How many remnant gibbon populations are left on Hainan? Testing the use of local ecological knowledge to detect cryptic threatened primates

Samuel T. Turvey[1,*], Jessica V. Bryant[1], Clare Duncan[1], Michelle H. G. Wong[1], Zhenhua Guan[2], Hanlan Fei[3], Changyong Ma[3], Xiaojiang Hong[4], Helen C. Nash[5], Bosco P. L. Chan[6], Yang Xu[7], Pengfei Fan[8]

[1]Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK

[2]Yunnan Academy of Biodiversity, Southwest Forestry University, Kunming, Yunnan 650224, China

[3]Institute of Eastern-Himalaya Biodiversity Research, Dali University, Yunnan 671003, China

[4]Bawangling National Nature Reserve Management Office, Changjiang Lizu Autonomous County, Hainan, China

[5]Department of Biological Sciences, National University of Singapore, 14 Science Drive 4, 117543, Singapore

[6]Kadoorie Conservation China, Kadoorie Farm & Botanic Garden, Lam Kam Road, Tai Po, New Territories, Hong Kong

[7]Spatial Ecology Center, School of Life Sciences, South China Normal University, Guangzhou, Guangdong 510631, China

[8]School of Life Sciences, Sun Yat-Sen University, Guangzhou, Guangdong 510275, China

***Corresponding author** (email: samuel.turvey@ioz.ac.uk; tel: +44 (0)207 449 6326)

Short title: Local ecological knowledge of gibbons

ABSTRACT For Critically Endangered "species of extreme rarity", there is an urgent need to clarify the potential survival of remnant populations. Such populations can be difficult to detect using standard field methods. Local ecological knowledge (LEK) represents an important alternative source of information, but anecdotal reports of rare or possibly extinct species can contain uncertainty and error. The Hainan gibbon (*Nomascus hainanus*), the world's rarest primate species, is confirmed to only survive as a tiny remnant population in Bawangling National Nature Reserve, China, but unverified gibbon sightings have been reported from other forest areas on Hainan. We conducted a large-scale community interview survey to gather new data on patterns of primate LEK from 709 respondents around 7 reserves across Hainan, to investigate the possibility of gibbon survival outside Bawangling and assess whether LEK can provide useful information for conservation management of cryptic remnant populations. Comparative LEK data for gibbons and macaques are consistent with independent data on the relative status of these species across Hainan. Local awareness and experience of gibbons was low across Hainan, including at Bawangling, but we recorded recent anecdotal gibbon reports from most reserves. A follow-up field survey at Limushan Provincial Nature Reserve did not detect gibbons, however, and documented intensive wildlife exploitation within this reserve. All other surveyed landscapes showed some statistically lower levels of respondent awareness, experience, or sighting histories of gibbons compared to Bawangling, and are therefore considered biologically unlikely to support gibbons. Unverified LEK data can provide important insights into the possible status of cryptic remnant populations when assessed carefully and critically in relation to data from known populations.

Key words: interview survey, last-sighting dates, *Nomascus hainanus*, possibly extinct, remnant population

INTRODUCTION

Effective conservation management of threatened species requires a robust, evidence-based understanding of key population parameters such as abundance and geographic distribution [Sutherland et al., 2004; Segan et al., 2011]. For Critically Endangered "species of extreme rarity" reduced to tiny remnant populations at very high risk of extinction [Groombridge et al., 2004], there is an urgent need to identify all surviving individuals and clarify the demographic status or potential survival of isolated populations, to ensure effective maintenance of genetic diversity and protection against both anthropogenic threats and stochastic extinction processes. There is continued debate over whether general spatial patterns of range contraction or fragmentation exist in the dynamic biogeography of extinction events, however, making it difficult to identify geographic areas or habitats where remnant populations might persist [Channell and Lomolino, 2000, 2002; Hemerik et al., 2006]. Tiny remnant populations can also be very difficult to study or even detect using standard ecological field techniques, meaning that alternative investigative methods may be necessary to inform appropriate conservation activities.

Local ecological knowledge (LEK), representing experiential knowledge derived from lived interactions with local environments, is often available for species of conservation concern from untrained respondents who use the same environments [Newing, 2011]. LEK is increasingly seen as an important source of data for conservation, especially for distinctive large-bodied vertebrates such as primates [Meijaard et al., 2011; Abram et al., 2015], and can provide information about past and present status of threatened species that may otherwise be challenging to study [Anadón et al., 2009; Turvey et al., 2015b]. Community interview surveys can collect large-scale LEK datasets across wide geographic areas, enabling assessment of

patterns of population survival and extinction between landscapes to inform spatial conservation prioritization [Meijaard et al., 2011; Ziembicki et al., 2013; Parry and Peres, 2015; Turvey et al., 2015b]. LEK represents records that are unverified by trained scientists, however, leading to potential for uncertainty, error and bias, especially for putative reports of rare or possibly extinct species [McKelvey et al., 2008]. Careful data collection and analytical procedures are thus required to interpret LEK data effectively, and to assess whether LEK can provide ecologically coherent and internally consistent information about cryptic populations of threatened species.

The Critically Endangered Hainan gibbon (*Nomascus hainanus*) is the world's rarest primate and possibly rarest mammal species [IUCN, 2015]. Formerly distributed across Hainan, a c. 34,000 km^2 island in the South China Sea and China's southernmost province (Fig. 1), the species experienced a precipitous range collapse during the 1960s and 1970s caused by habitat loss and hunting [Liu et al., 1984; Chan et al., 2005; Zhou et al., 2005]. Only a single tiny remnant population, currently comprising 4 social groups and c. 26 individuals [Bryant et al., in press], is confirmed to survive in a c. 15 km^2 forest fragment within Bawangling National Nature Reserve, which comprises almost 300 km^2 in total [Chan et al., 2005; Fellowes et al., 2008; Turvey et al., 2015a]. A second native primate, the rhesus macaque (*Macaca mulatta*), also occurs in Bawangling and is relatively common across Hainan [Kadoorie Farm & Botanic Garden, 2001–2003; Smith and Xie, 2008].

Based on direct evidence from surveys, Liu et al. [1984] considered that by 1978, Hainan gibbons survived only in Bawangling, Jianfengling, Limushan, Wuzhishan and Yinggeling, and by 1983 only a few individuals still persisted outside Bawangling on the southwest slopes of Limushan main peak and Yinggeling main peak. Later, based on information from local records, government agencies, hunters and workers

at conservation stations, Zhou et al. [2005] suggested that in 1978 gibbons still occurred in unspecified localities across Dongfang, Ledong, Lingshui and Qiongzhong counties, surviving in Diaoluoshan, Jianfengling and Wuzhishan until 1983 and in Limushan until 1995. Local forest users have continued to report unverified gibbon sightings in forest areas outside Bawangling, however, including all of the regions where gibbons apparently occurred in the 1980s and 1990s [Turvey et al., 2015a]. As the existence of any surviving individuals or remnant populations outside Bawangling would be of fundamental importance for Hainan gibbon conservation, systematic collection and assessment of these reports is identified as a high conservation priority [Chan et al., 2005; Turvey et al., 2015a].

