

Population and conservation strategies for the Chinese crocodile lizard (*Shinisaurus crocodilurus*) in China

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Abstract

Population and conservation strategies for the Chinese crocodile lizard (Shinisaurus crocodilurus) in China.—The Chinese crocodile lizard (*Shinisaurus crocodilurus*) is an unusual anguimorph lizard found mainly in China. Transect surveys estimate a total wild population of about 950 individuals in China. This is a dramatic decrease compared with previous surveys. At present, there are only eight areas of distribution. No Chinese crocodile lizards have been found in four former areas for several years. Investigations have demonstrated that poaching has contributed directly to the population decline. Habitat destruction, and in particular water flow, is the second most important factor. Mining, small scale dam construction, electro-fishing and poisoning of fish in the stream also contribute to population decline. Therefore, educating local people, punishing illegal poaching, and strengthening scientific research are urgent.

Key words: Chinese crocodile lizard (*Shinisaurus crocodilurus*), Population survey, Threatening factors, Conservation strategy.

Resumen

Población y estrategias para la conservación del lagarto cocodrilo chino (Shinisaurus crocodilurus) en China.—El lagarto cocodrilo chino (*Shinisaurus crocodilurus*) es un lagarto anguimorfo que se encuentra principalmente en China. Según los estudios de transectos se estima que en China existe una población salvaje total de aproximadamente 950 individuos. Ello constituye un espectacular descenso en comparación con los estudios anteriores. Actualmente sólo existen ocho áreas de distribución. Hace varios años que no se ha encontrado ningún lagarto cocodrilo chino en cuatro áreas que anteriormente estaban pobladas por esta especie. Las investigaciones han demostrado que la caza furtiva ha contribuido directamente a la disminución de las poblaciones. El segundo factor en importancia es la destrucción del hábitat, y particularmente las inundaciones. La minería, la construcción de pequeñas presas, y la pesca por envenenamiento o mediante la electricidad en los arroyos también contribuyen a que disminuyan las poblaciones. Por lo tanto, consideramos que serían tareas urgentes la educación de los nativos, la sanción de la caza furtiva y la intensificación de la investigación científica.

Palabras clave: Lagarto cocodrilo chino (*Shinisaurus crocodilurus*), Estimaciones de población, Factores de amenaza, Estrategias de conservación.

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Introduction

Reptiles and amphibians are among the most sensitive animals to global and regional environmental change, and can be the indicator of such changes (Eriksson, 2003; Li et al., 2006).

Shinisaurus crocodilurus, the Chinese crocodile lizard, inhabits the mountain ranges of Guangxi and Guangdong Provinces in China (Liu & Hu, 1962; Liu et al., 1989; Zhang, 1991; Li & Xiao, 2002). It has also recently been reported from Quang Ninh Province in Vietnam (Quyet & Ziegler, 2003). A comparative study of DAN, morphology, and ecology indicates that the Chinese crocodile lizard populations from China and Vietnam are not significantly different even though separated by at least 500 km (Ziegler et al., 2008).

The species was first collected in 1928 (Ahl, 1930; Fan, 1931) and remains monotypic as the most recently named lizard genus. Its rarity in captivity and in the wild has resulted in this lizard being poorly represented in museum collections and in the literature.

Shinisaurus crocodilurus is a semi-aquatic predator and a strong swimmer, preying on fish, tadpoles, and aquatic insects and their larvae (Ahl, 1930; Shen & Li, 1982; Yu et al., 2006). It is viviparous (Shen & Li, 1982; Zhang & Tang, 1985; Mägdefrau, 1987; Zhao et al., 1999) and breeds in July and August in the wild (Zhang & Tang, 1985; Zhang, 1991) but at different times in captivity (Hofmann, 2000).

The species was listed in CITES Appendix II in January 2007 and is a category I species under the Wild Animal Protection Law in China in view of its narrow distribution and small population (Mägdefrau, 1987; Sprackland, 1989; Zhang, 2002).

