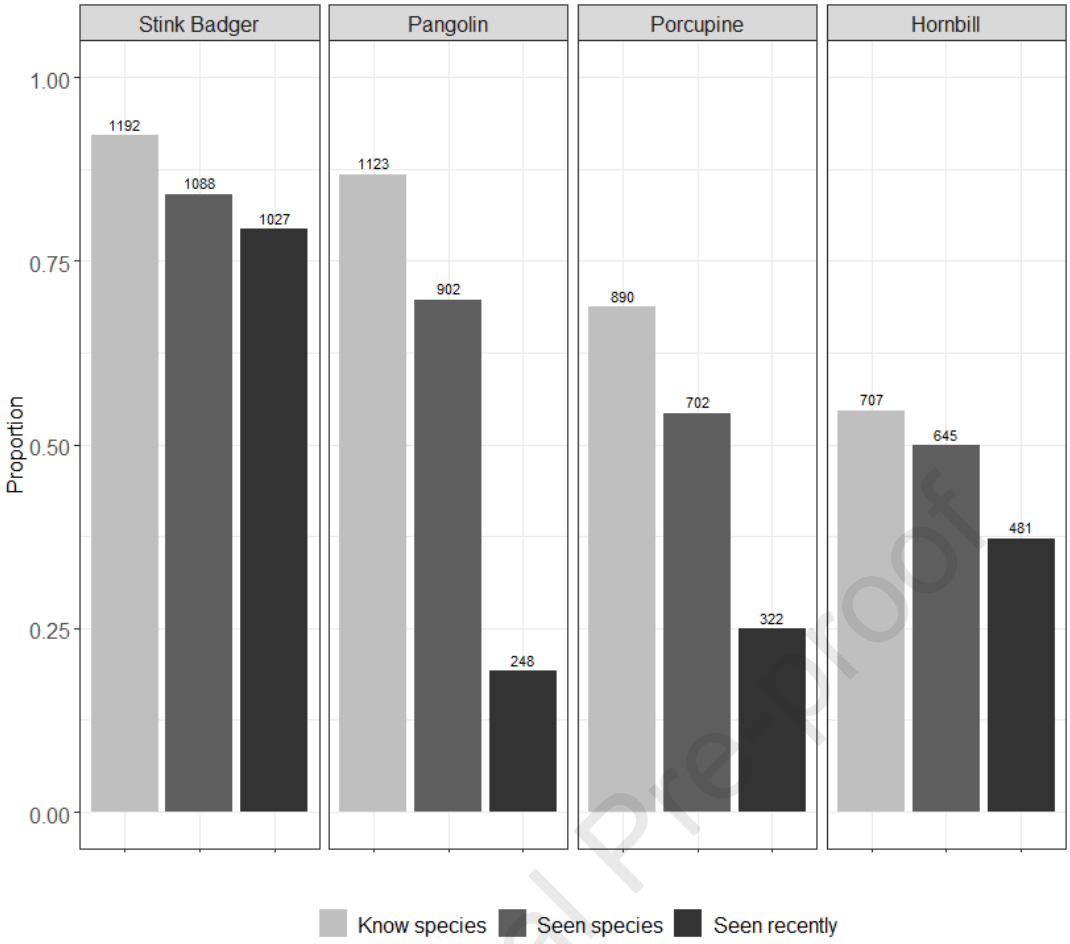


Figure 4. Proportion of respondents who recognised, had seen, and reported recent (2018-2019) sightings of four Palawan endemic species.

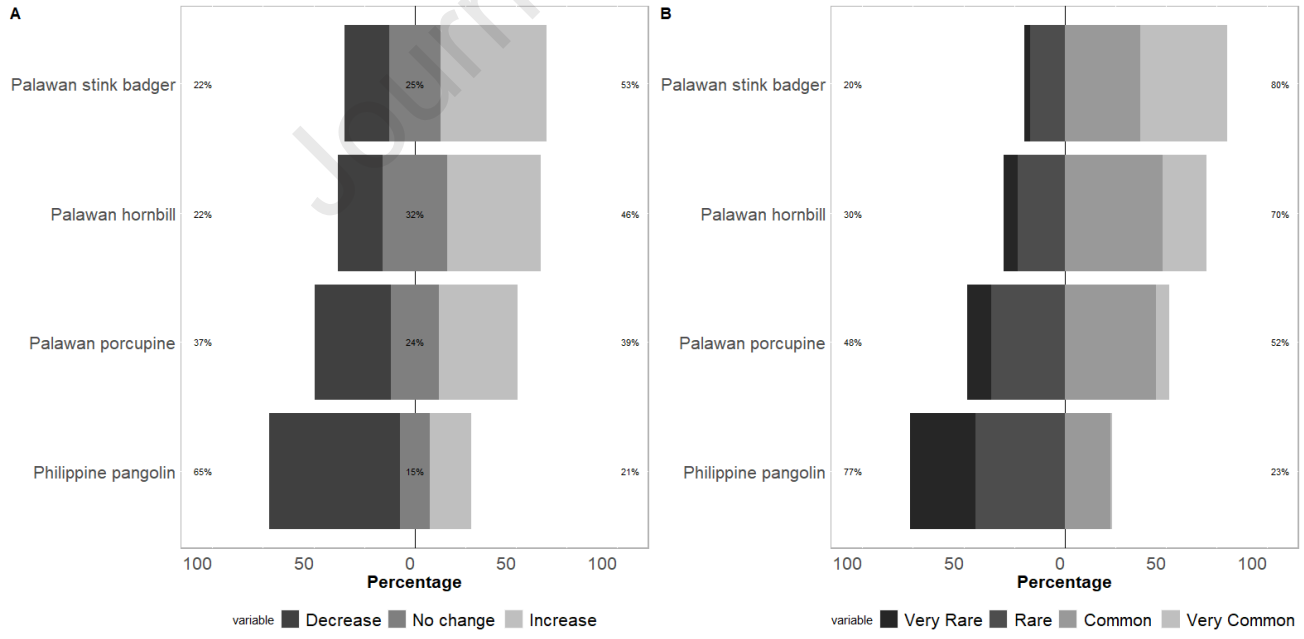
3.3. Perceived pangolin abundance and trends

Across the subset of respondents who could recognise a pangolin, 72% (n=811) perceived the pangolin population in their village to be either 'rare' or 'very rare', 22% (n=248) perceived it to be 'common' or 'very common', and 6% (n=64) were unsure. Municipality had a significant effect on perceived pangolin abundance (CLMM, X^2=43.405, df=16, p<0.001; Appendix 2: Figure 1), as did recent pangolin sightings (CLMM, X^2=150.220, df=1, p<0.001), with respondents who reported seeing pangolins in 2018-2019 more likely to give a higher abundance score. Age and gender did not have a significant effect, but occupation did (CLMM, X^2=9.881, df=4, p<0.042), with farmers more likely to report higher abundance scores compared to respondents in private employment.

Pangolin declines were reported by respondents from all municipalities (excluding Linapacan), with a most frequent response of 'decrease' for every municipality. Municipality significantly influenced results (CLMM, X^2= 40.142, df=16, p<0.001; Appendix 2: Figure 2), as did gender (CLMM, X^2=

279 6.117, df=1, p<0.013), with male respondents more likely to report negative population trends. Age
280 and occupation had no significant effect, but respondents who had seen a pangolin recently were
281 more likely to report either no population changes or increasing population trends (CLMM,
282 X^2=32.146, df=1, p<0.001).

283 Across focal species, pangolins were most frequently perceived to be rare or very rare by
284 respondents (Figure 5b), and were most frequently reported to have declined over the past ten
285 years (Figure 5a). Species abundance scores were significantly different (CLMM, X^2=1450.69, df=3,
286 p<0.001), with respondents significantly more likely to report lower abundance scores for pangolins
287 compared to all other species. Perceived abundance was also influenced significantly by
288 municipality (CLMM, X^2=65.44, df=14, p<0.001; Appendix 2: Figure 3), gender (CLMM, X^2=7.17,
289 df=1, p<0.001), and occupation (CLMM, X^2=23.62, df=4, p<0.001), with males more likely to report
290 higher abundance scores, and farmers more likely to report higher abundance scores compared to
291 fishers, people in private employment, or other occupations. Age and ethnicity had no significant
292 effect. Species trend scores were also significantly different (CLMM, X^2=586.05, df=3, p<0.001),
293 with reported pangolin trends significantly differing from trend reports of all other species. Scores
294 were significantly influenced by municipality (CLMM, X^2=33.42, df=14, p=0.002; Appendix 2: Figure
295 4), ethnicity (CLMM, X^2=42.89, df=7, p<0.001; Appendix 2: Figure 5) and occupation (CLMM,
296 X^2=27.08, df=4, p<0.001), with farmers and fishers more likely to give positive trend scores. Age
297 and gender did not influence results.



298

299 *Figure 5. a) Percentage of respondents who perceived each focal species as declining, stable or increasing.*
300 *b) Percentage of respondents who perceived each focal species as very rare, rare, common or very common.*

301

Mean last sighting dates for pangolins were the oldest of all species (Figure 6a). Across-species differences were also seen across municipalities (Figure 6b). The majority of last sightings for stink badgers and hornbills occurred in 2019 (88%, n=955 and 60%, n=384, respectively), giving these two species recent mean sighting years for most municipalities. Last sightings for porcupines and pangolins were more dispersed across time, resulting in older mean last sighting years for these two species. Overall, 21% (n=148) of porcupine last sightings occurred in 2019, with the majority of records (24%, n=165) occurring in 2018, whereas only 10% (n=93) of pangolin last sightings occurred in 2019 and 17% (n=155) in 2018.

