Using local ecological knowledge to assess the status of the Critically Endangered Chinese giant salamander *Andrias davidianus* in Guizhou Province, China

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Abstract The Critically Endangered Chinese giant salamander *Andrias davidianus*, the world's largest amphibian, is severely threatened by unsustainable exploitation of wild individuals. However, field data with which to assess the salamander's status, population trends, or exploitation across its geographical range are limited, and recent field surveys using standard ecological field techniques have typically failed to detect wild individuals. We conducted community-based fieldwork in three national nature reserves (Fanjingshan, Leigongshan and Mayanghe) in Guizhou Province, China, to assess whether local ecological knowledge constitutes a useful tool for salamander conservation. We collected a sample of dated salamander sighting records and associated data from these reserves for comparative assessment of the relative status of salamander populations across the region. Although Fanjingshan and Leigongshan are still priority sites for salamander conservation, few recent sightings were recorded in either reserve, and respondents considered that salamanders had declined locally at both reserves. The species may already be functionally extinct at Mayanghe. Although respondent data on threats to salamanders in Guizhou are more difficult to interpret, overharvesting was the most commonly suggested explanation for salamander declines, and it is likely that the growing salamander farming industry is the primary driver of salamander extraction from Guizhou's reserves. Questionnaire-based surveys can collect novel quantitative data that provide unique insights into the local status of salamander populations, and we advocate wide-scale incorporation of this research approach into future salamander field programmes.

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Received 14 May 2014. Revision requested 6 August 2014.
Accepted 25 September 2014. First published online 11 March 2015.

Keywords *Andrias davidianus*, community interviews, Fanjingshan, last-sighting data, Leigongshan, Mayanghe, questionnaire survey

This paper contains supplementary material that can be found online at http://journals.cambridge.org

Introduction

China's biodiversity is under threat from a range of anthropogenic activities, many of which are escalating in intensity, and the region is experiencing ongoing declines in vertebrate ranges, population extirpations and species extinctions (Li & Wilcove, 2005; Turvey et al., 2007; Redford et al., 2011). Many threatened Chinese species represent global conservation priorities, but identification of targeted management activities for these species is often impeded by limited recent baseline data on their status and distribution (Dudgeon, 2003; Fellowes et al., 2009). A prime example is the Chinese giant salamander *Andrias davidianus*, the world's largest amphibian, which is categorized as Critically Endangered on the IUCN Red List (IUCN, 2012) and is a priority for international amphibian conservation because of its extremely high level of unique evolutionary history (Isaac et al., 2012). The main threat to the species is unsustainable exploitation of wild individuals (Fellowes et al., 2003), primarily to stock the relatively new and rapidly growing farming industry that caters for the luxury food trade (Cunningham et al., 2015). Salamander rearing is carried out either in specialized farm buildings, or with offspring from farms distributed to individual households where local people act as smallholders (Cunningham et al., 2015). The species has been listed as a State II Protected Species in China since 1988, making collection of wild individuals from protected areas illegal (IUCN, 2012).

Although giant salamanders have been recorded from fast-flowing tributaries of the Yellow, Yangtze and Pearl river systems across 17 Chinese provinces or equivalent administrative areas (Wang et al., 2004), limited field data are available to assess their current occurrence, abundance, recent population trends, or local exploitation and other potential threats across their range. The most comprehensive study of the salamander's status was by Wang et al. (2004),

who conducted field surveys in six localities across five provinces and Chongqing municipality during 2000–2001 but only documented wild salamanders at one locality in Hunan Province. Although standardized field techniques are available for surveying cryptobranchid salamanders (Browne et al., 2011), single-site surveys employing these techniques in China have failed to detect wild individuals at localities where they were historically recorded (Pierson et al., 2014; Tapley et al., in press). Such absence of evidence may indicate either local population extirpation or alternatively that salamanders may persist at low densities and are difficult to detect directly during relatively short surveys (Wang et al., 2004), leading to uncertainty over patterns of survival across their range. Alternative approaches that permit rapid, wide-scale collection of more comprehensive field data on the status of salamander populations and that facilitate comparison of population status between different sites need to be identified to develop a robust scientific evidence-base for salamander conservation.