Based on its many primitive characteristics, including the lacrimale, supratemporale, small teeth on pterygoideum, chromosome number $2n = 32$, and other studies (Hu et al., 1984; Zhang, 1991; 2002; Zhang et al., 1996), it is considered to be a remnant reptile from the Pleistocene. It thus has great scientific value not only for systematics, but also for understanding the origin, adaptation, radiation and evolution of reptiles. However, heavy pressure from human poaching for pets, food, medicine, and specimens, as well as local environmental changes, have forced the population into severe decline (Mo & Zou, 2000; Zhang, 2002; Zeng, 2003). Its habitat has also become both fragmented and deteriorated, further increasing concern among scientists and the forestry administration. Therefore, we conducted this study to clarify the present status of the total wild population of Chinese crocodile lizards in China, and to investigate the factors which contribute to this population decline. Finally, we propose measures to be taken by local government and forestry administration personnel to protect this rare species.

Material and methods

Study area

All areas in this survey were determined by references, previous reports and information from local forestry departments. This included the counties of Jinxiu, Hexian, Zhaoping, Guiping, and Pingnan in Guangxi Province ($23^{\circ} 24' - 24^{\circ} 152' N$ and $109^{\circ} 522' - 111^{\circ} 512' E$) and

Table 1. Population density, hunting pressure and patch density in each distribution area: Da. Distribution area; Ppd. Population density (persons/km²); Ptd. Patch density (pieces/km²); Q. Questionnaires; N. Never; O. Occasionally; F. Frequently; I. Index. (For other abbreviations see Method of survey in Material and methods.)

Tabla 1. Densidad de la población humana, presión de caza y densidad de piezas cobradas en cada zona de distribución: Da. Área de distribución; Ppd. Densidad de población (personas/km²); Ptd. Densidad de las parcelas (piezas/km²); Q. Questionarios; N. Nunca; O. Ocasionalmente; F. Frecuentemente; I. Índice. (Para otras abreviaturas ver Método de reconocimiento en Material y métodos.)

Da	Ppd	Hunting pressure					Ptd
		Q	N	O	F	I	
LX	43.76	7	3	2	2	0.86	29.4
JL	32.82	47	10	22	15	1.11	10.1
LS	12.34	2	1	0	1	1	24.5
DG	0	2	1	1	0	0.5	10.5
LK	2.69	8	4	3	1	0.63	3.4
GX	9.09	2	1	1	0	0.5	2.7
S&L	19.26	5	1	2	2	1.2	8.4
D&B	5.75	2	0	2	0	1	5.4
Total		75	21	33	21		

Qujiang in Guangdong province (24° 36'2"–24° 39' N and 113° 13'2"–113° 22' E) (fig. 1) and Guposhan of Jianghua County (24° 33'2"–24° 35'2" N and 111° 32'2"–111° 37'2" E) in Hunan province. The survey was conducted between late April and early October 2004; this is the non-hibernation season for the Chinese crocodile lizard.

The average temperature in this region is 18.7° (–5.6°–39.5°) with an annual precipitation of 2,113.9 mm. The area surveyed belongs to the headwaters of the Pear River system. Mountains are 500–1,200 m above sea level. Vegetative cover is secondary subtropical evergreen broadleaf forest or cultivated forest. The dominant secondary species include *Liquidambar tawianiana*, *Alangium chinensis*, *Sapulum discolor*, *Neolitsea levinei*, *Machilus thunbergi* and *Castanopsis eyrei*, etc. *Cunninghamia lanceolata*, *Illicium verum*, *Cinnamomum cassia* have been planted for timber, fruit, and tea at lower levels of the mountain, the lizards' main habitat.

Method of survey

Questionnaire

We interviewed the local people to collect information about household economy, local human population, frequency of hunting the lizard, and the purposes for hunting (food, medicine, or sale) (table 1). We made random inquiries with a total of 75 local people in eight areas.