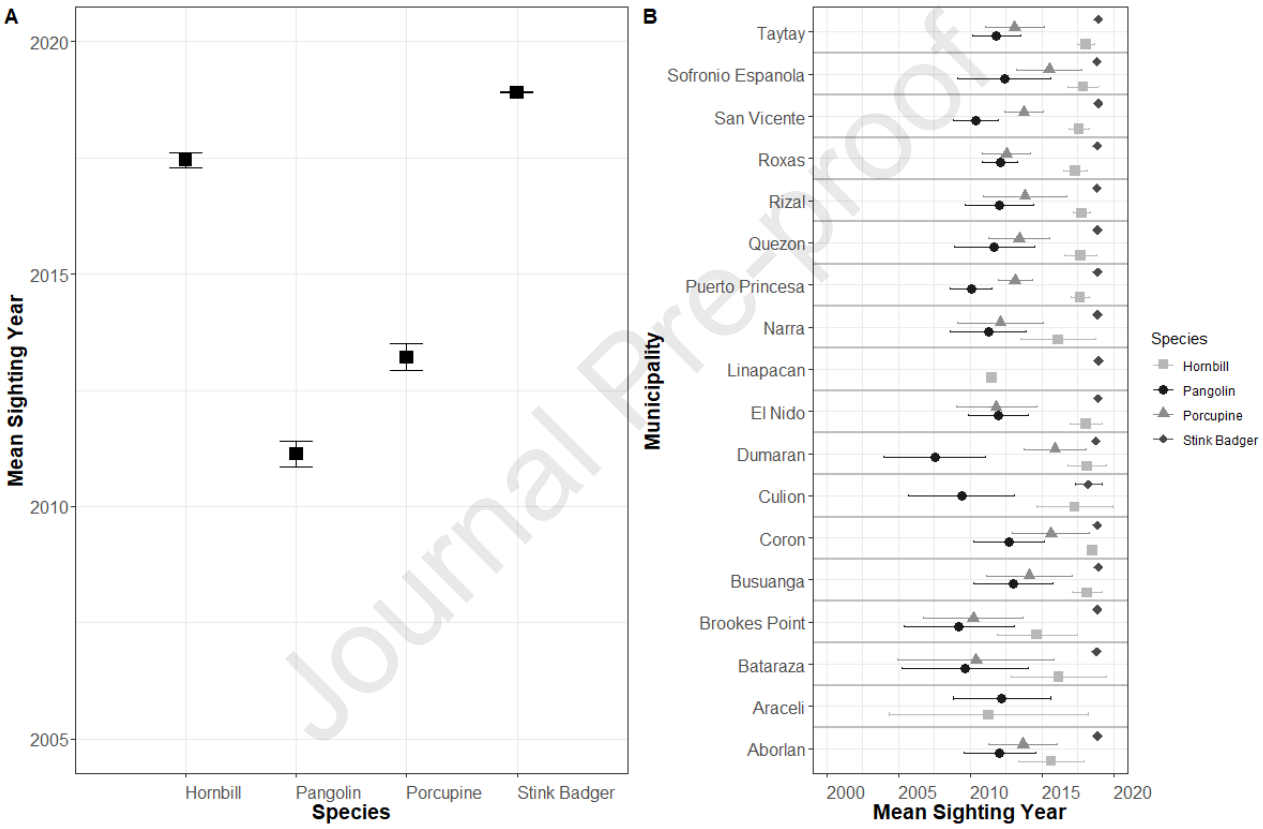


Figure 6a. Mean last sighting year per species. Figure 6b. Mean last sighting year per species per municipality. Both plots use a trimmed mean with the oldest 5% of data points excluded to remove outliers. Error bars indicate 95% confidence intervals.

3.4. Local uses of pangolins

Local use of pangolins was reported by 49% (n=553) of respondents, with many respondents describing multiple uses: 75% (n=492) of descriptions related to pangolin consumption, 20% (n=131) related to pangolin trade, and 5% (n=30) related to medicinal use. Pangolin scales, blood and internal organs were all reported to have medicinal properties and used to treat conditions such as asthma, tuberculosis, stomach aches, lung conditions and back pain (Appendix 2: Table 2). At the village level, 99% of villages (n=71 in 17/18 municipalities) reported pangolin consumption, 71%

(n=51 in 15/18 municipalities) reported pangolin trade, and 28% (n=20 in 9/18 municipalities) reported use of pangolins for medicinal purposes. Other cultural uses were reported at low frequencies (n=48), including the burning of scales to protect against bad spirits or to ward off insects in rice fields (Appendix 2: Table 3).

3.5. Respondent willingness to engage in conservation and perceived importance of conservation

Across respondents, few reported low or no willingness to help monitor wildlife and protecting wildlife was largely perceived to be important or very important (Appendix 2: Figures 6 and 7). However, willingness scores and importance scores were both significantly influenced by municipality (willingness: CLMM, X^2=49.268, df=17, p<0.001, Appendix 2: Figure 6; importance: CLMM, X^2=40.140, df=17, p<0.001, Appendix 2: Figure 7); in particular, respondents in Bataraza and Brooke's Point were more likely to give lower willingness and perceived importance scores compared to respondents in Aborlan, Busuanga, Culion, Narra, Puerto Princesa, Quezon and Roxas. Gender significantly influenced scores, with male respondents more likely to give higher willingness scores (CLMM, X^2=9.717, df=1, p<0.002) and higher importance scores (CLMM, X^2=5.905, df=1, p<0.015). Education also significantly influenced both willingness scores (CLMM, X^2=15.433, df=4, p<0.004) and importance scores (CLMM, X^2=16.546, df=4, p<0.002), with respondents with college-level education more likely to give higher willingness scores than respondents with no, elementary or high school-level education, and respondents with high school or college-level education more likely to give higher importance scores than respondents with no or elementary-level education. Occupation and ethnicity influenced willingness to help monitor wildlife, with those of 'other' occupations less likely than all other occupations to give high willingness scores, and respondents of Tagbanua ethnicity more likely to give higher willingness scores compared to all other ethnicities. Occupation and ethnicity did not influence perceived importance of wildlife protection and age did not significantly influence either model. All model results are presented in Appendix 2, Table 4.

4. Discussion

This study represents the first range-wide systematically compiled LEK dataset for the Philippine pangolin. With limited data previously available for this Critically Endangered species, we provide important new and up-to-date insights on where populations persist, their perceived status and population trends, and ongoing threats across their range, supporting findings elsewhere that suggest LEK can provide rapid data on the status and threats to species of conservation concern (Nash et al., 2016; Pan et al., 2016; Turvey et al., 2015, 2010). With pangolin populations facing an urgent need for both effective monitoring methods (Khwaja et al., 2019; Willcox et al., 2019) and conservation action, knowing where to begin can be a difficult first step. We propose that LEK is a valuable starting point to address both objectives in situations where robust baseline data are otherwise lacking, with the potential to rapidly determine species distributions and inform conservation efforts over large areas with relatively low budgets. We also demonstrate that LEK can provide a useful overview of variation in knowledge, sightings, local use, and conservation values across a large study area, which are essential for identifying appropriate precautionary measures, informing further research, and prioritising conservation actions.

Whereas increased trade levels (Gomez and Sy, 2018) and reports of large declines (Schoppe et al., 2020) have raised concerns that Philippine pangolins may have disappeared from much of their known range, our last sighting results indicate that pangolins are still present across most of Palawan Province, with sightings from 2018 and 2019 reported in all municipalities surveyed other than Linapacan, thus indicating the potential for conservation initiatives across the species' range. Pangolins have previously been assumed to not occur on Linapacan, but we provide the first field data to strongly suggest local absence, with no past or present records of pangolins reported by respondents. Elsewhere, our data provide no evidence that pangolins have been lost from any of the 17 surveyed municipalities across Palawan, representing over 70% of the province's 24 municipalities. Compared to similar studies on pangolin species elsewhere (Nash et al., 2016; Newton et al., 2008; Zanvo et al., 2020), these results suggest that Philippine pangolin populations may not have reached the critical levels shown by Chinese pangolins (*Manis pendadactyla*) in China (Nash et al., 2016) and Vietnam (Newton et al., 2008), or by giant pangolins (*Smutsia gigantea*) in Benin (Zanvo et al., 2020), with a high proportion of interview respondents in these studies considering some populations to be locally extinct.

However, although recent sightings indicate the species' continued persistence across the province, most participants considered it to be either rare or very rare, and declines were reported in every municipality. Further, abundance ratings for pangolins were significantly

lower than results for other Palawan species, most of which are also threatened and declining, with the majority of respondents perceiving the pangolin population in their local area to be rare or very rare. Pangolins were also the species most regularly reported to be declining, with the majority of respondents reporting declines, and pangolin trends significantly worse than trends reported for all other species. Indeed, despite high levels of respondent recognition and overall sighting frequencies for pangolins, mean sighting dates and recent pangolin sightings were the lowest for all our target species. High overall sighting frequencies coupled with relatively few recent sightings and high probability of reporting declines are indicative of substantial recent declines in pangolin populations. These results suggest that in absolute terms, pangolins are probably now relatively rare across the province, and despite a wide distribution, populations are likely to be small and declining. There is therefore an urgent need to establish conservation efforts before it is too late to help the species.