Possible gibbon survival across Hainan has been investigated periodically during recent decades using small-scale surveys (Diaoluoshan, 1998; Yinggeling, 2003, 2005; Exianling, 2007; Jiaxi, 2009, 2012; Limushan, 2011), but with no success [Fellowes et al., 2008; B.P.L. Chan, unpublished data]. These surveys have used the standard technique of passive listening-post auditory surveying [Brockelman and Srikosamatara, 1993], which is used for gibbon monitoring at Bawangling [Chan et al., 2005; Zhou et al., 2005; Fellowes et al., 2008]. We therefore conducted a large-scale community interview survey to gather new data on local patterns of LEK across areas of Hainan where unverified gibbon sightings have been reported, along with comparative LEK on macaques and for both primates from Bawangling (where both species definitely occur), accompanied by a new field survey to further investigate potential sightings. Quantitative assessment of data on local awareness and experience of primates tests the hypothesis that Hainan gibbons are restricted to Bawangling, investigates whether LEK can provide useful insights into extinction dynamics and potential survival of remnant populations, and provides important new understanding

on the extent to which LEK can strengthen the evidence base for conserving species of extreme rarity.

METHODS

Interview survey

We conducted community-based surveys around 5 National Nature Reserves (Bawangling: N 18°56'–19°15', E 109°16'–109°25', 300–1510 m asl; Diaoluoshan: N 18°39'–18°48', E 109°43'–109°57', 50–1499 m asl; Jianfengling: N 18°37'–18°47', E 108°45'–108°56', 100–1412 m asl; Wuzhishan: N 18°49'–18°58', E 109°39'–109°47', 250–1864 m asl; Yinggeling: N 18°57'–19°08', E 109°15'–109°34', up to 1550 m asl) and 2 Provincial Nature Reserves (Jiaxi: N 18°50'–18°56', E 109°05'–109°14', 400–1654 m asl; Limushan: N 19°06'–19°20', E 109°38'–109°49', up to 1412 m asl) (Fig. 1), which contain much of Hainan's remaining good-quality forest. We selected these reserves because local forest users had reported unverified recent gibbon encounters from each reserve prior to our survey.

Numerous villages occur close to the boundaries of each reserve, with local people using animal and plant resources collected within the protected areas [Kadoorie Farm & Botanic Garden, 2001–2003; Chan et al., 2005; Turvey et al., 2015a]. For most reserves, we obtained a full list of neighboring villages from the respective reserve management office, and randomly selected 10 villages/reserve in which to conduct interviews. For Limushan and Yinggeling, gibbon reports were associated with specific regions of the reserve; we obtained a list of villages considered to use these regions from each reserve management office, and randomly selected 10 villages in total from these subsets for each reserve in which to conduct interviews (Fig. 1). This stratified random sampling strategy aimed to ensure that data

would be representative of wider patterns of LEK for each reserve while targeting areas potentially likely to retain gibbons. We aimed to conduct a target number of 10 interviews per village to comply with predicted response saturation levels and capture existing variation in responses [Guest, 2006]. We used a standard questionnaire for all interviews, which took up to 1 hour to complete and comprised a series of contrast, structured and open-ended questions (Supporting Information). We conducted pilot studies at Bawangling in August 2014 and January 2015, with main interviews conducted in Bawangling, Jiaxi and Yinggeling in January 2015 and in Diaoluoshan, Limushan, Jianfengling and Wuzhishan in April 2015. Interviews were mainly conducted in Mandarin or Hainanese, and recorded in Chinese, by pairs of volunteers recruited from universities or NGOs in Hainan; most local people could understand and communicate in these languages, although other local ethnic minority languages (Li, Miao/Hmong) were also relatively widely spoken in target communities. The four-person team of interviewers changed between January 2015 and April 2015 except for one team member, who led the second survey period to ensure consistency in interview methods. Respondent selection criteria/methods and interview protocols are given in Nash et al. [2016].

We collected demographic data on respondent age, sex, ethnicity, primary occupation, how regularly they reported visiting local forests, and how long they had lived in the community where they were interviewed. We then showed respondents color photographs of 9 mammals (wild pig, *Sus scrofa*; rhesus macaque; Hainan gibbon; clouded leopard, *Neofelis nebulosa*; Asian black bear, *Ursus thibetanus*; Chinese pangolin, *Manis pentadactyla*; binturong, *Arctictis binturong*; sambar deer, *Rusa unicolor*; giant anteater, *Myrmecophaga tridactyla*) to establish if they recognized each species. We sourced photographs from www.arkive.org and the

Zoological Society of London, and showed them in the same order in all interviews. Most of these species are known or suspected to occur on Hainan [Smith and Xie, 2008; Lau et al., 2010]; giant anteaters, native to Central and South America, were a negative control to check response accuracy [cf. Turvey et al., 2014]. We expected most respondents to recognize macaques, which are still relatively common across Hainan, so we included this species as a positive control to assess effectiveness of LEK for providing information on regional status of primates [cf. White et al., 2005]. Incorporation of a range of species was intended to obscure the potential importance to interviewers of any single species, and therefore increase likelihood of respondents reporting potentially sensitive information about these species [Turvey et al., 2015b].

After showing each photograph, we asked respondents to provide further ecological and morphological details to confirm accurate species recognition. If they did not recognize species from photographs, we used standard Chinese names to prompt recall (wild pig: *shanzhu*; macaque: *houzi*/*mihou*; gibbon: *changbiyuan*; clouded leopard: *yunbao*; bear: *xiong*; pangolin: *chuanshanjia*; binturong: *xiongli*; sambar: *shuilu*; giant anteater: *juxingshiyishou*). We asked respondents if they had heard of or seen the animals in the photographs, and if so how frequently and recently, and about their perception of local species status and abundance.

Finally, we played respondents a series of distinctive calls from 5 tropical forest mammals or birds (pant-grunt of chimpanzee, *Pan troglodytes*; male solo call followed by male-female duet of Hainan gibbon; green peafowl, *Pavo muticus*; mantled howler monkey, *Alouatta palliata*; screaming piha, *Lipaugus vociferans*), none of which occur on Hainan other than the gibbon. Gibbon calls had been recorded by the second author from social group “B” in Bawangling on 6 August 2011; we sourced other calls from www.gombechimpanzees.org, www.naturesongs.com and

www.xeno-canto.org. We played calls in the same order in all interviews. We asked respondents if they recognized each call, if they had heard it in the forest and how frequently and recently, with no prompting about the identity of any calls.

This research complied with protocols approved by the Provincial Forestry Department of Hainan, the Hainan Provincial Government and the management office of each protected area where fieldwork was conducted, and adhered to the legal requirements of the People's Republic of China and to the American Society of Primatologists' Principles for the Ethical Treatment of Non Human Primates. The Zoological Society of London's Ethics Committee also approved project design.

Analysis

We analysed data using R version 3.2.3 [R Development Core Team, 2015]. To investigate the robustness of our sampling strategy, we conducted initial exploratory tests to assess whether respondent demographic characteristics varied between reserves, using chi squared tests (ethnicity) or univariate generalized linear models (GLMs) using reserve as predictor and Gaussian error structure (age) or binomial error structure with logit link function (sex, frequency of forest visits, occupation). Nearly all respondents (89%, n=681) had always lived in their local village, so we did not include the low variation associated with this parameter in subsequent analyses.