Whereas most conservation field research is based on ecological data collected directly by trained scientists, local ecological knowledge about the status of threatened species is often also available from untrained local people utilizing the same environments (White et al., 2005; Rist et al., 2010; Newing, 2011). In the absence of standard ecological data, local respondents can often provide important information on various aspects of the status, extinction drivers, or last occurrence of threatened or recently extinct species, with community interview surveys representing a robust, cost-effective approach for collecting data across wide geographical areas, especially for rare or elusive species that are otherwise difficult to study (Turvey et al., 2010a; Meijaard et al., 2011; Ziembicki et al., 2013). Untrained observers are considered particularly likely to provide useful information on charismatic, easily identifiable species, typically large-bodied or otherwise distinctive vertebrates, and/or species with significant socio-economic or cultural importance (Johannes et al., 2000; Jones et al., 2008; Turvey et al., 2014).

Small-scale community interviews were used by Wang et al. (2004) within a wider suite of survey techniques to collect qualitative data on salamander habitat preferences, broad-scale distribution and threats. Similar discussions with knowledgeable respondents have been used to gather general information of conservation relevance for other threatened Chinese species (e.g. Li et al., 2007; Han et al., 2013). However, community interviews can also be conducted in a more standardized manner to gather comparative data from different respondent groups. This approach can generate a quantitative evidence-base on species status and threats, and represents a more powerful tool for informing conservation management (Turvey et al., 2010a, 2013).

Given the urgent need to acquire a comprehensive evidence-base on the presence and population trends of the giant salamander and threats to the species across its range, we conducted community-based fieldwork to assess whether respondent data can constitute a useful tool for salamander conservation. We aimed to establish whether questionnaire-based surveys can provide quantitative data of use for conservation management on the local status of salamander populations and associated anthropogenic threats, whether this research approach can generate comparative data across different study regions to permit wider-scale surveys beyond the single-site level, and whether any demographic or environmental factors affect the usefulness of respondent data for salamander surveys. Fieldwork was carried out at three sites in Guizhou Province, a region with amongst the highest known number of historical salamander records (Fei et al., 2006) and that is likely to be a key geographical area for salamander conservation. Two of these sites have also been surveyed recently for giant salamanders using standard ecological field methods (Tapley et al., in press; see below), thus facilitating further comparison between the relative efficacy of various techniques for investigating the presence and status of wild populations.

Study area

Community-based surveys were carried out during 11 May–10 June 2013 in three national nature reserves in Guizhou Province: Fanjingshan, Leigongshan and Mayanghe (Fig. 1). Fanjingshan (41,900 ha, 500–2,571 m, 80% forest cover) was established as a protected area in 1978 and promoted to national nature reserve in 1986; it represents one of the best-preserved subtropical ecosystems in China. Leigongshan (47,300 ha, 650–2,179 m, 88.8% forest cover) was established as a protected area in 1982 and promoted to national nature reserve in 2001. Mayanghe (31,113 ha, 280–1,441 m, 63.7% forest cover) was established as a protected area in 1987 and promoted to national nature reserve in 2003. Salamanders have been recorded historically from Fanjingshan and Leigongshan (Gui, 1998; Xu et al., 2008). There are no specific published salamander reports from Mayanghe, but historical records from Wuquan County, one of the two counties in which Mayanghe is situated, probably refer to an area now included within this reserve (Fei et al., 2006).

There are numerous small villages within or immediately adjacent to all three reserves (Fanjingshan, $n = 65$; Leigongshan, $n = 25$; Mayanghe, $n = 40$). Most contain < 30 households and are mainly inhabited by non-Han ethnic minorities (Tujia in Fanjingshan and Mayanghe; Miao in all reserves), with inhabitants farming rice and tea or harvesting bamboo.