Though in overall terms, multiple metrics of pangolin status indicate that the species is now relatively rare across the province, geographical differences in sighting frequencies, trends and perceived status were seen, suggesting that occurrence and threats may not be equally distributed across the species' range. The northern municipalities of Busuanga, Culion, El Nido, Puerto Princesa, Roxas, San Vicente and Taytay had significantly higher sighting probabilities compared to the southern municipalities of Bataraza, Brooke's Point, Narra and Quezon, and respondents in Aborlan, Bataraza, Brooke's Point and Narra had a high likelihood of reporting pangolins as rare or very rare. Respondents from Aborlan, Roxas, San Vicente and Sofronio Espanola had the highest likelihood of reporting negative trends in local pangolin populations, despite high overall sightings reported by respondents in Roxas and San Vicente. This pattern, coupled with low levels of recent sightings, could suggest these two municipalities have suffered substantial pangolin declines in recent years.

Although these results should be interpreted with caution, as villages were surveyed at random and hence important pangolin areas may not have been captured evenly across the province, our results provide evidence that pangolin populations may be healthier in some northern municipalities compared to the south. Whereas socio-demographic differences between respondent populations have the potential to impact respondent awareness and interactions with wildlife, demographic parameters were accounted for in our models and similar findings for pangolins have been suggested elsewhere (Schoppe and Cruz, 2009). Southern Palawan is subject to high levels of land conversion (Haughland et al., 2010), with major mining activities present in Bataraza and Brooke's Point. Over the past decade, palm oil expansion has taken place in Aborlan, Bataraza, Brooke's Point, Rizal, Quezon and

Sofronio Española, with >8000 hectares converted to palm oil by 2015 and 20,000 hectares set to follow suit (Larsen, Dimaano and Pido, 2014; Martinico-Perez, Quiling and Mendoza, 2015). This conversion has included forests both inside and around protected areas (Larsen et al., 2014). Compared to forests, palm oil plantations support lower species diversity (Fitzherbert et al., 2008), including a lower species richness of ants (Brühl and Eltz, 2010). This could be a concern due to pangolins' myrmecophagous diets (Chao et al., 2020), though further research is required to better understand the dietary requirements of the Philippine pangolin. Although a wide variety of pangolin habitat types were reported by respondents during this study, supporting previous suggestions that pangolins use multiple habitats (Chong et al., 2020; Schoppe et al., 2020), forest habitats were most frequently reported. The removal of such habitats may thus have disproportionately impacted pangolin populations in some areas of southern Palawan, although further research is required to determine if land conversion has resulted in lower overall pangolin abundance, or whether pangolin populations have suffered range contractions and 'refugial' occupancy into forested upland areas or protected landscapes, a pattern seen in other populations undergoing declines due to habitat loss or exploitation (Bauer et al., 2015).

In addition to land conversion, southern Palawan has been subject to high levels of illegal wildlife trade, and during the early 2000s was considered to be one of the trade hotspots in the Philippines (Cruz et al., 2007). By 2008, local hunters considered the species to be rare in southern Palawan and pangolins were reportedly easier to source in northern Palawan (Schoppe and Cruz, 2009). More recent analysis of trade data suggests that trade hotspots are now found in northern Palawan, with evidence of seizures from El Nido, Puerto Princesa, Roxas and Taytay in 2018-2019 (Sy and Krishnasamy, 2020), possibly indicating a shift in trade routes and hotspots as populations have been depleted. However, seizure data are subject to bias and provide conservative estimates of trade levels and limited data on source areas (Underwood et al., 2013); further research is therefore needed to investigate past and present trade levels across the province. Data from this study suggest widespread pangolin use; pangolin consumption was reported from all but one surveyed municipality and pangolin trade was reported in all municipalities other than Brooke's Point, Linapacan and Rizal, suggesting that these are threats across much of the province. Previous studies have reported that dietary consumption within the province is infrequent (Eder 1987; Schoppe and Cruz 2008; Lacuna-Richman 2004; Van den Beukel *et al*. 2008), perhaps suggesting that pangolins comprise an opportunistic rather than targeted part of the diet. Nonetheless, even if consumption is infrequent, it has the potential to represent a substantial threat given the reportedly low pangolin abundance. Further, 'other' (sightings associated with pangolin

captures) represents the third most frequent sighting 'habitat' reported by respondents, suggesting that pangolin use within local communities is largely overt and remains a social norm. The medicinal use of pangolins was also reported during this research but less frequently than pangolin consumption or trade, indicating that although this use exists it is likely to occur at lower intensity. Further research into the local use of pangolins is recommended using sensitive questioning techniques (Nuno et al., 2013; Nuno and St. John, 2014), but these initial findings suggest that targeted behavioural change campaigns to address local consumption in lowland communities could be of value in addition to tackling pangolin trade (John, Edwards-Jones and Jones 2011), with high levels of pangolin recognition already providing the foundation for such behaviour change interventions.

Interviews in this study were conducted in non-indigenous lowland communities, many of which were comprised of migrant groups from across the Philippines. Despite this, respondent knowledge was high, demonstrating the value of LEK for informing pangolin conservation on Palawan from across all rural communities and groups, with multiple metrics of pangolin status studied here not influenced by ethnicity. Our data also challenge the assumption that common species are more appropriate for LEK research (Nyhus et al., 2003); respondent recognition of pangolins did not significantly differ from recognition of stink badgers (classified as Least Concern by IUCN), and was significantly higher than recognition of porcupines and hornbills (both listed as Vulnerable by IUCN; IUCN, 2020). Instead, pangolins were widely known due to their distinct morphology and use by local people, supporting the usefulness of LEK data to establish conservation baselines for some species that are otherwise challenging to study using standard ecological survey methods (Pan et al., 2016; Turvey et al., 2015). However, demographic differences were observed in respondent awareness, experience and attitudes. Younger respondents were less likely to recognise or report pangolin sightings, which could suggest the potential presence of shifting baseline syndrome (Papworth *et al.*, 2009), and males were more likely to report sightings. Comparable demographic patterns have been documented elsewhere (Boissière et al., 2013; Iniesta-Arandia et al., 2014; Nash et al., 2016) and can be caused by variation in interactions with nature within many communities (e.g. gender-based and age-based division of labour), which thus need to be considered when planning future research or conservation interventions (Nyhus et al., 2003).

With high frequencies of pangolin sightings in secondary forest reported by respondents from non-indigenous lowland communities, establishing conservation efforts outside of existing protected areas has high potential, with areas of secondary or degraded forest likely to provide suitable habitat for the species and offer additional protection. However, with such

habitats in proximity to local communities, we suggest a community-based conservation (CBC) approach will be fundamental. Though diverse in their implementation, CBC approaches should safeguard the wellbeing and rights of local communities living around areas of conservation interest by engaging local people as active stakeholders, with an emphasis on their involvement and autonomy (Berkes, 2007; Brooks et al., 2012). With high knowledge levels, willingness to engage with conservation, and use of pangolins widely reported in this study, local involvement could provide conservation planners with information on key ecological and social considerations, and help build local support for conservation (Agardy et al., 2011; Bennett and Dearden, 2014; Christie, 2004). However, though a CBC approach is now a widely accepted conservation model, it is not without its criticism and has had mixed success (Brooks et al., 2012; Campbell and Vainio-Mattila, 2003; Waylen et al., 2010). Socio-ecological systems are complex and various community characteristics will influence project outcomes (Brooks et al., 2012). Further, there has also been criticism of LEK, with concerns of its misuse and failures to integrate LEK into conservation beyond its use as a data source (Eythórsson and Brattland, 2012; Latulippe and Klenk, 2020). By combining LEK and local attitudes, studies such as this can provide an initial baseline to better understand local considerations and demographic influences at an earlier stage in the conservation planning process. This can help to prioritise conservation efforts to areas with higher potential success and move beyond the use of LEK solely for data collection, towards a more integrated approach that views local knowledge as a legitimate and central part of the management process and provides a starting point for collaborative and inclusive conservation (Latulippe and Klenk, 2020).

5. Conclusion

Our data indicate that conservation initiatives for Philippine pangolins need to be scaled up and developed as a priority. Sighting frequencies, perceived pangolin abundance, and willingness to help monitor wildlife are higher in northern municipalities, and we suggest that these areas could be focused on initially. However, although we found geographical variation across multiple metrics of pangolin population status, recent pangolin reports are documented across the province, and high levels of local support for conservation offer hope that it is not too late to develop range-wide conservation initiatives. With limited data on pangolin status and threats available for some municipalities prior to this research, we hope this study will provide the evidence needed to encourage municipal government bodies across Palawan to engage in pangolin conservation efforts.

Our findings provide evidence that LEK data can offer valuable insights to confirm species' presence, assess their status, and understand local use and values. LEK therefore not only

provides important insights into many relevant species-specific parameters, but also provides conservation planners with an understanding of key considerations that are outside the bounds of individual ecological studies but are crucial to consider (Agardy et al., 2011; Bennett et al., 2017; Christie, 2004). This unique body of information can thus help facilitate decisions and establish a starting point for further research in areas with confirmed species presence and local support, thus providing an invaluable baseline to be considered within wider social, cultural and political contexts to aid decision-making for *in situ* conservation planning.

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Appendix 2

Table 1: Description of predictor variables selected a priori and used in models.