Our study framework then investigated whether variation in respondent awareness or experience of primates was determined by variation in interview locality (reserve) using multiple regression. Respondent awareness or experience of primates was captured in 7 response variables: ability to identify photographs of either species; experience of having seen either species; familiarity with standard Chinese name for gibbon; ability to identify recording of gibbon call; and experience of having heard

gibbon call (all 0 or 1). Due to some significant variation in demographic parameters between reserves (see Results), we were unable to control for these potential influences on primate awareness and experience variables within a mixed model framework. Instead, for each of the 7 response variables, we constructed full additive multivariate GLM models (binomial error structure with logit link function), including all 5 demographic variables and interview locality (reserve) as fixed effects. We then applied a hypothesis-testing approach using step-wise model selection, deleting the non-significant predictor variable with the highest *P*-value at each step and model-checking to assess subsequent significance of changes in deviance resulting from removal of terms [Crawley, 2007]. We then conducted the same GLM hypothesis-testing approach at a finer spatial resolution for Bawangling, to investigate whether variation in respondent awareness or experience of gibbons was determined by variation between survey villages or respondent demographic characteristics. For this analysis, we excluded the small number of reserve employees interviewed in Bawangling town rather than in a local community (leaving n=97 respondents). Bawangling-only models included only village, age, sex, and frequency of forest visits, due to limited ethnic variation within villages around this reserve. We also investigated whether perceptions about local primate status varied between species using chi squared tests.

Finally, we investigated time-series data for primate last-encounter dates reported from different reserves. We converted all records (gibbon and macaque sightings and gibbon calls) to direct calendar years (Supporting Information), and used associated location information to assign events to specific reserves for analysis. We pooled gibbon sighting and call reports into a combined gibbon encounter dataset to increase sample size. We analysed differences in last-encounter histories between reserves

during 1990–2015 using GLMs; frequency of last-encounter dates per reserve per year was expressed as a proportion of total number of observations for each reserve's encounter history dataset, and regressed on year (predictor), following Turvey et al. [2012, 2015b]. We excluded the oldest 5% of records from the total datasets for each species for each reserve from analysis, as a standardized approach to reduce the effect of a long encounter data "tail" artefactually extending the time series used for analysis [Turvey et al., 2015b]. We used a binomial error structure unless data showed overdispersion, when a quasibinomial error structure was used. For each species, we considered last-encounter history trajectories between reserves to be significantly different if confidence intervals of regression slopes did not overlap; we used 83% confidence intervals for comparison because these give an approximate $\alpha=0.05$ test, whereas comparisons using 2 sets of 95% confidence intervals are too conservative [Payton et al., 2003]. Lower encounter history slopes indicate that fewer encounters have occurred close to the present.

Field survey

We conducted fieldwork to investigate possible gibbon survival in Limushan on 8th to 24th September 2015, using 2 methods: passive listening-post auditory surveying and call playback, which has recently been demonstrated to be able to detect Hainan gibbon social groups and solitary individuals [Bryant et al., in press]. We initially investigated all areas where possible recent gibbon sightings or older accounts of gibbon occurrence had been reported (Zhufeng [main peak], Wugongli [5 km north of main peak], Qigongli [7 km east of main peak], Sanxingjian, Yinggeao) to assess habitat quality and likelihood of gibbon persistence. Most sites contained poor-quality secondary forest, and we considered them unlikely to support gibbons, but some

good-quality habitat remained at Sanxingjian (scattered primary forest distributed in small patches within secondary forest across c. 8 km^2) and Yinggeao (continuous c. 1 km^2 patch of primary forest along steep cliffs across c. 4 km^2).

A team of 8 trained researchers and 9 local participants conducted systematic survey work at Sanxingjian and Yinggeao (Sanxingjian: 6 days' fieldwork with 3 effective work days, 10th to 16th September; Yinggeao: 4 days' fieldwork with 3 effective work days, 19th to 22nd September). We established 4 elevated listening posts on mountain ridges at Sanxingjian (LP1: N 19°08.819', E 109°41.732', 921 m asl; LP2: N 19°08.649', E 109°41.915', 864 m asl; LP3: N 19°08.925', E 109°42.316', 716 m asl; LP4: N 19°08.662', E 109°41.604', 890 m asl) and 2 at Yinggeao (LP5: N 19°10.863', E 109°41.477', 653 m asl; LP6: N 19°11.188', E 109°41.198', 895 m asl). Locations were selected based on topography, forest quality and distance from camp, and spaced 519 to 921 m apart to cover all areas of forest that could potentially support gibbons. The peak Hainan gibbon singing period is 06:00 to 07:00 am, with singing continuing at decreasing regularity for several hours [Chan et al., 2005], so 2 to 3 surveyors occupied each listening post from c. 6:00 am until noon for 3 consecutive days. We employed call playback at both sites, using the same Hainan gibbon calls described above and a FOXPRO 'Hellfire' (FOXPRO Inc. Lewistown, Pennsylvania) portable speaker. We conducted playback twice daily for 10 to 15 minutes each time between 7:02 am and 11:15 am over 5 survey days. We also recorded signs of human disturbance and other biodiversity at both sites.

RESULTS

Interview survey

We interviewed 709 respondents (Bawangling, *n*=107; Diaoluoshan, *n*=100; Jianfengling, *n*=100; Jiaxi, *n*=101; Limushan, *n*=100; Wuzhishan, *n*=100; Yinggeling, *n*=101; mean age=50.1, range=20–94, SD=15.3; male=83%, female=17%). Not all respondents answered all questions, and we excluded data from 2 respondents at Jianfengling because they claimed to have seen giant anteaters. Respondents reported belonging to 4 ethnic groups (Li, 84%; Miao, 11%; Han, 4%; Zhuang, <1%; *n*=706); due to low occurrence of Zhuang respondents (*n*=2), we considered only respondents belonging to Han, Li and Miao ethnic groups in analyses of the influence of ethnicity on responses. Most respondents (84%, *n*=706) were farmers, but a range of other primary occupations was also reported; we assigned occupations to 2 categories for analysis: "forest-related jobs" (9%, including rubber harvesters, loggers, and reserve and forestry employees) and "non forest-related jobs" (91%, including farmers, production managers, manual labourers, migrant workers, salespeople/shopkeepers, fishers, teachers, and local party officials). Respondents reported frequency of forest visits in a variety of ways; we assigned data to 2 categories, more than once/month (29%) and less than once/month (71%) (*n*=707), as this represented a natural break in the data, and different answers could generally be assigned to one of these relatively broad categories. Univariate GLMs showed no significant differences between reserves in respondent age profiles or reported occupations; we interviewed significantly more men than women at Diaoluoshan (P=0.007), Limushan (P<0.001) and Wuzhishan (P<0.001) compared to Bawangling, however, and respondents reported visiting the forest significantly more frequently at Jiaxi (P=0.03) and Limushan (P<0.001) than at Bawangling. There was also a significant difference in relative proportions of ethnic groups represented in respondent samples between reserves (χ^2=146.26, df=12, P<0.001).

Overall, 54% of our total respondent sample could identify a gibbon photograph, 49% were familiar with the standard Chinese name for gibbon, 17% had reportedly seen a gibbon, 15% could identify a recording of a gibbon call, and 17% had reportedly heard the call (with some respondents reportedly having heard it without knowing what it was) (Fig. 2). At Bawangling, 74% of respondents could identify the photograph, 65% were familiar with the name, 24% reported having seen a gibbon, 34% could identify its call, and 41% reported having heard the call. Most respondents in our total sample who had seen gibbons and provided quantitative information on number of sightings had seen the species only once (58%, n=84). Respondents used numerous names when discussing gibbons, including both *changbiyuan* or its stem word *yuan*, and other words in both standard Chinese (e.g., *xingxing*) and different minority languages (e.g., *bang*, *bian*, *fei*, *guan*, *men*, *vei*, *vien*, *wei*). Conversely, 94% of respondents could identify a macaque photograph, and 75% had reportedly seen a macaque.