Field survey

All surveys were made in the daytime (Mo & Zou, 2000). We selected survey areas according to previous reports and information from the local forestry administration. We then determined the transect stream lines and marked them on the map (1:10,000). We surveyed a total of 199 transects, with 50 in Luoxiang (LX) in Jinxiu County, 54 in Jiulong (JL) in Zhaoping County, 19 in Daguishan (DG) and Lisong (LS) in Hexian County, 13 in Hema (HM) in Wuxuan County, seven in Guxiu (GX) in Mengshan County, 16 in Sanlian & Luoyi (S&L) and Datunxia & Bitan (D&B) in Guiping County, 15 in Guoan (GA) in Pingnan County in Guangxi province, and 25 in Luokeng (LK) in Qujiang County in Guangdong Province. The transect streams ranged in length from 570 m to 2,100 m.

Guided by local villagers, we carefully searched for Chinese crocodile lizards along the stream transect at a speed of 1.5 km/hour. Once we found an animal, we established the location with GPS, and recorded habitat characteristics including landscapes of: broadleaf forest, conifer forest, conifer–broadleaf mixed forest, shrub, bare land or stone, built-up land, agricultural land, and water. All of the transect streams were surveyed once; we adopted an "invisible rate" index (*i*) to compensate for any individuals present but not seen in a one-time survey. In one area, we conducted three consecutive time surveys on each sample transect stream with one in daytime and two in the evening. We then calculated the "invisible rate" at this location (table 2).

We marked the captured animals in each survey in order to distinguish them from those captured later. The total crocodile lizard population was calculated by adding the observed numbers to the estimated "invisible" animals.

Data analysis

The total population was estimated using the following formula:

$$N = \Sigma [n \cdot (1 + i)]$$

where *N* is the total population, *n* is the number of observed individuals in a distribution area, and *i* is the invisible rate in a certain distribution area.

The habitat area was calculated on a map with a scale 1:10,000 by GIS (Chen et al., 2006).

We incorporated hunting pressure, a human interference index, and a habitat fragmentation index to evaluate habitat quality. Hunting pressure was obtained from the questionnaire given to local people living near the habitat, with: 0. Never hunting; 1. Occasional hunting; and 2. Frequent hunting. We used the averaged value to represent the hunting pressure on the habitat. The human population in the distribution area constituted the human interference index. On a satellite map (1:10,000), we calculated the patch density index (patches/km²) and used the index to represent the extent of habitat fragmentation. Data for habitat characteristics and landscape have already been published (Ning et al., 2006; Chen et al., 2006; Yu et al., 2006).

Table 2. The calculation of invisible rate in three sample transects on three consecutive days: T1. Transect 1 (550 m); T2. Transect 2 (810 m); T3. Transect 3 (580 m); * Newly observed lizards.

Tabla 2. Cálculo de la tasa de invisibles en tres transectos de muestra, en tres días consecutivos: T1. Transecto 1 (550 m); T2. Transecto 2 (810 m); T3. Transecto 3 (580 m); * *Lagartos* observados recientemente.

	T1	T2	T3
First daytime	2	1	2
Second night-time	2+1*	1+1*	2+1*
Third night-time	3	2+1*	3
Total individuals	3	3	3
Average invisibility rate (<i>i</i>)	$[(3-2)+(3-1)+(3-2)] / (2+1+2) = 0.8$		
Total number			
First survey	$(2+1+2) + \text{invisible } (2+1+2) \times 0.8 = 9$		