Predictor Category	Variable Predictor	Response variable for questions on:								Data format	Description of dependent variable and hypothesised relationship	Variable type	Literature example(s)
		Pangolin recognition	Pangolin sightings	Recent pangolin Sightings	Perceived pangolin abundance	Perceived pangolin population changes	Willingness to help monitor wildlife	Importance of conservation	Species Comparisons				
Demographic: Personal	Age	✓	✓	✓	✓	✓	✓	✓	✓	Continuous (years)	Older participants have more time to learn to recognise and encounter pangolins, and to form perceptions of pangolin abundance, population change and opinions on conservation.	Fixed	(Papworth et al., 2009)
	Gender	✓	✓	✓	✓	✓	✓	✓	✓	Categorical dichotomous (male or female)	Gender differences in labour allocation influence how likely someone is to encounter a pangolin, thereby influencing recognition and sightings, and perceptions of abundance and trends.	Fixed	(Boissière et al., 2013; Iniesta-Arandia et al., 2014)
	Occupation	✓	✓	✓	✓	✓	✓	✓	✓	Categorical (nominal)	Determines a respondent's time spent in natural places and type of places they visit. This influences how likely they are to encounter pangolins and therefore their likelihood of recognition and sightings, and how they perceive abundance and population changes.	Fixed	(Beaudreau and Levin, 2014)

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	Education	✓					✓	✓	✓	Categorical (ordinal - level of education)	Highest educational level the respondent has gained. Educational level may influence whether someone knows what a pangolin is, their perceived importance of conservation and willingness to engage in conservation.	Fixed	(Delaney et al., 2008)
	Ethnicity	✓	✓	✓	✓	✓	✓	✓	✓	Categorical (nominal)	Only ethnicities reported by >10 respondents were included in models.	Fixed	(McMillen, 2012)
Demographic: Location	Municipality	✓	✓	✓	✓	✓	✓	✓	✓	Categorical (nominal)	Municipalities are individual political units and are therefore subject to different natural resource management strategies. Pangolin abundance may naturally vary spatially or may vary due to differing levels of protection or natural resource management.	Fixed	(Nash et al., 2016)
	Village	✓	✓	✓	✓	✓	✓	✓	✓	Categorical (nominal)	Village is the governing organisational unit that sits below municipality and is the lowest administrative unit. Villages may be subject to different natural resource management strategies. Included as a random effect to account for non-independence in the data.	Random	(Nash et al., 2016)
Active experience and interaction with	Respondent sightings in the past 18 months				✓	✓				Categorical (binomial – yes or no)	Recent sightings may influence how someone perceives pangolin abundance or trends. We hypothesise that respondents who have	Fixed	(Thurstan et al., 2016)

pangolins											recently seen a pangolin are more likely to perceive the pangolin population as more abundant and less likely to be in decline.		
External	Interviewer	✓	✓	✓	✓	✓	✓	✓	✓	Categorical (nominal)	Interviews can be subject to interviewer bias, with the potential for questions to be answered differently depending on who is asking the questions. This was therefore included in the models to check for bias.	Random	(Newing, 2011)

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Figure 1: Perceived pangolin abundance - CLMM predicted probabilities of a 'very rare'; 'rare'; 'common'; or 'very common' response per municipality.

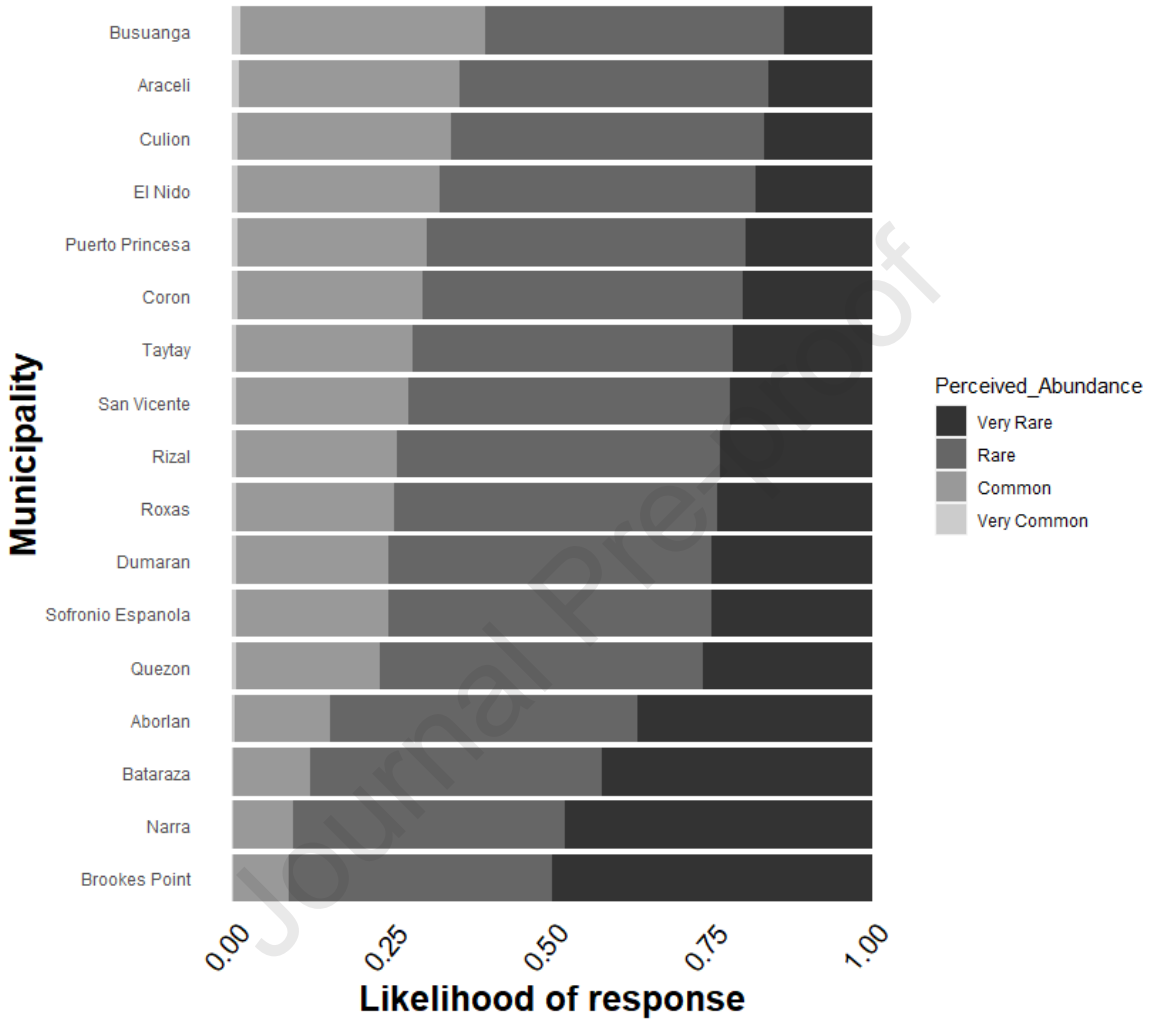

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Figure 2: Perceived pangolin declines - CLMM predicted probabilities of a 'decrease', 'no change' or 'increase' response per municipality.