Respondent perceptions of local population status varied substantially between gibbons and macaques. Significantly more respondents reportedly did not know the local status of gibbons (28%) compared to macaques (10%) (n=707; χ^2=77.51, df=1, P<0.001). For the subset of respondents who assigned either primate to an abundance category, the great majority of respondents considered that gibbons did not occur locally, with very few respondents considering gibbons to be present in any abundance (none: 86%; very few: 10%; not many: 3%; very many: 1%; n=540); in contrast, far more respondents assigned macaques to higher abundance categories (none: 16%; very few: 35%; not many: 19%; very many: 30%; n=640), with these differences in perceived abundance between species differing significantly (χ^2=578.22, df=3, P<0.001). Respondent perceptions about gibbons also varied

between Bawangling and other reserves, with significantly more respondents reportedly unaware of local gibbon status at Bawangling (54%) compared to other reserves (23%) (χ^2=40.57, df=1, P<0.001), and for the subset of respondents who assigned gibbons to an abundance category, significantly more assigned gibbons to higher categories at Bawangling (none: 41%; very few: 29%; not many: 25%; very many: 6%; n=49) compared to other reserves (none: 91%; very few: 8%; not many: <1%; very many: <1%; n=461) (χ^2=140.53, df=3, P<0.001).

All measures of awareness and experience of primates showed significant differences between Bawangling and other reserves, and were also correlated with some of our demographic predictor variables, with gibbon and macaque data showing markedly different statistical patterns (Fig. 2; Tables 1–2). For gibbons, older respondents were statistically more likely to identify photographs, be familiar with the standard Chinese name, have seen the species, and identify and have heard the call (P<0.001 in all models); a 1-year increase in respondent age was associated with an increased probability of 3% in familiarity with Chinese name and correct photograph identification, 5% in likelihood of having heard the call and correct call identification, and 7% in likelihood of having seen the species. Male respondents were more likely to identify calls (P=0.047), respondents with forest-related jobs were more likely to identify photographs (P=0.005), be familiar with the Chinese species name (P=0.007), and identify calls (P=0.023), and respondents who reported visiting the forest more frequently were more likely to have heard gibbon calls (P=0.005). Compared to Bawangling, respondents were less likely to recognise gibbons in Diaoluoshan (P<0.001), Jianfengling (P<0.001), Limushan (P<0.001) and Wuzhishan (P=0.001); were less likely to be familiar with the Chinese name for gibbon in Diaoluoshan, Jianfengling, Limushan and Wuzhishan (P<0.001 in all models); were

374 less likely to have seen a gibbon in Diaoluoshan (P=0.006) and Wuzhishan
375 (P=0.002); were less likely to identify gibbon calls in Diaoluoshan (P<0.001),
376 Jianfengling (P<0.001), Jiaxi (P=0.001), Limushan (P<0.001) and Wuzhishan
377 (P<0.001); and were less likely to have heard gibbon calls in all other reserves
378 (Yinggeling, P=0.002; other reserves, P<0.001). Respondents were, however, more
379 likely to be familiar with the Chinese species name for gibbon in Jiaxi than in
380 Bawangling (P=0.025) (Fig. 2).
381 Conversely, not only age (P<0.001) but also male sex (P<0.001) and Han
382 ethnicity compared to Li (P=0.030) and Miao (P=0.028) were associated with
383 increased likelihood of having seen macaques in our final models. Compared to
384 Bawangling, respondents were more likely to recognise macaques in Jiaxi (P=0.048),
385 and more likely to have seen macaques in Jianfengling (P<0.001), Jiaxi (P=0.006),
386 Limushan (P<0.001) and Yinggeling (P=0.004) (Fig. 2).
387 For respondents interviewed around Bawangling, awareness and experience of
388 gibbons was also correlated with both demographic predictors and interview locality
389 (full final models not shown). Age was the only significant predictor of likelihood of
390 having seen gibbons (effect size=0.058, SE=0.017, P<0.001). Community was the
391 only significant predictor of whether respondents could identify gibbons from
392 photographs (respondents from Gunong Cun and Zibao Yicun were more likely to
393 identify gibbons in comparison to randomly selected reference village Dayan Laocun;
394 effect size=2.234, SE=1.049, P=0.033 for both comparisons) or had heard gibbon
395 calls (respondents from Zibao Yicun were more likely to have heard call in
396 comparison to Dayan Laocun; effect size=2.773, SE=1.118, P=0.013). Likelihood of
397 identifying gibbon calls was predicted by both frequency of forest visits (effect
398 size=2.122, SE=1.062, P=0.046) and community (respondents from Zibao Yicun

were more likely to identify calls in comparison to Dayan Laocun; effect size=3.345, SE=1.329, *P*=0.012). None of our chosen predictors were associated with variation in whether respondents were familiar with the Chinese name for gibbon.

We collected a total of 119 gibbon last-sighting records, from all reserves (Bawangling, *n*=31; Diaoluoshan, *n*=9; Jianfengling, *n*=17; Jiaxi, *n*=19; Limushan, *n*=13; Wuzhishan, *n*=12; Yinggeling, *n*=18) (Fig. 3). Nearly all represent first-hand sightings, although there were also a small number (*n*=9) of second-hand records. The most recent sightings for almost all reserves dated from post-2000, and in many cases were surprisingly recent, although mean last-sighting dates/reserve were much older (Bawangling: latest=2015, mean=1996; Diaoluoshan: latest=1992, mean=1968; Jianfengling: latest=2002, mean=1983; Jiaxi: latest=2014, mean=1978; Limushan: latest=2014, mean=1979; Wuzhishan: latest=2010, mean=1983; Yinggeling: latest=2009, mean=1981). Only 45% (*n*=31) of gibbon last-sightings from Bawangling dated from within the past decade, and respondents living near other reserves but who had evidently spent time within gibbon habitat at Bawangling reported some recent Bawangling sightings (Jianfengling: 2013 sighting; Jiaxi: 2 2014 sightings; Limushan: 2013 sighting; Yinggeling: 2014 sighting). A gibbon poaching event at Bawangling by local villagers during the past decade was also reported during the pilot study in August 2014. We collected 68 dated records of correctly identified gibbon calls, again from all reserves (Bawangling, *n*=16; Diaoluoshan, *n*=4; Jianfengling, *n*=5; Jiaxi, *n*=12; Limushan, *n*=3; Wuzhishan, *n*=12; Yinggeling, *n*=16), and again with several recent post-2000 records reported from outside Bawangling (Jianfengling: 2005; Jiaxi: 2013, 2010; Limushan: 2014; Yinggeling: 2014, 2013, 2011, 2000) (Fig. 3). We also collected 433 macaque last-sighting records (Bawangling, *n*=66; Diaoluoshan, *n*=58; Jianfengling, *n*=60; Jiaxi, *n*=75; Limushan,