Methods

The distribution of villages within and around each reserve was determined from maps made available by the reserve

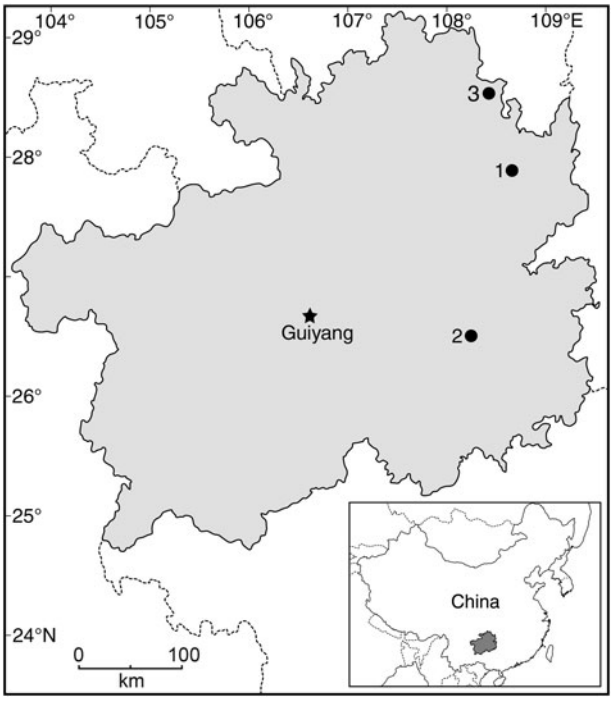

FIG. 1 Locations of (1) Fanjingshan National Nature Reserve, (2) Leigongshan National Nature Reserve and (3) Mayanghe National Nature Reserve in Guizhou Province. The shaded area on the inset indicates the location of Guizhou Province in China.

management offices; each village was numbered, and a random number generator was used to select 10 villages from each reserve (Fig. 2). Ten respondents, a sample size likely to provide near-saturation of relevant perceptions and experiences for many respondent groups (Guest et al., 2006), were interviewed in each of the villages selected for surveying. Interviews were conducted by YP and SL, who are both native Mandarin Chinese speakers. Detailed demographic data and maps of households were unavailable for all study villages, and thus it was not possible to design a random respondent sampling strategy in advance; respondents were therefore located by walking a transect through each village, approaching households and interviewing people opportunistically until 10 interviews were conducted. Given the small size of the villages, this process typically involved walking through the entire village before all interviews were completed. Only one person per household was interviewed. Respondents of all ages and both sexes were targeted to investigate potential demographic variation in knowledge and experience of salamanders across the study sites; however, there was bias towards selecting male respondents in Leigongshan because the majority of women in this region could not understand Mandarin Chinese and only spoke Miao.

All respondents were interviewed one-to-one using a standard anonymous Chinese-language questionnaire containing descriptive, structured and contrast questions, which took c. 20–30 minutes to complete and consisted of four sections: respondent background, salamanders, freshwater resource use, and conservation attitudes (Supplementary Material 1). At the beginning of the section on salamanders, respondents were asked to describe the appearance of giant salamanders and to identify one, without prompting, from illustrations of different salamander species (including *Paramesotriton caudopunctatus* and *Tylototriton asperrimus*) from Fei (1999). Questions were also asked about other species and environmental resources to make respondents feel that we were not only interested in salamanders, in case of any sensitivity about answering questions concerning either the species or local behaviours and activities that could adversely affect them. The questionnaire design and structure were refined during a pilot study in one village at Fanjingshan before the main survey. Interview methods followed Zoological Society of London (ZSL) guidelines for ensuring appropriate ethical standards in projects involving data collection from people for research purposes, and fieldwork protocols were approved by ZSL's Ethics Committee before fieldwork began. All respondents were informed at the outset about the study's general aims (collecting data to understand the status of locally important species and wider freshwater resources) and were assured that data would be anonymized; interviews were conducted only after participants gave verbal consent.

Statistical analysis was carried out using *R v. 2.15.3* (R Development Core Team, 2013). Differences in responses between study areas were investigated using χ^2 tests. Factors affecting the likelihood of respondents reporting salamander sightings were investigated using generalized linear mixed models, with binomial error structure because the response variable (salamanders seen/not seen) was binary. The maximal model was fitted first, and the minimally adequate model was found using the dredge function of the *MuMIN* package in *R*. Any insignificant interacting terms or factors were removed sequentially. The maximal model included the following fixed effects (nested within target villages): reserve identity, interviewer identity, respondent age, ethnicity, gender, occupation, whether respondent goes fishing in reserve, and whether respondent collects any aquatic species inside reserve. Village identity was incorporated as a random effect. Models were assessed using Akaike's information criterion (AIC), and the model with the smallest AIC value was selected (Burnham & Anderson, 2002).