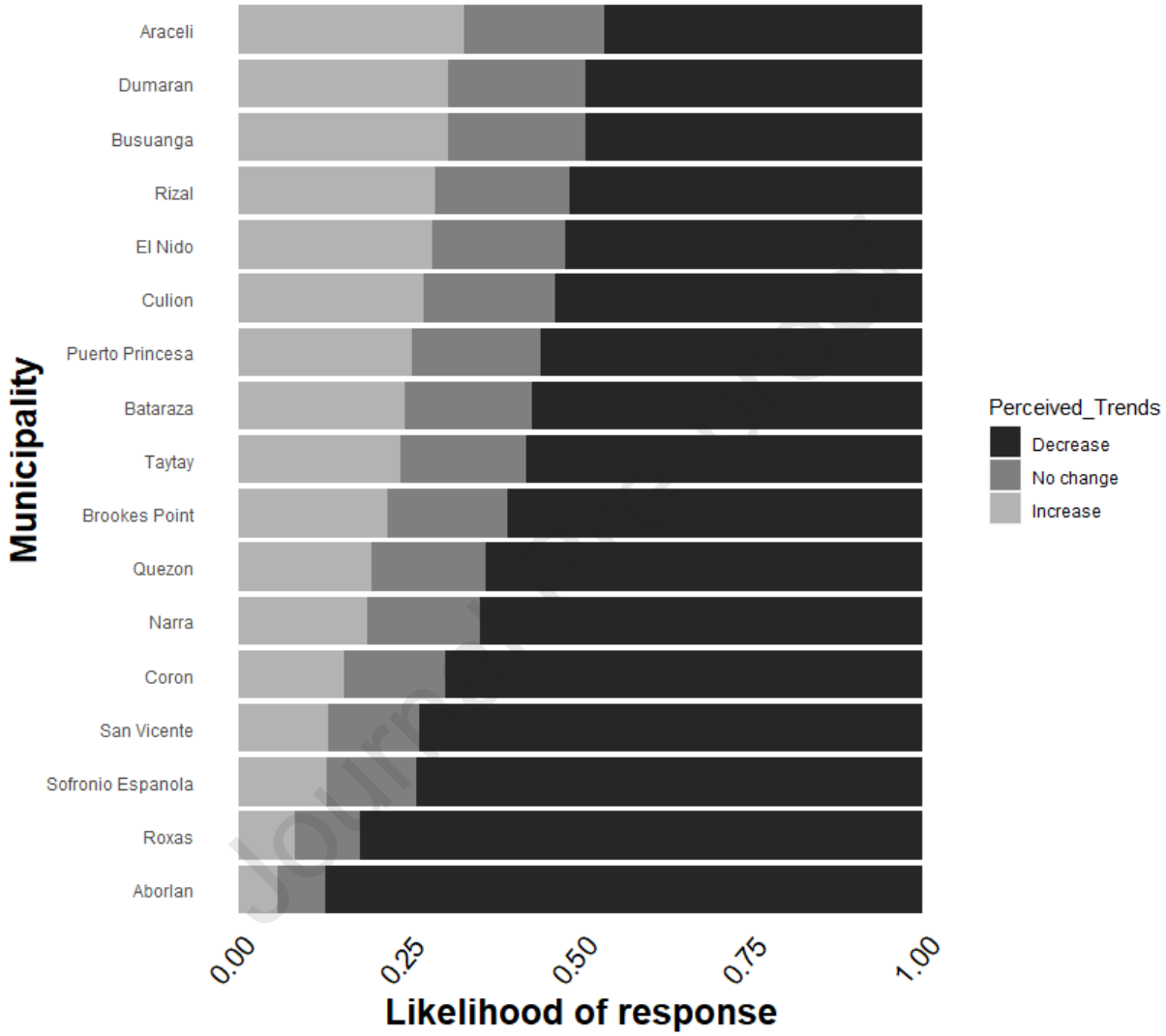

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Figure 3: Perceived species abundance across municipalities – CLMM predicted probabilities (using the subset of respondents who reported seeing all species)

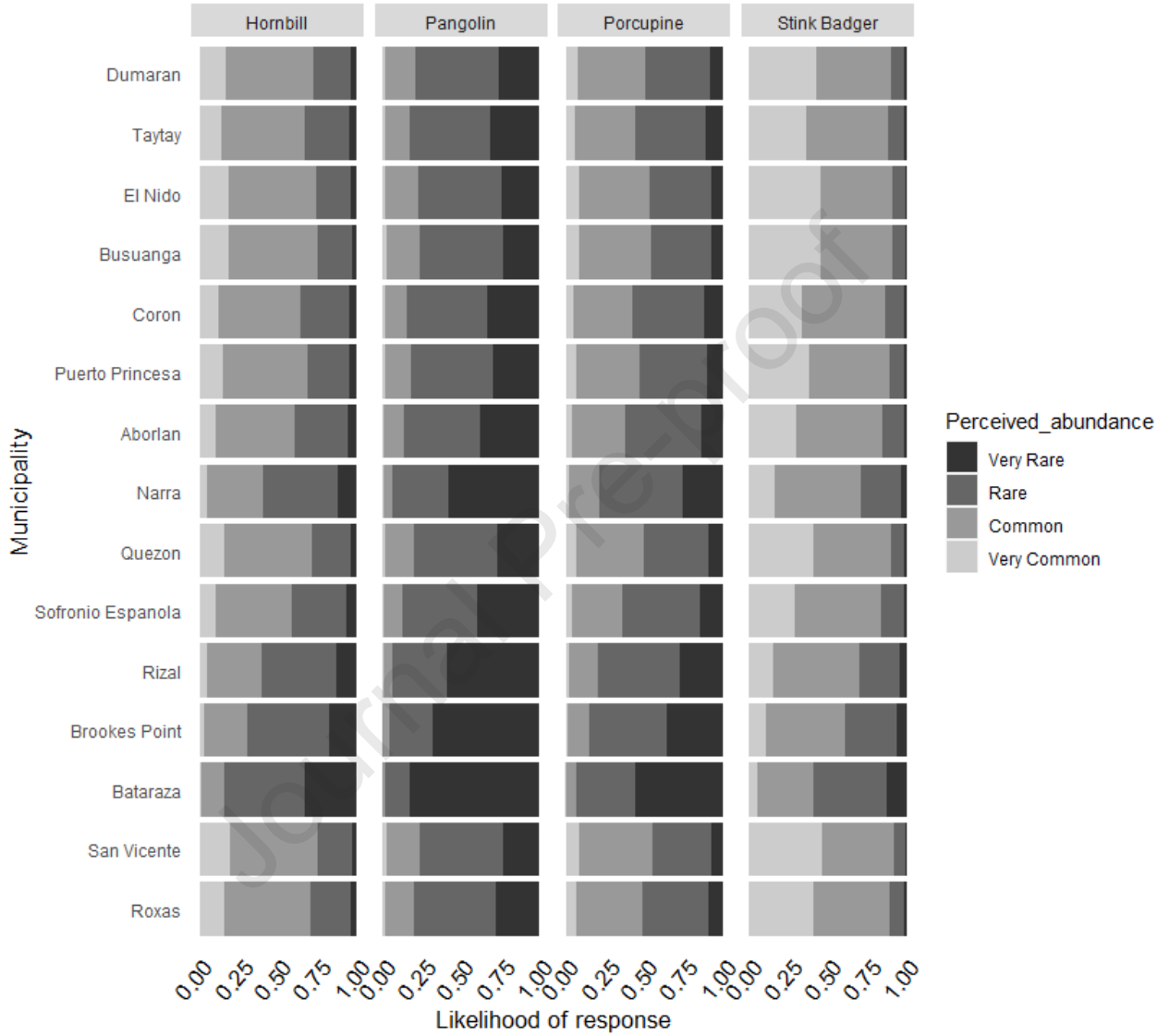

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Figure 4: Perceived species population trends across municipalities – CLMM predicted probabilities (using the subset of respondents who reported seeing all species)

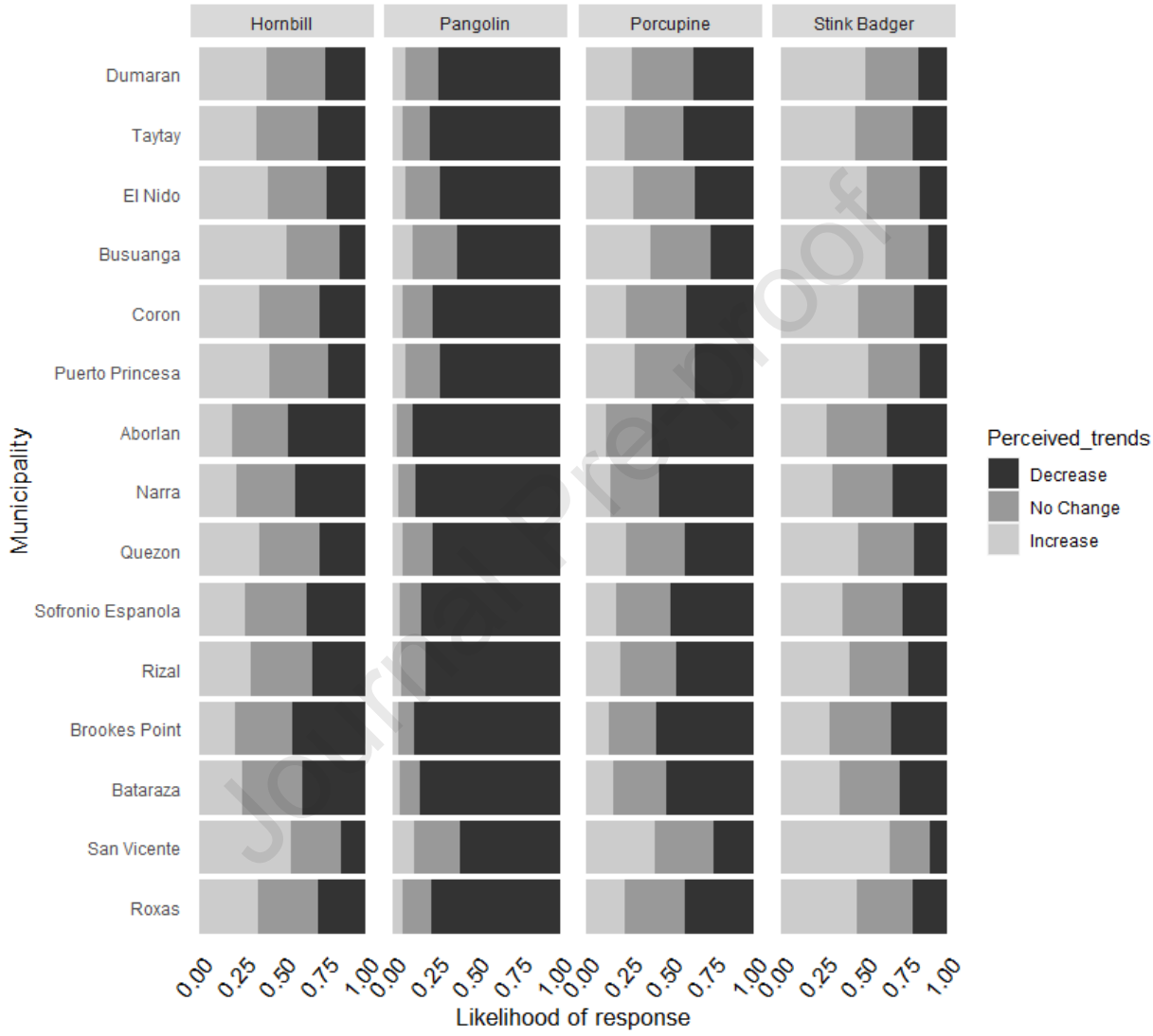

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Figure 5: Perceived species population trends across ethnicity – CLMM predicted probabilities (using the subset of respondents who reported seeing all species)