424 *n*=58; Wuzhishan, *n*=39; Yinggeling, *n*=77); latest records dated from 2015 for all
425 reserves (Fig. 3).
426 Two respondents from Limushan, who were both familiar with macaques,
427 reported detailed and relatively convincing accounts of recent apparent gibbon
428 encounters in the reserve. One respondent reportedly saw a golden-yellow primate in
429 mid-March 2014, which had one long arm, short legs, and a "short tail" (described as
430 much shorter than the long tail of a macaque), and which he identified as a gibbon.
431 The same one-armed animal had also reportedly been seen by someone else 5-6 years
432 ago, and was believed locally to have lost its other arm through being shot about 10
433 years ago. Another respondent, a former village head, reportedly saw 2 greyish-black
434 gibbons at 8 a.m. in August 2012. These animals reportedly had short legs, arms that
435 were longer than a macaque's, but also "tails that were longer than a macaque's". This
436 respondent also reported that he had periodically heard an unusual animal call in the
437 forest, most recently in February 2014; he did not initially know what this call was,
438 but described it to his 91 year old father, a former hunter, who told him it was a
439 gibbon call. When we played call recordings to this respondent without prompting, he
440 showed a strong animated reaction to the gibbon call and confirmed this was the noise
441 he had heard.
442 Analysis of combined gibbon dated sighting and call records showed that
443 compared to Bawangling, Jianfengling, Wuzhishan and Yinggeling had significantly
444 lower regression slopes of encounter histories, whereas there was no statistical
445 difference in slopes between Bawangling, Jiaxi and Limushan (Fig. 4a; Table 3). We
446 excluded Diaoluoshan from analysis of gibbon data, as only 2 local encounter records
447 were available for the period 1990–2015. Conversely, compared to Bawangling,
448 Diaoluoshan, Jianfengling and Limushan had significantly higher regression slopes of

449 macaque sighting histories, whereas there was no statistical difference in slopes
450 between Bawangling, Jiaxi, Wuzhishan and Yinggeling (Fig. 4b; Table 3).
451
452 **Field survey**
453 We detected no evidence of gibbons at either field site in Limushan during survey
454 work, and found that illegal hunting was common within the reserve, which was not
455 protected by any patrol teams. Survey teams heard 4 gunshots in 8 days and saw 8
456 hunters carrying guns at Sanxingjian, and heard 4 gunshots and saw 4 hunters
457 carrying guns at Yinggeao; survey teams were threatened by hunters at both sites. We
458 found 6 permanent or temporary campsites at Sanxingjian and 5 at Yinggeao typical
459 of those used by hunters, with one well-managed campsite at Sanxingjian surrounded
460 by small vegetable plots, indicating lengthy residence by hunters in the forest. We
461 observed traps and snares and illegal felling of agarwood at both sites, and found that
462 guns were very common in villages neighboring the reserve. We detected relatively
463 limited wild mammal biodiversity at either site: we observed macaques and wild boar
464 tracks at both sites, a black giant squirrel (*Ratufa bicolor*) and signs and trails of
465 brush-tailed porcupine (*Atherurus macrourus*) at Sanxingjian, and a giant flying
466 squirrel (*Petaurista philippensis*) at Yinggeao. Hunters and rangers encountered
467 during fieldwork reported that they had not seen gibbons in the reserve for c. 30 years.
468
469 **DISCUSSION**
470 Our extensive new LEK dataset provides instructive new insights on the extent to
471 which this non-standard category of data can provide useful or consistent information
472 for assessing status and possible survival of remnant populations of threatened
473 species. Overall, several aspects of our LEK data match expected ecological patterns

474 based on independent knowledge of Hainan's mammal fauna. Compared to levels of
475 awareness or experience of the extremely rare Hainan gibbon, far more respondents
476 had seen or heard of the much more common rhesus macaque, could provide
477 information on its local status, and thought that it was locally more abundant.
478 Similarly, respondents from Bawangling reported generally greater levels of gibbon
479 awareness and experience compared to most other reserves, consistent with this being
480 the one reserve confirmed to contain a remnant Hainan gibbon population, and the
481 higher gibbon encounter-history regression slope at Bawangling indicates that more
482 gibbon encounters have occurred close to the present compared to the timing of
483 encounters reported from other reserves. Our macaque LEK data conversely show
484 very different patterns of awareness, experience and sighting histories between
485 reserves, matching the known survival of macaques across all of the study landscapes.
486 The different statistical relationship of forest-related jobs and forest visits in
487 predicting awareness or experience for each primate is likely to reflect the different
488 level of access to forest environments needed for respondents to become aware of or
489 encounter rare gibbons restricted to core forest habitat versus ecologically more
490 cosmopolitan macaques. The documented major gibbon decline and range contraction
491 on Hainan in living memory is also reflected in the strong effect of age in predicting
492 all aspects of awareness and experience of gibbons; our data provide a new example
493 of "shifting baseline syndrome", whereby age- or experience-related differences in
494 perception of environmental conditions are consistent with independently
495 demonstrated biological change [Papworth et al., 2009; Turvey et al., 2010]. LEK
496 obtained from our respondents can therefore demonstrably provide at least broadly
497 accurate baseline data on the local status of arboreal primates, which has important
498 implications for using LEK as a tool to assess possible gibbon survival across Hainan.

499 At Bawangling, the only reserve on Hainan which definitely contains gibbons and
500 which was established specifically to protect the species and its habitat [Chan et al.,
501 2005], levels of reported gibbon awareness and experience were still not particularly
502 high. Only 74% of respondents could identify a gibbon photograph and only 65%
503 were familiar with the standard Chinese name for gibbon; ≤41% could identify or had
504 heard a gibbon call; and only 24% reported ever having seen a gibbon, with over 50%
505 of these sightings more than a decade old. Over 50% of respondents at Bawangling
506 were unaware of the local status of gibbons, and over 40% reported that gibbons did
507 not occur locally. There was also significant variation between communities around
508 Bawangling in levels of awareness of gibbons. Although we deliberately chose not to
509 ask questions about potentially sensitive behaviors such as hunting practices or
510 bushmeat consumption, and made further efforts to minimise the risk of respondent
511 reticence in our interview design, the possibility of such reticence cannot be ruled out;
512 these values should therefore be interpreted as minimum estimates of local awareness
513 and experience, and future community-focused studies in Hainan may benefit from
514 using interview techniques designed specifically to gather information on illegal
515 behaviors (St John et al., 2012; Nuno et al., 2013). Despite this potential concern, our
516 findings still have important implications for conservation management at
517 Bawangling. Although community-based conservation initiatives (e.g., to assess
518 natural resource use) have been carried out periodically around parts of the reserve for
519 over a decade [Fauna & Flora International China Programme, 2005], a substantial
520 proportion of local forest users still apparently have little knowledge of gibbons or
521 their conservation status, suggesting that modification of these community-based
522 initiatives to include more awareness-raising activities could be extremely beneficial
523 for effective protection of gibbons at Bawangling. More worryingly, the relatively

524 recent reported gibbon poaching event at Bawangling, which may represent one of the
525 events reported by Fellowes et al. [2008], indicates that direct hunting of gibbons may
526 not have been completely eliminated, a cause for extreme concern for the tiny and
527 extremely vulnerable surviving population [Fellowes et al., 2008; Turvey et al.,
528 2015a]. The recent gibbon sightings made at Bawangling by respondents who live
529 near Jianfengling, Jiaxi, Limushan and Yinggeling also suggest that forest users move
530 widely across Hainan to access resources in different reserves, raising further
531 concerns about intensity of resource use and poaching within Bawangling and
532 associated threats to the reserve's gibbons.