Results

Three hundred respondents were interviewed, comprising 100 respondents in each reserve. Most (69%) were male, and the mean age of respondents was 47.2 ± SD 15.5 years (range 16–83 years). All respondents belonged to one of

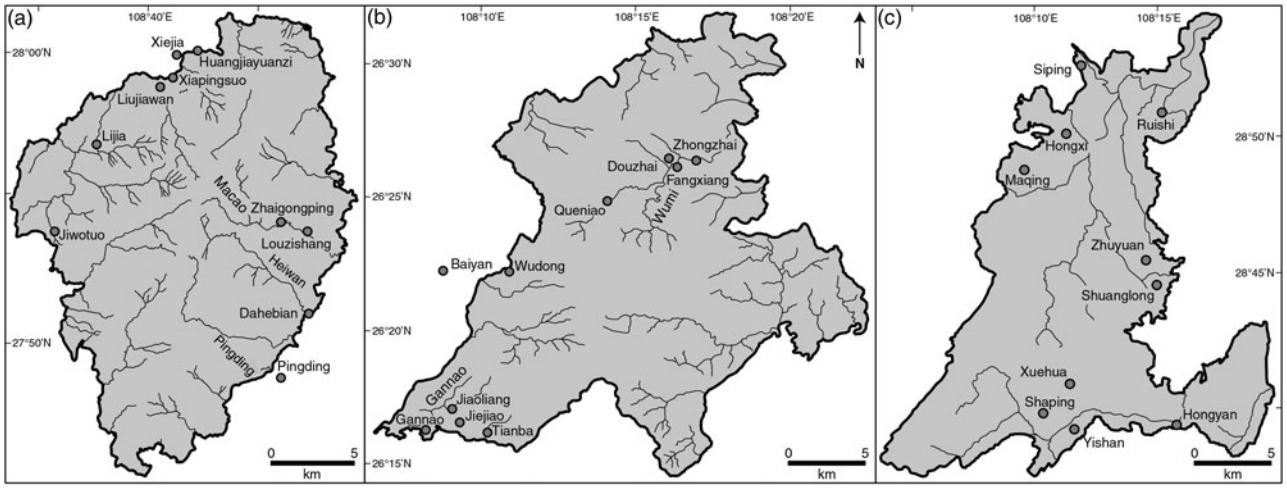

FIG. 2 Locations of named survey villages and river systems in (a) Fanjingshan, (b) Leigongshan, and (c) Mayanghe National Nature Reserves.

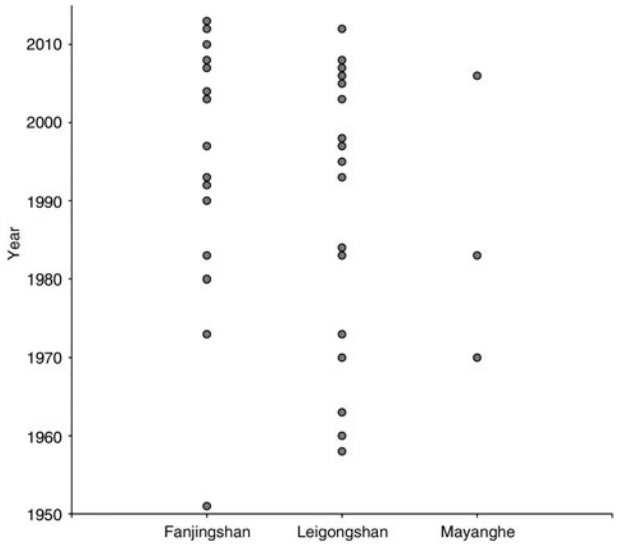

FIG. 3 Temporal distribution of Chinese giant salamander *Andrias davidianus* last-sighting records from Fanjingshan, Leigongshan, and Mayanghe National Nature Reserves.

three ethnic groups: Tujia (53.3%), Miao (40.3%) or Han (6.3%). Nearly all respondents (96.3%) were farmers, and nearly all (93.6%) frequently visited the reserve where their village was located. Further anecdotal information on salamanders was collected through discussions with reserve staff.