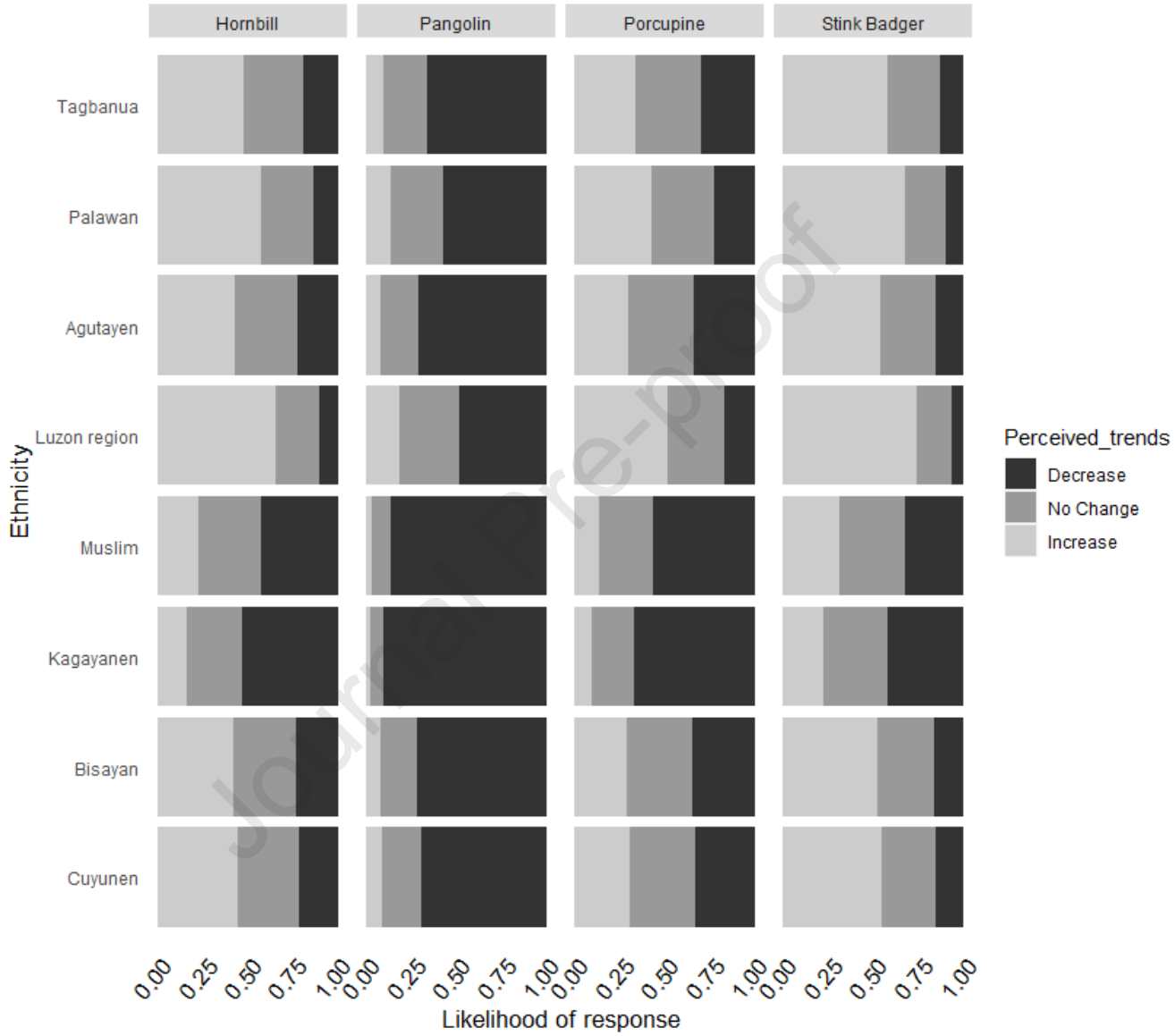

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Table 2: Reported local uses of pangolins

Local use	Use Type	Frequency of response	Descriptions
Consumption	Consumption as a food source	489	*"eat the meat"* *"meat is food"*
	Consumption with alcohol	3	*"meat eaten as side dish when drinking alcohol"*
Trade	General trade reports	50	*"people sell the scales"* *"people catch it and sell it"* *"there was trading before"* *"the meat is for food, and scales for sale – ₱10,000 per kilo"* *"trading 2017 price was ₱12,000 per kilo of scales, people eat the meat also"* *"2014 buyer from Puerto asking to buy the whole pangolin alive for ₱5000"* *"in community scales is for sale"*
	Recent trade reports	11	*"trading is still ongoing"* *"even now there is trading but just hiding, catching by chance"* *"this year 2019 - ₱700-1,200 per kilo and it is common food for some people here"* *"last year there was people catching it to sell"* *"trading here even now and ₱5,000 per kilo of scales, meat is ₱300 per kilo"* *"before people hunt it to sale but not now anymore"*
Medicinal	Medicinal – general uses	19	*"traditional medicine"* *"scales are medicine"* *"blood is medicine"* *"eat the meat, it can heal sick people"* *"internal organ is medicine"* *"only the scales for medicine - burn and drink the charcoal of scales"*

	Medicine to treat asthma	10	*"blood and liver cure asthma"* *"scales and blood as treatment for asthma"* *"blood as cure for asthma"* *"scales and blood medicine for asthma"*
	Medicinal value for women who have given birth	2	*"the poop is good to increase the health of woman who have given birth. Dry the poop and grill it and drink the ash"* *"scales are medicine for women who have given birth"*
	Medicinal value for back and body pain	1	*"scales medicine for body pain and backbone"*

Table 3: Reported cultural values of pangolins

Pangolin part	**Belief type or use**	**Subcategory**	**Frequency of response**	**Descriptions**
Scales	Medicinal	Treatment of asthma	11	*"scales medicines for asthma, burn it and mix to milk or coffee".*
	Medicinal	Treatment for stomach-ache	4	*"ancestor story - scales medicines for stomach-ache".*
	Medicinal	General	2	*"scales are medicine".*
	Medicinal	Treatment for back and joint pain	1	*"scales medicines for back and hip pain".*
	Protection	Protection against bad spirits	6	"*scales make smoke around the house while the mother give birth".* *"scales protect against strong thunder and lightning".* *"scales good to scare the bad spirits".*
	Tool	Protection against insects	2	*"scales are burnt in kaingin area to scare the insect".*
	Tool	Used for fighting	1	*"scales are used for fighting against fighting other people".*
	Tool	Guitar pick	1	"*scales for string of guitar"*.
Blood	Medicinal	Treatment of asthma	5	"*blood medicine for asthma and lung illness".*
	Medicinal	Treatment for tuberculosis	1	*"blood is medicine for tuberculosis".*
	Medicinal	Gives strength	3	*"drinking of blood gives strength to the body".*
	Medicinal	General	8	*"elders drink the blood before as they believe it is medicine and good for health".*

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				"blood is medicine for internal organ pain body becomes strong and no illness".
Liver	Medicinal	Treatment of asthma	1	*"pangolin liver is a medicine for asthma".*
Gall-bladder	Medicinal	Treatment for stomach aches	1	*"gallbladder medicine for stomachache".*
Pangolin general	Cultural belief	Superstition	1	*"Ancestors tell of a story, that pregnant women cannot handle this animal, because it will be hard to give birth".*
	Cultural belief	Ability to be invisible	2	*"it has a superpower that you can't see it. Even if it is just beside your house".*
	Cultural value	General uses	2	*"they help our environment, so we need to respect them".* *"story from ancestor that don't catch because it helps to illness people".*
	Food source	Eaten as a local dish	2	*"According to ancestor it is a viand (food dish)".* *"the meat is viand (a food dish) but for consumption only".*
	Medicinal	A medicine for women who have given birth	1	*"medicinal for woman give birth".*

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Figure 6: Willingness to help monitor wildlife - CLMM model predictions, showing the likelihood of a 'not at all willing', low willing', 'possibly willing', 'willing' or 'very willing' response per municipality.