533 In addition to practical implications for conservation management, the relatively
534 low levels of reported respondent awareness and experience of gibbons when a
535 remnant local population is definitely extant presents an interesting framework for
536 interpreting LEK data from other reserves across Hainan. Our data suggest that even
537 if gibbons persist at low densities, a substantial proportion of local respondents may
538 be unaware of their presence, may not have encountered them recently or at all, and/or
539 may be unable to provide relevant information about them. The generally low level of
540 local awareness and experience of gibbons elsewhere on Hainan may therefore not, in
541 itself, provide robust evidence that gibbons are extirpated from other reserves. The
542 statistically significant differences from Bawangling across multiple indices of
543 awareness, experience, and sighting histories provide stronger and reasonably
544 consistent support for likely extinction of gibbons in Diaoluoshan, Jianfengling and
545 Wuzhishan, although surprisingly recent alleged sightings from Jianfengling and
546 Wuzhishan may suggest later survival than previously assumed of remnant
547 populations or lone individuals. It is less straightforward to assess the possibility of
548 gibbon survival at Jiaxi, Limushan and Yinggeling on the basis of our LEK data, as

these reserves show fewer statistical differences from Bawangling in local gibbon awareness, experience, or sighting histories; indeed, respondents at Jiaxi showed higher levels of gibbon name familiarity compared to Bawangling, our Yinggeling gibbon data were statistically indistinguishable from Bawangling data except for sighting-history regression slopes and whether respondents had heard gibbon calls, and our Limushan gibbon data showed statistically similar sighting-history regression slopes to Bawangling and contained detailed recent sightings.

The possibility of continued gibbon survival outside Bawangling is challenged by conflicting survey data and further considerations. Most significantly, our targeted field survey in Limushan failed to detect gibbons within the small remaining area of ecologically suitable primary forest, and documented intensive and unregulated illegal exploitation of wildlife inside the reserve. Extreme levels of wildlife overexploitation have been documented across Hainan outside national nature reserves [e.g., Liang et al., 2013], and respondents in our dataset reported entering forests significantly more frequently in Limushan and Jiaxi, provincial reserves that receive less financial support than national reserves. Poaching pressure at Jiaxi is therefore also likely to be high, reducing the likelihood of local gibbon survival. Despite stronger reserve management and protection, high levels of illegal wildlife exploitation are also reported at Yinggeling [Wan et al., 2015]. Jiaxi and Yinggeling are both geographically adjacent to Bawangling in the upper Changhua River watershed (Fig. 1), suggesting that at least some gibbon LEK collected in these reserves may be derived from their relatively close proximity to a landscape that definitely contains gibbons. Greater levels of awareness (although not experience) of gibbons at Yinggeling may also be partly associated with increased conservation education activities that have been conducted locally with support from external conservation

organizations [Kadoorie Farm & Botanic Garden, 2016]. Variation in familiarity of the standard Chinese name for gibbon between reserves may also reflect the diversity of Mandarin and local names used across Hainan and variation in Mandarin usage in different ethnic minority communities, rather than variation in continued local presence of gibbons.

Acceptance of LEK data, particularly unverified sightings, as empirical evidence for continued presence of possibly extinct species in the absence of conclusive physical proof of survival can lead to biological misunderstanding, with potential for significant overestimation of species distribution and abundance and failure to recognise true levels of range loss [McKelvey et al., 2008]. Potential misconceptions of regional species status created by acceptance of inconclusive anecdotal occurrence data represent a mismatch between data quantity and quality. Small numbers of recent gibbon reports from almost all of the reserves we surveyed could be treated as potential confirmation of much wider recent or continued survival of remnant gibbon populations across Hainan than previously supposed, but we consider that such wide-scale survival is extremely unlikely. One solution may be to assess these data in relation to information from Bawangling, the one region where gibbons are definitely known to occur on Hainan. The Bawangling gibbon population is extremely small and intrinsically at risk of stochastic extinction, and must be close to the threshold for even medium-term sustainability for a primate population [Turvey et al., 2015a]. As such, landscapes showing statistically lower levels of respondent awareness, experience, or sighting histories of gibbons compared to Bawangling may be unlikely to support gibbons, because populations that are even more reduced in size and/or distribution than the Bawangling population may be biologically unable to persist.

598 This paradigm suggests the pessimistic conclusion that most or all of the
599 surveyed areas outside Bawangling do not contain gibbons, with the handful of recent
600 alleged sightings from these areas possibly representing misidentifications or
601 inaccurate recall or reporting of sighting dates or locations [cf. McKelvey et al.,
602 2008]. Conversely, last-sighting records rarely capture the final occurrence of
603 declining species [Boakes et al., 2015], and it is not unreasonable to assume that some
604 remnant gibbon populations may have persisted beyond the dates for regional
605 extinction proposed by previous authors. In addition, whereas we have been able to
606 define the LEK signal for a remnant population of c. 26 gibbons, we do not know the
607 LEK signal of a single remaining gibbon pair or lone individual. We also do not know
608 the relative sensitivity of standard survey techniques versus LEK for detecting
609 remnant gibbon or other primate populations, so cannot yet determine either how well
610 LEK-based methods actually perform when trying to detect extremely rare species, or
611 the level of negative field survey effort required to reject positive LEK-derived
612 results. It therefore remains possible that the recent detailed sightings from Limushan
613 are indeed genuine, and while we consider it unlikely that gibbons still survive in this
614 reserve, this population may have become extinct only within the last few years. If
615 Hainan gibbons still survive anywhere outside Bawangling, our LEK data suggest that
616 this may be most likely in the Jiaxi-Yinggeling region of the upper Changhua River
617 watershed. While allocation of further resources to investigate this possibility may not
618 constitute a conservation priority following our large-scale survey, it may be
619 appropriate to conduct further targeted surveys in the Jiaxi-Yinggeling region using
620 methods that are cost-effective and not labour-intensive, such as acoustic technologies
621 [Turvey et al., 2015; Bryant et al., in press]. Ultimately, the continued survival of
622 gibbons outside Bawangling may be unknowable, and the dynamics of decline and

623 extinction of cryptic remnant populations may be impossible to adequately reconstruct
624 or understand. When interpreted carefully and critically, however, LEK can represent
625 a highly useful component of the modern conservation toolkit, which must draw upon
626 different complementary types of data to prevent future extinctions of highly
627 threatened species in China and elsewhere.
628

629 **ACKNOWLEDGMENTS**

630 Fieldwork support was provided by Hongyu Fu, Qiaomei Li and Yuegui Lin (Hainan
631 University), Cong Zhou, Hao Zhang and Jinghua Zhang (Sanya University), the
632 Bawangling National Nature Reserve and Limushan Provincial Nature Reserve
633 management offices, local reserve staff from each protected area, and the Provincial
634 Forestry Department of Hainan. All fieldwork adhered to the legal requirements of the
635 People's Republic of China, and to all relevant animal care regulations. Funding was
636 provided by the Arcus Foundation and the Royal Society (UF130573).

637 **REFERENCES**

638 Abram NK, Meijaard E, Wells JA, et al. 2015. Mapping perceptions of species'
639 threats and population trends to inform conservation efforts: the Bornean
640 orangutan case study. Diversity and Distributions 21:487–499.
641 Anadón JD, Giménez A, Ballestar R, Pérez I. 2009. Evaluation of local ecological
642 knowledge as a method for collecting extensive data on animal abundance.
643 Conservation Biology 23:617–625.
644 Boakes EH, Rout TM, Collen B. 2015. Inferring species extinction: the use of
645 sighting records. Methods in Ecology and Evolution 6:678–687.
646 Brockelman WY, Srikosamatara S. 1993. Estimation of density of gibbon groups by
647 use of loud songs. American Journal of Primatology 29:93–108.
648 Bryant JV, Brulé A, Wong MHG, et al. In press. Detection of a new Hainan gibbon
649 family group using acoustic call playback. International Journal of Primatology.
650 Chan BPL, Fellowes JR, Geissmann T, Zhang J. 2005. Hainan gibbon status survey
651 and conservation action plan. Hong Kong: Kadoorie Farm & Botanic Garden.
652 Channell R, Lomolino MV. 2000. Dynamic biogeography and conservation of
653 endangered species. Nature 403:84–86.
654 Channell R, Lomolino MV. 2002. Trajectories to extinction: spatial dynamics of the
655 contraction of geographical ranges. Journal of Biogeography 27:169–179.
656 Crawley MJ. 2007. The R book. Chichester, UK: Wiley.
657 Fauna & Flora International China Programme. 2005. Action plan for implementing
658 co-management in the Bawangling nature reserve and adjacent communities in
659 Qingsong township. Beijing: Fauna & Flora International China Programme.