Significantly fewer respondents could recognize salamanders at Mayanghe (38%) compared to Fanjingshan (100%) and Leigongshan (91%; $\chi^2 = 124.0$, df = 2, $P < 0.01$). Fifty-three respondents from Leigongshan, 43 from Fanjingshan, and only 3 from Mayanghe (Fig. 3) reported having seen salamanders inside their reserve in the past, representing statistically significant variation in sighting frequencies between reserves ($\chi^2 = 60.5$, df = 2, $P < 0.01$). There was also significant variation in the number of reports of salamanders from villages in Jiangkou County (n = 32) compared to Yinjiang County (n = 11) within Fanjingshan ($\chi^2 = 34.7$, df = 1, $P < 0.01$). Only eight reports from Fanjingshan (21.6% of total reported sightings from this reserve) and eight reports from Leigongshan (16.7% of total reported sightings from this reserve) dated from the previous decade (2004–2013), and only three reports in total dated from the previous 2 years (reports from 2012 and 2013 from Fanjingshan, and a 2012 report from Leigongshan; Fig. 3). The minimally adequate generalized linear mixed model was also the most parsimonious of the models, with $\Delta AIC < 2$. It contained three fixed effects: reserve identity, respondent age and gender (Table 1). Both reserve identity and respondent age significantly affected the likelihood of reporting a salamander sighting, with respondents in Mayanghe reporting significantly fewer sightings and older respondents reporting significantly more sightings. Male respondents were more likely to report sightings, probably because they were more likely to be in locations where salamanders could be found (Table 2).

When asked about the general status of biodiversity within the reserves, 126 of the total sample of respondents (42%) considered that the number of animal species had decreased over the past decade, whereas 109 considered that there was no change, 21 reported an increase in species number, and 44 did not know. Of the subset who reported a decline in biodiversity, 38 (30.1%) considered that all species had declined, and six specifically mentioned salamanders as having declined. When asked about trends in salamander status, 38% of all respondents in Fanjingshan and 43% in Leigongshan considered that salamander numbers inside the reserve had decreased during their lifetime; 11 and 18%, respectively, thought that numbers had stayed the same; and 51 and 39%, respectively, did not

TABLE 1 The top four models explaining factors that affect the likelihood of reporting a Chinese giant salamander *Andrias davidianus* sighting in three national nature reserves in Guizhou Province, China (Fig. 1), with AIC, ΔAIC, and weight. Fixed effects include reserve, respondent age and gender, and identity of interviewer.

Rank	Model	AIC	ΔAIC	Weight
1	Reserve + Age + Gender + (1 | Village)	272.7	0	0.189
2	Reserve + Age * Gender + (1 | Village)	273.0	0.26	0.166
3	Reserve + Age + (1 | Village)	273.6	0.84	0.124
4	Reserve + Age * Gender + Interviewer + (1 | Village)	274.4	1.63	0.084

TABLE 2 Results of the minimally adequate model for the effects of reserve, respondent age and gender on the likelihood of reporting a salamander sighting. Estimate values show how coefficients differ from the intercept of reserve (Fanjingshan) and gender (female).

Coefficient	Estimate	Standard error	*z*	P
Intercept	−2.498	0.873	−2.862	0.004
Reserve (Leigongshan)	0.350	0.771	0.455	0.649
Reserve (Mayanghe)	−3.871	1.043	−3.712	< 0.001
Gender (male)	0.756	0.442	1.713	0.087
Age	0.033	0.012	2.692	0.007

know. In contrast, no respondents in Mayanghe reported a decrease in salamander numbers, possibly because of markedly lower levels of awareness or experience of the species in this region. The majority of all respondents (78%) did not know why salamanders had declined; overharvesting was the commonest explanation when a reason was suggested (n = 45). The majority of respondents (75.7%) thought that salamanders should be protected everywhere, with 59.7% already aware that the species was legally protected, and 54.3% considered that they could benefit personally in the future from this protection, mainly as a result of increased tourism (n = 49) and a better environment (n = 28). Across all respondents, 70.7% knew destructive fishing methods were forbidden and 44.7% knew fishing was banned inside reserves. Although 29.3% of respondents had heard about prosecutions for illegal fishing inside reserves and 21% had heard about prosecutions for other illegal activities inside reserves (e.g. poaching threatened primates), only 5.3% had heard about people being prosecuted for hunting salamanders inside reserves.