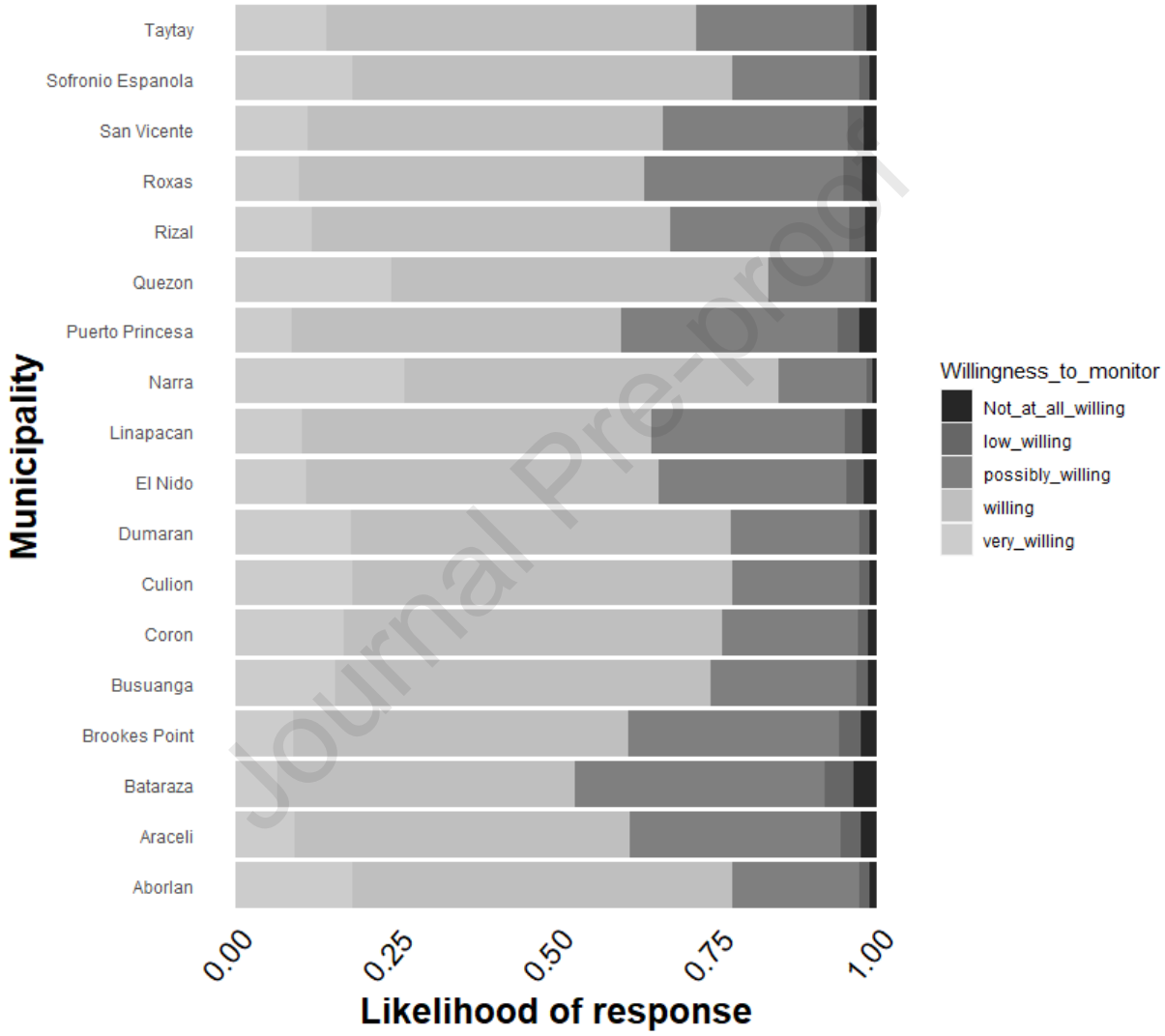

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Figure 7: Perceived importance of wildlife protection - CLMM model predictions, showing the likelihood of a 'low importance', neutral', 'important' or 'very important' response per municipality.

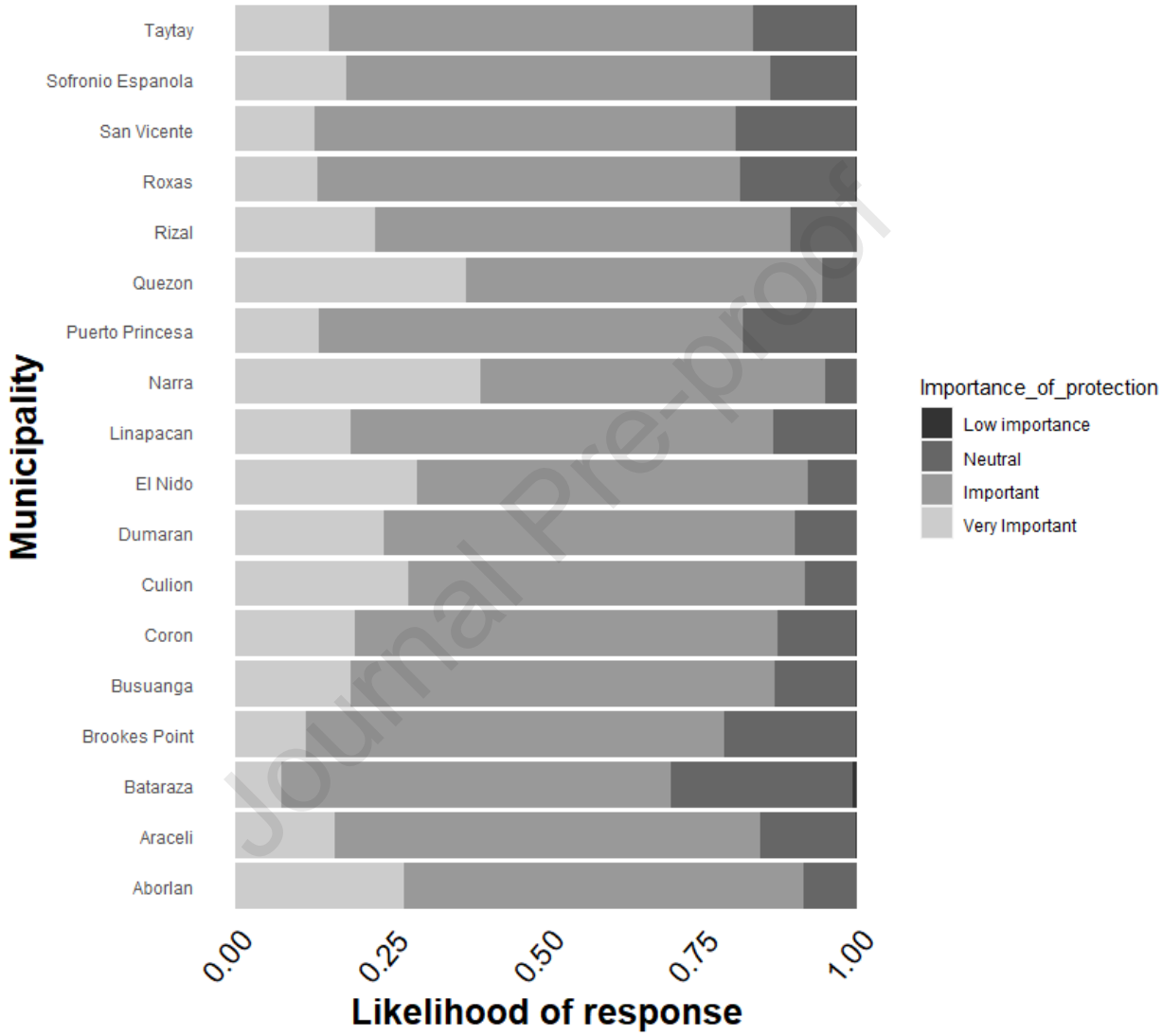

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Table 4: Summary of generalized linear mixed model (GLMM) and cumulative link mixed model (CLMM) results.

	Full model	Significant Variables	Chi-Squared	df	p.value	R^2m	R^2c
GLMM	Model 1: Pangolin recognised ~ municipality + age + gender + occupation + education + ethnicity (1|village) + (1|interviewer)	Municipality	71.644	17	<0.001	0.797	0.806
		Age	23.236	1	<0.001		
		Gender	6.420	1	0.011		
		Occupation	10.244	4	0.037		
		Education	1.979	4	0.739		
		Ethnicity	21.235	7	0.003		
GLMM	Model 2: Pangolin sighting ~ municipality + age + gender + occupation + ethnicity + (1|village) + (1|interviewer)	Municipality	67.825	16	<0.001	0.129	0.147
		Age	10.782	1	0.001		
		Gender	10.273	1	0.001		
		Occupation	18.950	4	<0.001		
		Ethnicity	11.501	7	0.118		
GLMM	Model 3: Pangolin recent sighting ~ municipality + age + gender + occupation + ethnicity +	Municipality	36.360	16	0.003	0.209	0.209
		Age	0.420	1	0.517		

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	(1|village)	Gender	17.482	1	<0.001		
		Occupation	3.015	4	0.555		
		Ethnicity	10.332	9	0.171		
CLMM	Model 4: Pangolin population trends ~ municipality + age + gender + occupation + recent pangolin sighting + ethnicity + (1|interviewer) + (1|village)	Municipality	40.142	16	<0.001	0.15	0.26
		Age	0.548	1	0.459		
		Gender	6.117	1	0.013		
		Occupation	3.618	4	0.460		
		Recent pangolin sightings	32.446	1	<0.001		
		Ethnicity	4.167	7	0.760		
CLMM	Model 5: Perceived pangolin abundance ~ municipality + age + gender + occupation + ethnicity + recent pangolin sighting + (1|village) + (1|interviewer)	Municipality	43.405	16	<0.001	0.21	0.39
		Age	0.003	1	0.960		
		Gender	1.783	1	0.182		
		Occupation	9.881	4	0.042		
		Recent pangolin sightings	150.220	1	<0.001		
		Ethnicity	5.479	7	0.602		

Appendix 2 - Scaling up local ecological knowledge to prioritise areas for protection: determining Philippine pangolin distribution, status and threats.