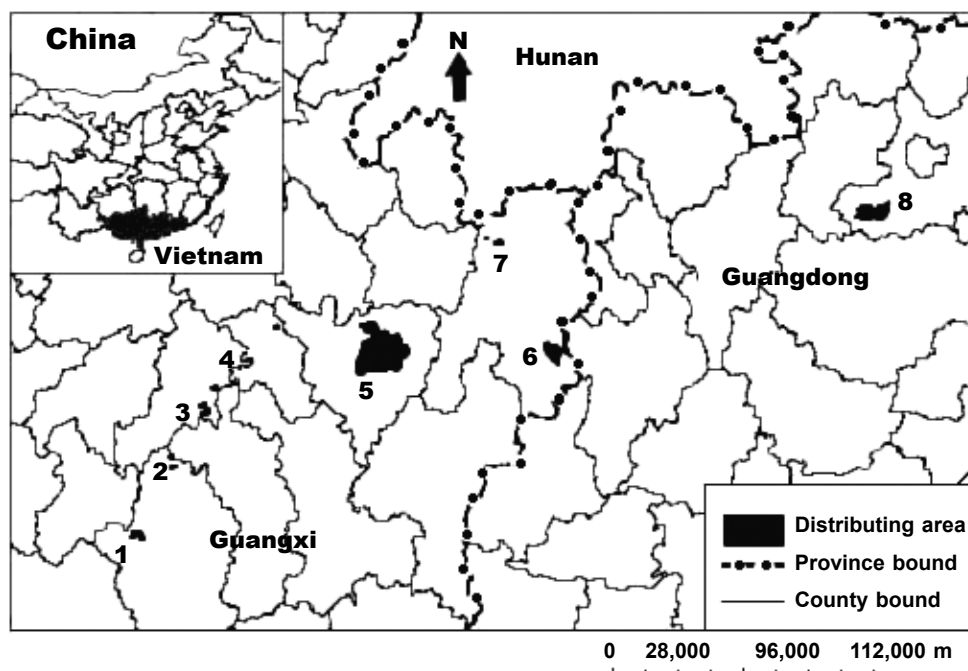


Fig. 1. Present distribution of the Chinese crocodile lizard (*Shinisaurus crocodilurus*) in China. Numbers indicate the eight areas of distribution: 1. D&B; 2. S&L; 3. LX; 4. GX; 5. JL; 6. DG; 7. LS; 8. LK. (For abbreviations see Method of survey in Material and methods.)

Fig. 1. Distribución actual del lagarto cocodrilo chino (*Shinisaurus crocodilurus*) en China. Las cifras indican las ocho áreas de distribución: 1. D&B; 2. S&L; 3. LX; 4. GX; 5. JL; 6. DG; 7. LS; 8. LK. (Para las abreviaturas ver Método de reconocimiento en Material y métodos.)

Results

Distribution

The transect surveys indicated that there are eight areas of distribution for the Chinese crocodile lizard in five Counties in Guangxi Province and one county in Guangdong (fig. 1). Wuxuan and Pingnan Counties of Guangxi Province were surveyed without finding any Chinese crocodile lizards. No sightings of crocodile lizards over the last 10 years were reported in the questionnaire for the other previously-reported areas of Xiayi in Mengshan County, Beituo and Xi-anhui in Zhaoping County in Guangxi Province and Guposhan in Jianghua County in Hunan Province (Zhang, 1991). The species might already be extinct in these regions.

Among the eight areas of current distribution, seven are in Guangxi Province and one is in Qujiang County in Guangdong Province. All of these local ranges are separated from each other by a minimum distance of 10 km (from S&L to D&B). The total habitat range of crocodile lizards in China is estimated as 456.45 km² with the biggest in JL (335.19 km²) and the smallest in GX (2.2 km²) (table 3).

The total surveyed population of crocodile lizards

in China is 950. Average density is 2.08 individuals/km². Site JL in Zhaoping County has the largest subpopulation of 350 individuals, while LK in Qujiang County has the second largest subpopulation (220 individuals) and GX in Mengshan County has the smallest subpopulation (only 10 individuals) (table 3). LS has the highest density of Chinese crocodile lizards (10.29 individuals/km²), while JL has the lowest (1.04 individuals/km²) (table 3).

Conservation status

Among these eight habitat ranges, only three are in nature reserves: LK in Luokeng Nature Reserve, LX in Dayaoshan Nature Reserve, and GX in Guxiu Nature Reserve. Less than one third of the total population is therefore protected. In the nature reserves, the habitats were protected well, but the illegal hunting activities still occurred occasionally. In other areas, the habitats were seriously damaged and illegal hunting activities happened frequently (table 1).