A small number of respondents (Fanjingshan, n = 14; Leigongshan, n = 5) admitted to catching wild salamanders, typically in rivers close to their villages (Fanjingshan: Heiwan, Macao and Pingding rivers; Leigongshan: Gannao and Wumi rivers; Fig. 2); one respondent said that he fished for salamanders in the Heiwan and Macao rivers every week during March–July. Indirect information provided on hunting activities by other people also suggested that some hunting of salamanders occurred at Fanjingshan and Leigongshan, both by other community members (Fanjingshan: 13 respondents said very few people catch salamanders, seven said < 50% of people catch them, and one said > 50% of people catch them; Leigongshan: four respondents said very few people catch them) and by people from outside the local community, who came from as far as Hubei and Hunan provinces specifically to catch salamanders (Fanjingshan: 13 respondents reported that this occurred; Leigongshan: five respondents reported that this occurred). One respondent at Fanjingshan reported that he caught salamanders for sale to Guangdong Province, and reserve staff in Fanjingshan confirmed the local trade in salamanders to Guangdong, where salamander consumption is popular. When respondents were asked what methods other people used to catch salamanders, bow-hooks were the most commonly reported method (n = 30), followed by using hands (n = 20), spotlighting with torches and using nets at night (n = 5), and using lime to poison the water (n = 4). A relatively small number of respondents reported that they regularly go fishing (Fanjingshan, n = 15; Leigongshan, n = 7; Mayanghe, n = 3) or harvest other aquatic species (Fanjingshan, n = 27; Leigongshan, n = 3; Mayanghe, n = 4) within their local reserves, with only two respondents who fished inside the reserves stating that they used destructive fishing methods (poison or explosives).

Most respondents (77.3%) reported that salamanders were not consumed locally; only 13% admitted to having consumed wild salamanders themselves, of which almost all (n = 34) had eaten the animal in their homes rather than in a restaurant or elsewhere. A small number of respondents reported using salamanders in Traditional Chinese Medicine (to treat coughs, asthma, indigestion, leprosy or burns; n = 9) or for other uses (e.g. in cosmetics or as pets, n = 3). A similarly small number of respondents (Fanjingshan, n = 3; Leigongshan, n = 2) admitted to small-scale farming of salamanders in their homes, with three of these respondents admitting they had caught

animals from the wild themselves. Considerably more respondents reported that other community members farmed salamanders (Fanjingshan, n = 27; Leigongshan, n = 8), with two respondents reporting that these animals were wild-caught.

Discussion

This is the first study to assess the usefulness of respondent data for giant salamander conservation in a systematic manner. Fieldwork in 2013 at Fanjingshan and Mayanghe using standard cryptobranchid survey techniques failed to detect salamanders at either reserve (Tapley et al., in press; G. Wei, unpubl. data). However, our community-based fieldwork collected a large sample of dated salamander sighting records and associated data across this region, demonstrating the effectiveness of interview surveys for establishing a conservation evidence-base for this charismatic, distinctive and economically important species. This quantitative dataset facilitates comparative assessment of the status of salamander populations in reserves in Guizhou.

The only demographic factor in this study that influences the likelihood of respondents having seen salamanders is respondent age, with older respondents being more likely to have seen the species. Significant age effects in respondent experience and awareness are a common finding in studies investigating declining species that would have been more detectable in the past (Papworth et al., 2009; Turvey et al., 2010b). Other potentially confounding demographic effects that might be harder to control for, notably geographical variation in ethnic groups (Nyhus et al., 2003; Turvey et al., 2014), did not appear to influence reporting rates. This suggests that community interviews represent a feasible approach for gathering comparable baseline data on salamanders from ethnically different areas across the species' range.