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CLMM	Model 6: Willingness to help monitor wildlife ~ municipality + age + gender + occupation + education + ethnicity + (1|interviewer)	Municipality	49.268	17	<0.001	0.076	0.356
		Age	0.246	1	0.620		
		Gender	9.717	1	0.002		
		Occupation	16.297	4	0.003		
		Education	15.433	4	0.004		
		Ethnicity	14.208	7	0.048		
CLMM	Model 7: Importance of wildlife protection ~ municipality + age + gender + occupation + education + ethnicity + (1|interviewer) + (1|village)	Municipality	40.140	17	0.001	0.099	0.207
		Age	3.513	1	0.061		
		Gender	5.905	1	0.015		
		Occupation	1.626	4	0.804		
		Education	16.546	4	0.002		
		Ethnicity	9.066	7	0.247		
CLMM	Model 8: abundance scores ~ municipality + species + gender + age + occupation + ethnicity + (1|village) + (1|hh_id)	Municipality	65.44	14	<0.001	0.379	0.495
		Species	1450.69	3	<0.001		
		Gender	7.17	1	0.007		
		Age	0.03	1	0.854		

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		Occupation	23.62	4	<0.001		
		Ethnicity	9.99	7	0.189		
CLMM	Model 9: trend scores ~ municipality + species + gender + age + occupation + ethnicity + (1|village) + (1|hh_id)	Municipality	33.42	14	0.002	0.547	0.221
		Species	586.05	3	<0.001		
		Gender	0.87	1	0.351		
		Age	2.05	1	0.151		
		Occupation	27.08	4	<0.001		
		Ethnicity	42.89	7	<0.001		

** a lack of variation in the random effects of i) interviewer for model three and ii) village for model six were preventing model convergence, these random effects were therefore removed from the respective models.*

Scaling up local ecological knowledge to prioritise areas for protection: determining Philippine pangolin distribution, status and threats.

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Appendix 1: Household Questionnaire.

Metadata: The following metadata will be collected automatically using ODK collect.

Start (time)	
End (time)	
Today (date)	
Username	
Deviceid	

Location Information (to be completed before interview commences)

Municipality: _____ Barangay: _____ Purok _____

Protected area (if applicable): _____Interviewer: _____

Interview ID: _____ (interviewer initials followed by interview number)

Introduction and free prior informed consent:

Hello. My name is _____ and I am conducting research on behalf of the University of London and ZSL Philippines. We'd like to know more about your local environment and the wildlife living here. I'd like to ask you some questions as part of a quick survey.

Participating in this survey is completely voluntary. None of the information you tell me will be shared with anyone in the village, your name and address will not be recorded, and your answers will remain entirely anonymous and will be treated with complete confidence. All the information you provide will only be used for this research and analysis, including any resulting publications. We will not disclose any of the information you give us to a third party, however the overall findings and results will be shared with other organisations.

I hope you can help me because this survey is very important to help us learn more about Palawan's wildlife. However, if at any point you want to stop the survey please say and we will end immediately, and you can decide whether you want your answers to be used. If following the survey you no longer wish for your answers to be used as part of the research, please let your barangay captain or traditional leader know within one week of this survey.

Are you willing to participate in this survey? Yes □ No, unwilling □

If no, record reason and move on to the next household.

Scaling up local ecological knowledge to prioritise areas for protection: determining Philippine pangolin distribution, status and threats.

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1. Respondent socio-demographics

1.1. Gender: *M/F*

1.2. Age:

1.3. Ethnicity: *Palawano / Palaw'an/ Batak/ Tagbanwa/ Kagayanen/ Agutaynen/ Taaw't Bato/ Molbog/ Palawenos/ Bisayan/ Cuyunen/ Ilongo/ Masbateno/ Cebuana/ Other (please state).*

1.4. Interview language*: Tagalog / Cuyonon / Hiligaynon / Palawano / Batak / Tagbanwa / Kagayanen / English/ Other (describe)*

1.5. Household size:

1.6. Occupation
1.6.1. Primary household occupation:
1.6.2. Secondary household occupation:
1.6.3. Other household occupation:

1.7. Average monthly household income (in PhP):

1.8. Have you always lived in this barangay*: Yes / No*

1.8.1. If no, when did you move to your current barangay? [year] _____

1.8.2. Where did you live before? [select municipality > select barangay] _____

1.9. Highest level of education received by the respondent: *[multiple choice tick box - choices: None / Elementary level / High-school level / Vocational qualification / College-level]*

2. Detectability

2.1. Do you ever visit any of the following places in your barangay? [select_multiple_habitat_type_or_other]

- *Kagubatan – upland forest*
- *Kagubatan – lowland forest*
- *Bakhawan - mangroves*
- *Palm oil plantation*
- *Timber plantation*
- *Rubber tree plantation*
- *Coconut plantation*
- *Riverine habitat*
- *Rice field*
- *Lake*
- *Agro-forest*
- *Grassland*
- *Mining area*
- *Beach / marine environment*
- *Other (please specify)*

If YES

2.1.1. *If yes*, how often do you visit these places? [select one_freq_visits]
Daily / Weekly / Monthly/ Twice a year / Yearly / Less than yearly

2.1.2. How long do you spend in these places per trip? [select one_time_spent_natural_places] *<2hours / >2 – 4 hours / >4 – 6 hours / >6 – 8 hours / > 8 hours*

2.1.3. Can you tell me some more about why you visit these places? [open text box]

2.1.4. Has the time you spend in these places remained the same over the past ten years? *[Y/N]*
2.1.4.1. *If NO*, has the time you spend in these places increased or decreased? *Increased / Decreased*
2.1.4.2. Can you tell me some more about why the time you spend in these places has changed? [open text box]

If NO

2.2. If you don't visit these places, why is that?
2.3. Does anyone else in your household spend time in these places? Y/N

2.3.1. If yes, who? [please state which household member]
2.3.2. Can you tell me what places this household member visits? [select_multiple_habitat_type_or_other]

2.4. I'd like to know some more about the importance of natural places for local people - does your household use any natural resources from the forest or other natural places? [Yes/No]

2.4.1. I*f YES* what types of natural resources does your household use?? _____

2.4.1.1. Do you sell any of these resources? Y/N

2.4.1.2. How much does your household earn per month from these resources?

I'd now like to show you some photographs to understand what animals live in your local area. Please take a look at each photo and I will ask you some questions. Some of the animals in the photos might not exist here in this area, so don't worry if you haven't seen these animals before.

3. Local Ecological Knowledge

3.1. Show photo of ***Palawan Stink Badger (Pantot)*** *Positive control species*

3.1.1. Do you know this animal: Yes / No

If the respondent does not know this animal, ask whether they have heard of this species and its features (describe its appearance and size). If they know the characteristics of this species and can provide independent accurate information (beyond what you've told them), continue to ask the following questions. If no and the respondent cannot provide independent accurate information, continue to next animal.

3.1.2. Do you have a local name for this animal?

3.1.3. Have you ever seen this animal in this barangay? Yes / No

If yes continue to 3.1.3.1., if no, continue to 3.1.4.

3.1.3.1. Have you seen this animal in the past 12 months? Yes/No

3.1.3.2. When was the last time you saw this animal? (Please specify the year if possible. If respondent cannot remember the year clearly, please note down any points of reference and information they provide).

[select year]

3.1.3.3. Notes on the last time the respondent saw this animal [open text box]

3.1.3.4. Where did you see this animal during this last sighting and can you remember what it was doing? [open text box]

3.1.3.5. How frequently do you see this animal? [select one]
Daily
Weekly
Monthly
Yearly
Less than yearly
Other (please specify)

3.1.3.6. Have you seen this animal in any other places? [select_multiple_habitat_type_or_other]

- Kagubatan – upland forest
- Kagubatan – lowland forest
- Bakhawan - mangroves
- Palm oil plantation
- Timber plantation
- Rubber tree plantation
- Coconut plantation
- River or river bank
- Rice field
- Residential area
- Lake
- Agro-forest
- Grassland
- Mining area
- Beach / marine environment
- Other (please specify)

If No

3.1.4. If no, how do you know about this animal?

- People in this village talk about this animal
- People in this village use this animal
- My parents have told me about this animal
- Other (please describe)

3.1.5. Over the past ten years, do you think the number of these animals in your barangay has changed? Yes/No/Unsure

3.1.5.1. If yes, please state how the numbers of this animal has changed? [select_one_increase_decrease]

Increased / Decreased / Not sure ___

3.1.6. How common or uncommon do you think this animal is in this barangay? [select_one_abundance]

0 (very rare) 1 (rare) 2 (common) 3 (very common)

3.1.7. Is this animal part of your local culture? E.g. folklore, IP stories or legends [open text box]

3.1.8. Is this animal used in any way by local people in this barangay? Yes / No
3.1.8.1. If yes, can you tell me some more about this?

3.1.9. Do you think this animal needs protecting? Yes / No / Unsure
3.1.9.1. Why do you think that? [open text box]

***Repeat LEK section for:**

Giant Anteater
Philippine pangolin
Palawan porcupine
Palawan Hornbill

4. Species comparisons and triangulation of results

4.1. Using the photos we've just looked at, please rank the species in order of most common to least common

[ask respondents to place the photos in order from most common on the left, to least common on the right – (only using the animals they reported that they know of)]

4.2. Are there any other animals that used to exist in this area that no longer occur here today?
4.2.1. *If yes*, how do you know about these animals?

5. Conservation Attitudes

5.1. Finally, before we go we'd like to understand how important or unimportant protecting wildlife is to people in this barangay. Please indicate how important or unimportant protecting wildlife is to you. Please be honest, there are no right or wrong answers.
[Not at all important / Low importance / Neutral / Important / Very important]

5.2. And finally, how willing or unwilling are you to help scientists monitor animals in this area?
[Not at all willing / Low willingness / Possibly willing / Willing / Very willing]

Thank respondent for their time and end interview.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: