Imminent extinction in the wild of the world's largest amphibian

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Species with large geographic ranges are considered resilient to global decline [1]. However, human pressures on biodiversity now affect increasingly large areas, in particular across Asia, where market forces drive overexploitation of economically valuable species even within landscapes retaining good-quality habitat [2]. Establishing a robust status assessment for widely-distributed species requires costly, co-ordinated activities involving multiple methods, and range-wide threat assessments are therefore often extrapolated from potentially non-representative local studies [3]. The Chinese giant salamander (CGS; *Andrias davidianus*), the world's largest amphibian, is thought to occur across much of China, but populations are harvested to stock a farming industry supporting a new domestic luxury food market [4]. Between 2013-2016, we conducted field surveys and interviews in 97 counties across 16 Chinese provinces or equivalent administrative units, representing 7.47 person-years of fieldwork and data collection from 2,872 respondents in possibly the largest wildlife survey conducted in China. This extensive effort revealed that populations of this once-widespread species are now critically depleted or extirpated across all surveyed areas of their range, and illegal poaching is widespread.

The CGS, a top predator in Chinese freshwater ecosystems, reaches 1.8 metres and represents an ancient lineage (Cryptobranchidae) that diverged >170 million years ago [3-5]. Endemic to China, it occupied a huge distribution across several watersheds but has declined through overexploitation and habitat loss, and is considered Critically Endangered and a global conservation priority for maintaining evolutionary history [3]. Chinese legislation prohibits harvesting wild CGS populations, but China's Ministry of Agriculture supports widespread releases of farmed animals by provincial fisheries offices and licenced breeding companies, a strategy that fails to meet IUCN reintroduction guidelines and may be harmful to wild populations (e.g., mixing genetic

lineages; spreading pathogens) [4]. CGS now detected in the wild might therefore represent releases or escapes.

To assess these concerns, we conducted a four-year survey to investigate CGS status across China at sites in 97 counties selected using historical records or habitat-suitability modelling [3]. All sites contained intact habitat and diverse amphibian faunas. Fieldwork was conducted in May-October (peak-activity period of the closely-related Japanese giant salamander *A. japonicus* [6]). Surveys covered a cumulative 1km transect of suitable river habitat at each site (if impassable landscape features blocked survey routes, transects continued from the next accessible point), and used active (searching) and passive (trapping) techniques [7]. Environmental DNA detection was precluded due to likelihood of false positives from CGS farm discharge. Fieldwork represented 7.20 cumulative person-weeks of active searching and 7.33 person-years of passive searching, and detected 24 CGS at four sites: Liannan (Guangdong), 17 (active search=11, passive search=6); Jiangkou (Guizhou), 1 (passive search); Lüeyang (Shaanxi), 5 (active search=1, passive search=4); Zhouzhi (Shaanxi), 1 (passive search). This represents a catch-per-unit-effort (CPU) of 16.23 weeks/CGS (active search CPU=4.20 days, passive search CPU=222.97 days) (Figure 1A-B). This effort is substantially greater than for other cryptobranchids (*A. japonicus*, 1.2 hours active searching; hellbender *Cryptobranchus alleganiensis*, 2.2 hours active searching) [6,8]. Illegal traps, bow hooks, and/or evidence of electro-fishing or poison (known methods for harvesting CGS) were detected at 24 sites, including within protected areas (Supplemental information).

We verified our findings using local ecological knowledge (LEK). CGS are economically significant, large-bodied and easily identifiable, making them suitable targets for LEK surveys [9]. We conducted interviews within 1km of surveyed rivers,

using a standard questionnaire about CGS awareness and experience [7]. Of our respondents, 85.5% recognised CGS and 46.9% reported sightings, but mean last-sighting date was 18.96 years earlier (range=0-71 years; SD=14.7; Table S1). Although 9.6% of reports dated from within 5 years, the temporal distribution of sightings is not unimodal (Hartigan's dip test, D=0.046, p<0.001), a pattern not seen for other declining species [9]; this may represent an older peak of wild CGS sightings and younger peak of sightings of releases/escapes (Figure 1C). We pooled LEK data for the 4 counties with CGS detections, and compared these pooled data against each of the other 93 counties (Supplemental information). Of these, 74 counties had no sightings, significantly older/fewer sightings, and/or significantly more respondents reporting declines. Of the 19 counties where LEK was statistically indistinguishable from counties with CGS detections, 18 contained CGS farms or had experienced releases close to survey villages, suggesting sightings could represent releases/escapes. Only one county (Yuqing, Guizhou) had no local source of farmed CGS, suggesting that sightings were truly wild individuals (Table S2).

Our field surveys and interviews, comprising the largest-ever assessment of CGS across China, indicate the species has experienced catastrophic range-wide decline apparently driven by overexploitation. The status of wild populations may be even worse than our data suggest. CGS releases had occurred shortly before surveys at two sites where we detected individuals (Liannan, Lüeyang); excluding these data, CPU becomes 3.73 person-years/CGS. Despite population structuring between watersheds representing evolutionarily significant management units [5], genetic sampling revealed individuals detected in the Yangtze and Pearl watersheds (Liannan, Jiangkou) had a Yellow River matriline, indicating they were farm releases/escapes (Supplemental information). It is therefore possible we detected no wild CGS individuals. Our

extremely low detection also provides little evidence that government-supported releases establish viable populations. We found dead CGS in 2015-2016 following known releases, and released animals might be unlikely to persist long-term if poaching continues.

We cannot confirm survival of wild CGS populations at any survey sites, and consider the species to be extremely depleted or functionally extinct across the huge surveyed area. We were unable to survey many protected areas, and populations are reported from some reserves [10]. However, government-supported releases occur inside many reserves, and wide-scale poaching of herpetofauna is documented across China's protected areas [2]. Our survey results reveal the future of all CGS populations in the wild, whether native or restocked, is doubtful under current management. Co-ordinated monitoring and protection is required, but immediate strengthening of legislation and enforcement to protect any surviving wild CGS populations across China is almost certainly impossible. Targeted *ex situ* actions, including establishing captive populations of genetically distinct lineages for conservation breeding [5], are probably now essential for the future of the world's largest amphibian.

Author Contributions

Conceptualization, A.A.C., S.C., and S.T.T.; Methodology, B.T., S.O., S.T.T., A.A.C., and S.K.P.; Investigation, S.C., B.T., G.W., F.X., F.Y., J.Y., Z.L., H.T., M.W., S.O., J.W., J.L., F.Z., J.R., T.B., and J.C.; Writing – Original Draft, S.T.T., A.C.C., and B.T.; Writing – Review & Editing, S.T.T. and A.C.C.; Funding Acquisition, A.C.C. and S.C; Supervision and Project Administration, S.C., A.A.C., B.T., and S.T.T.

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1 **Figure 1. Results of fieldwork from our four-year (2013–2016) Chinese giant**

2 **salamander survey.**

3 (A) Map of survey localities in 97 counties across 16 Chinese provinces or equivalent

4 administrative units; stars indicate sites where CGS individuals were detected during

5 fieldwork. (B) CGS individual found in Jiangkou County, Guizhou, in May 2014. (C)

6 Frequency distribution for CGS last-sighting records from local respondents (given as

7 number of years before interview was conducted).