The large number of respondents who recognized and reported salamanders at Fanjingshan and Leigongshan indicates that these are priority sites for salamander conservation. In contrast, very few sighting records or other data were reported from Mayanghe, where the species may be functionally extinct. Specific landscape-level records from Fanjingshan and Leigongshan (e.g. recent reports of hunting in specific rivers) can further inform future salamander field surveys and conservation actions. However, although our data indicate likely continued salamander survival in Fanjingshan and Leigongshan, we collected few recent reports of sightings from either reserve, suggesting that salamanders are rarely encountered; over a third of respondents in each reserve thought that salamanders had declined locally. It is therefore unlikely that either Fanjingshan or Leigongshan is providing adequate conservation for salamanders. This finding is of concern given the high level of biodiversity protection supposedly provided by both reserves, the Critically Endangered status of the species, and the decline and/or disappearance of salamanders across other parts of their range (Wang et al., 2004; Pierson et al., 2014). Ongoing harvesting of wild salamanders, and the general lack of awareness of prosecutions for salamander poaching in comparison to enforcement of other illegal activities, suggests that existing legislation to protect wild populations is insufficiently enforced. Given the high value of wild-caught salamanders in the farming industry and continuing poaching pressure on wild individuals (Cunningham et al., 2015), we strongly recommend that salamander protection is increased at both Fanjingshan and Leigongshan before the species becomes locally extinct, and that alternative approaches such as awareness-raising and the use of salamanders as a flagship species for ecotourism are also explored.

Respondent data on drivers of salamander decline in Guizhou are more difficult to interpret but still provide insights into probable threats. Respondents were likely to be reticent in admitting direct involvement in sensitive and/or illegal behaviours that adversely affect salamander populations, especially because many people were aware that salamanders are protected and taking them from the wild is illegal, even if there was little awareness of any previous prosecutions for salamander poaching. Future community-focused studies of local pressures on salamander populations may require investigation using interview techniques designed to gather information on illegal behaviours (e.g. randomized response technique, St John et al., 2012; unmatched count technique, Nuno et al., 2013). However, overharvesting was the most widely suggested explanation for salamander declines, and respondents admitted that both local people and outsiders poach salamanders in reserves. Techniques for catching salamanders were reported by a greater number of respondents than those who admitted to catching animals themselves, suggesting that local harvesting pressure was higher than directly reported. These techniques (e.g. bow hooks, liming) are similar to those documented in other provinces (Fellowes et al., 2003; Wang et al., 2004). It is also likely that the farming industry is the primary driver of salamander extraction from Guizhou's reserves, as a relatively large number of local people are reportedly involved in small-scale salamander farming in their homes (almost certainly as part of the company-plus-smallholders farming model; Cunningham et al., 2015), sometimes admitting their animals were directly wild-caught.

It is difficult to predict the future of wild salamander populations in Guizhou or elsewhere in China. It is heartening to note that our respondents were generally supportive of salamander conservation and associated the local persistence of salamanders with personal economic or environmental benefits, notably those associated with tourism.

This suggests that community-based conservation initiatives could constitute an important component of managing wild populations, in combination with greater top-down enforcement of existing legislation. However, as fewer than half of all respondents were aware that salamanders were declining, there is a considerable need for further community-level educational work about salamander conservation. The highest levels of extraction and farming were reported from Fanjingshan, the reserve currently undergoing the greatest level of infrastructural development for tourism, emphasizing the threats posed by increased access to salamander habitat and indicating that economic pressures are likely to continue to threaten wild populations into the future. Tourism and increased access to reserves is particularly developed in Jiangkou County, the area of Fanjingshan where most salamander sightings were reported, suggesting this population may be particularly vulnerable. To establish an effective, sustainable management plan to prevent the extinction of wild salamanders, more extensive baseline data on status and threats across their range are needed to inform specific conservation objectives. Our study demonstrates the usefulness of standardized community interview surveys for collecting these key data, and we advocate wide-scale incorporation of this research approach into future field programmes for the giant salamander.

Acknowledgements

We thank Niu Kefeng, Ben Tapley, Jay Redbond, Sumio Okada, Lü Jingcai, and reserve staff at Fanjingshan, Leigongshan and Mayanghe for assistance and support during fieldwork. Funding was provided by Darwin Initiative project 19003, National Natural Science Foundation of China grant 31360144, and an Imperial College London graduate student travel grant.

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