660 Fellowes JR, Chan BPL, Zhou J, et al. 2008. Current status of the Hainan gibbon
661 (*Nomascus hainanus*): progress of population monitoring and other priority
662 actions. Asian Primates Journal 1:2–9.
663 Groombridge JJ, Massey JG, Bruch JC, et al. 2004. An attempt to recover the po'ouli
664 by translocation and an appraisal of recovery strategy for bird species of extreme
665 rarity. Biological Conservation 118:365–375.
666 Guest G. 2006. How many interviews are enough? An experiment with data saturation
667 and variability. Field Methods 18:59–82.
668 Hemerik L, Hengeveld R, Lippe E. 2006. The eclipse of species ranges. Acta
669 Biotheorica 54:255–266.
670 IUCN. 2015. The IUCN Red List of Threatened Species. Version 2015.4. Available
671 at: http://www.iucnredlist.org (last accessed 31 March 2016).
672 Kadoorie Farm & Botanic Garden. 2001–2003. Rapid biodiversity assessments in
673 Hainan. Hong Kong: Kadoorie Farm & Botanic Garden.
674 Kadoorie Farm & Botanic Garden. 2016. Programmes: Yinggeling National Nature
675 Reserve, Hainan. Available at: http://www.kfbg.org/eng/yinggeling.aspx (last
676 accessed 31 March 2016).
677 Lau MWN, Fellowes JR, Chan BPL. 2010. Carnivores (Mammalia: Carnivora) in
678 South China: a status review with notes on the commercial trade. Mammal
679 Review 40:247–292.
680 Liang W, Cai Y, Yang C. 2013. Extreme levels of hunting of birds in a remote village
681 of Hainan Island, China. Bird Conservation International 23:45–52.
682 Liu Z, Yu S, Yuan X. 1984. The resource of the Hainan black gibbons at its present
683 situation. Chinese Wildlife 6:1–4.

684 McKelvey KS, Aubry KB, Schwartz MK. 2008. Using anecdotal occurrence data for
685 rare or elusive species: the illusion of reality and a call for evidentiary standards.
686 BioScience 58:549–555.
687 Meijaard E, Mengersen K, Buchori D, et al. 2011. Why don't we ask? A
688 complementary method for assessing the status of great apes. PLoS ONE
689 6(3):e18008.
690 Nash HC, Wong MHG, Turvey ST. 2016. Using local ecological knowledge to
691 determine status and threats of the Critically Endangered Chinese pangolin
692 (*Manis pentadactyla*) in Hainan, China. Biological Conservation 196:189–195.
693 Newing H. 2011. Conducting research in conservation: a social science perspective.
694 Abingdon, UK: Routledge.
695 Nuno A, Bunnefeld N, Naiman LC, Milner-Gulland EJ. 2013. A novel approach to
696 assessing the prevalence and drivers of illegal bushmeat hunting in the Serengeti.
697 Conservation Biology 27:1355–1365.
698 Papworth SK, Rist J, Coad L, Milner-Gulland EJ. 2009. Evidence for shifting baseline
699 syndrome in conservation. Conservation Letters 2:93–100.
700 Parry L, Peres CA. 2015. Evaluating the use of local ecological knowledge to monitor
701 hunted tropical-forest wildlife over large spatial scales. Ecology and Society
702 20:15.
703 Payton ME, Greenstone MH, Schrenker N. 2003. Overlapping confidence intervals or
704 standard error intervals: what do they mean in terms of statistical significance?
705 Journal of Insect Science 3:34.
706 R Development Core Team. 2015. R: a language and environment for statistical
707 computing. Vienna: R Foundation for Statistical Computing.

708 Segan DB, Bottrill MC, Baxter PWJ, Possingham HP. 2011. Using conservation
709 evidence to guide management. Conservation Biology 25:200–202.
710 Smith AT, Xie Y, editors. 2008. A guide to the mammals of China. Princeton:
711 Princeton University Press.
712 St John FAV, Keane AM, Edwards-Jones G, et al. 2012. Identifying indicators of
713 illegal behaviour: carnivore killing in human-managed landscapes. Proceedings
714 of the Royal Society B 279:804–812.
715 Sutherland WJ, Pullin AS, Dolman PM, Knight TM. 2004. The need for evidence-
716 based conservation. Trends in Ecology and Evolution 19:305–308.
717 Turvey ST, Barrett LA, Hao Y, et al. 2010. Rapidly shifting baselines in Yangtze
718 fishing communities and local memory of extinct species. Conservation Biology
719 24:778–787.
720 Turvey ST, Risley CL, Barrett LA, Hao Y, Wang D. 2012. River dolphins can act as
721 population trend indicators in degraded freshwater systems. PLoS ONE
722 7(5):e37902.
723 Turvey ST, Fernández-Secades C, Nuñez-Miño JM, et al. 2014. Is local ecological
724 knowledge a useful conservation tool for small mammals in a Caribbean
725 multicultural landscape? Biological Conservation 169:189–197.
726 Turvey ST, Traylor-Holzer K, Wong MHG, et al., editors. 2015a. International
727 conservation planning workshop for the Hainan gibbon: final report.
728 London/Apple Valley, MN: Zoological Society of London/IUCN SSC
729 Conservation Breeding Specialist Group.
730 Turvey ST, Trung CT, Quyet VD, et al. 2015b. Interview-based sighting histories can
731 inform regional conservation prioritization for highly threatened cryptic species.
732 Journal of Applied Ecology 52:422–433.

733 Wan JPH, Chan BPL, Liao C, et al. 2015. Conservation status of freshwater turtles on
734 Hainan Island, China: interviews and field surveys at Yinggeling Nature Reserve.
735 Chelonian Conservation Biology 14:100–103.
736 White PCL, Jennings NV, Renwick AR, Barker NHL. 2005. Questionnaires in
737 ecology: a review of past use and recommendations for best practice. Journal of
738 Applied Ecology 42:421–430.
739 Zhou J, Wei F, Li M, et al. 2005. Hainan black-crested gibbon is headed for
740 extinction. International Journal of Primatology 26:453–465.
741 Ziembicki MR, Woinarski JCZ, Mackey B. 2013. Evaluating the status of species
742 using indigenous knowledge: novel evidence for major native mammal declines
743 in northern Australia. Biological Conservation 157:78–92.

744 **Fig. 1.** Locations of reserves on Hainan at which interviews were conducted, showing
745 locations of surveyed villages (circles) and inferred Hainan gibbon distribution in
746 1900 (pale grey), after Chan et al. [2005]. B, Bawangling; D, Diaoluoshan; JN,
747 Jianfengling; JX, Jiaxi; L, Limushan; W, Wuzhishan; Y, Yinggeling.

748 **Fig. 2.** Proportion of respondents who (a) identified gibbon photograph, (b)
749 recognized Chinese name for gibbon, (c) had seen gibbon, (d) identified gibbon call,
750 (e) had heard gibbon call, (f) identified macaque photograph, (g) had seen macaque.
751 B, Bawangling; D, Diaoluoshan; JN, Jianfengling; JX, Jiaxi; L, Limushan; W,
752 Wuzhishan; Y, Yinggeling; asterisks, reserves with significantly lower
753 awareness/experience levels than Bawangling; stars, reserves with higher levels.

754 **Fig. 3.** Frequency distributions for gibbon and macaque last-encounter records across
755 seven reserves on Hainan for the period 1990–2015. Dark closed bars, gibbon last
756 sightings; dark open bars, gibbon call records; pale closed bars, macaque last
757 sightings.

758 **Fig. 4.** Slopes and 83% confidence intervals of last-encounter history regressions for
759 (a) gibbons and (b) macaques across Hainan. B, Bawangling; D, Diaoluoshan; JN,
760 Jianfengling; JX, Jiaxi; L, Limushan; W, Wuzhishan; Y, Yinggeling.

761 **Table 1.** Final models investigating respondent awareness and experience of gibbons
762 across Hainan. Bawangling represents the randomly selected reference category for
763 reserve.
764

Predictor	**Estimate**	**SE**	**z value**	***P*-value**
1. Recognize gibbon photograph				
Intercept	0.302	0.423	0.714	0.475
Reserve (Diaoluoshan)	-1.494	0.311	-4.804	<0.001
Reserve (Jianfengling)	-2.077	0.325	-6.393	<0.001
Reserve (Jiaxi)	-0.547	0.314	-1.745	0.081
Reserve (Limushan)	-1.661	0.311	-5.334	<0.001
Reserve (Wuzhishan)	-1.023	0.310	-3.302	0.001
Reserve (Yinggeling)	-0.310	0.320	-0.967	0.334
Age	0.033	0.006	5.776	<0.001
Occupation (Non-forest)	-0.851	0.304	-2.801	0.005
2. Familiar with standard Chinese name for gibbon				
Intercept	0.087	0.426	0.203	0.839
Reserve (Diaoluoshan)	-1.577	0.307	-5.143	<0.001
Reserve (Jianfengling)	-1.830	0.318	-5.751	<0.001
Reserve (Jiaxi)	0.737	0.329	2.239	0.025
Reserve (Limushan)	-1.875	0.319	-5.875	<0.001
Reserve (Wuzhishan)	-1.249	0.299	-4.176	<0.001
Reserve (Yinggeling)	0.332	0.313	1.061	0.289
Age	0.028	0.006	4.784	<0.001
Occupation (Non-forest)	-0.834	0.310	-2.689	0.007
3. Seen gibbon				
Intercept	-4.990	0.505	-9.880	<0.001
Reserve (Diaoluoshan)	-1.172	0.424	-2.762	0.006
Reserve (Jianfengling)	-0.442	0.377	-1.173	0.241
Reserve (Jiaxi)	-0.535	0.383	-1.400	0.162
Reserve (Limushan)	-0.522	0.399	-1.310	0.190
Reserve (Wuzhishan)	-1.359	0.431	-3.155	0.002
Reserve (Yinggeling)	-0.429	0.379	-1.133	0.257
Age	0.073	0.008	9.392	<0.001
4. Recognize gibbon call				
Intercept	-2.807	0.591	-4.749	<0.001
Reserve (Diaoluoshan)	-2.770	0.564	-4.907	<0.001
Reserve (Jianfengling)	-2.246	0.484	-4.639	<0.001
Reserve (Jiaxi)	-1.161	0.360	-3.226	0.001
Reserve (Limushan)	-2.801	0.630	-4.446	<0.001
Reserve (Wuzhishan)	-1.475	0.380	-3.883	<0.001
Reserve (Yinggeling)	-0.523	0.329	-1.590	0.112
Age	0.047	0.007	6.250	<0.001
Sex (Male)	0.657	0.330	1.990	0.047
Occupation (Non-forest)	-0.859	0.378	-2.269	0.023
5. Heard gibbon call				
Intercept	-2.739	0.424	-6.460	<0.001
Reserve (Diaoluoshan)	-2.935	0.518	-5.665	<0.001

Reserve (Jianfengling)	-2.279	0.425	-5.357	<0.001
Reserve (Jiaxi)	-1.548	0.356	-4.348	<0.001
Reserve (Limushan)	-3.363	0.633	-5.310	<0.001
Reserve (Wuzhishan)	-1.828	0.376	-4.858	<0.001
Reserve (Yinggeling)	-1.014	0.327	-3.098	0.002
Age	0.045	0.007	6.323	<0.001
Forest frequency	0.686	0.245	2.799	0.005

765

766 **Table 2.** Final models investigating respondent awareness and experience of
767 macaques across Hainan. Bawangling represents the randomly selected reference
768 category for reserve, and Han represents the randomly selected reference category for
769 ethnicity.

770

Predictor	**Estimate**	**SE**	**z value**	***P*-value**
1. Recognize macaque photograph				
Intercept	2.167	0.318	6.806	<0.001
Reserve (Diaoluoshan)	0.420	0.505	0.832	0.405
Reserve (Jianfengling)	1.289	0.667	1.932	0.053
Reserve (Jiaxi)	1.320	0.667	1.979	0.048
Reserve (Limushan)	1.012	0.602	1.682	0.093
Reserve (Wuzhishan)	0.276	0.487	0.566	0.571
Reserve (Yinggeling)	0.596	0.528	1.129	0.259
7. Seen macaque				
Intercept	0.950	1.102	0.863	0.388
Reserve (Dialuoshan)	0.484	0.341	1.419	0.156
Reserve (Jianfengling)	1.198	0.352	3.401	<0.001
Reserve (Jiaxi)	0.906	0.328	2.763	0.006
Reserve (Limushan)	1.301	0.370	3.515	<0.001
Reserve (Wuzhishan)	-0.248	0.305	-0.813	0.416
Reserve (Yinggeling)	0.945	0.332	2.847	0.004
Age	0.021	0.006	3.358	<0.001
Sex (Male)	0.957	0.234	4.087	<0.001
Ethnicity (Li)	-2.254	1.039	-2.169	0.030
Ethnicity (Miao)	-2.339	1.065	-2.197	0.028

771

772 **Table 3.** Slopes and 83% confidence intervals of last-encounter history regressions
773 for primates across Hainan. Reserve last-encounter histories differ statistically if there
774 is no overlap between respective upper and lower confidence interval bounds.
775 Degrees of freedom for all analyses=25. Error structure=binomial (gibbon data: all
776 reserves except Bawangling) or quasibinomial.
777

Reserve	Slope	Lower bound (8.5%)	Upper bound (91.5%)	Statistically different from Bawangling?
1. Gibbon encounter data				
Bawangling	0.184	0.104	0.282	—
Jianfengling	-0.047	-0.139	0.037	Y
Jiaxi	0.035	-0.031	0.105	N
Limushan	0.259	0.121	0.456	N
Wuzhishan	-0.098	-0.195	-0.016	Y
Yinggeling	-0.018	-0.075	0.039	Y
2. Macaque sighting data				
Bawangling	0.053	0.010	0.098	—
Diaoluoshan	0.163	0.115	0.217	Y
Jianfengling	0.214	0.139	0.305	Y
Jiaxi	0.082	0.035	0.133	N
Limushan	0.232	0.152	0.329	Y
Wuzhishan	0.093	0.038	0.154	N
Yinggeling	0.121	0.079	0.165	N

778