Human population densities in these eight ranges varied greatly (table 1). The human population densities of LX and JL were the highest, both of them were more than 30 persons/km². The human interference

Table 3. Subpopulation and density in different areas: Q. Qujiang county; G. Guiping County; H. Hezhou County; J. Jinxiu County; Z. Zhaoping County; M. Mengshan County.

Tabla 3. Subpoblación y densidad en distintas áreas: Q. Condado de Qujiang; G. Condado de Guiping; H. Condado de Hezhou; J. Condado de Jinxiu; Z. Condado de Zhaoping; M. Condado de Mengshan.

	Guangdong		Guangxi					
	Q	G		H	J	Z	M	
	LK	S&L	D&B	DG	LS	LX	JL	GX
Subtotal	220	50	100	100	50	70	350	10
Total	950							
Area (km ²)	55.6	5.71	10.43	28.8	4.86	13.7	335.19	2.2
Density (individuals/km ²)	3.96	8.76	9.59	3.47	10.29	5.11	1.04	4.54

in these two areas was therefore much higher. The DG area was not inhabited. The densities of LK, D&B and GX were less than 10 persons/km², suggesting human interferences in these four range areas was relatively low.

Surveys among the 75 local people in the villages who filled out the questionnaires showed that 21 hunted the lizard "frequently" and 33 "occasionally"; only 21 men "never did" (table 1). Among the 54 people who hunted the animal, only four hunted for food and four for medicine; all others hunted the lizards to sell them for money. The price for one Chinese crocodile lizard ranged from 10 to 200 RMB, and occasionally reached 1,000 RMB. A price of 200 RMB (about U.S. \$27.40) equals two-month's average wage for one person in these remote mountain areas. This helps explain why the local people hunt the lizard.

Further investigation indicates that illegal collection, or poaching, is the most serious threat directly contributing to the population decline. Illegal collectors were from bigger cities nearby. They sell the lizards to urban residents for use as pets, food, or medicine. A small amount of the lizards are illegally exported, bringing double or triple the price. For this reason, Taiwan has a small population of as many as 30 individuals since the 1980's (personal communication with Dr. Pei Jiaqi).

In addition to illegal hunting, local villagers often use electro-fishing and poisonous chemicals to fish in the stream and this can kill all of the crocodile lizards in the water.

Vegetation changes contribute directly to the decrease in aquatic resources in the streams. The ideal habitat for the crocodile lizards is broadleaf forest (Zhang, 1991) which maintains water flow in streams all year round. In most altered reserve habitats, natural broadleaf forest has been gradually cut down for sale and replaced with bush forest. Where more profitable trees such as *Illicium verum* and tea shrubs are planted, the ground vegetation is clear-cut and fertilized. In such cases, the vegetation that withholds water disappears.

Streams then flood in the rainy season and dry out in the non-rainy season, leaving a habitat that is no longer suitable for the crocodile lizard.

Mining and small-scale dam constructions also influence the survival of the crocodile lizard. Mining pollutes the stream water. Dam construction upstream changes water distribution and some streams dry up.

At present, all of these eight areas have high habitat fragmentation (table 1, fig. 1). The patch densities of LX and LS were the highest (more than 20 pieces/km²). Although the patch densities of LK and GX were lowest, both of them were higher than 2 pieces/km². The habitat qualities in LK and GX were the best among these eight range areas, since human population densities, hunting pressures, and habitat fragmentation were relatively low. Over time, this situation will restrict migration of individuals and reduce the gene flow.

Discussion

Method of survey

Chinese crocodile lizard population surveys have been conducted six times in China since 1978. Some were conducted during the night and the researcher argued that the lizard slept deeply and couldn't escape during the night, so they were easy to count (Zhang, 2002; Zeng, 2003). Others have considered that night surveying is inconvenient and poses the risk that researchers could easily miss the animal, resulting in population underestimation. Furthermore, they state that researchers have better visibility surveying in the daytime (Mo & Zou, 2000; Ning et al., 2006). We adopted the daytime survey plus an invisibility index to estimate the population. This takes advantage of better visibility in daytime and decreases the lower count due to the escape of animals. However, without doubt we could not observe every individual in the habitat.

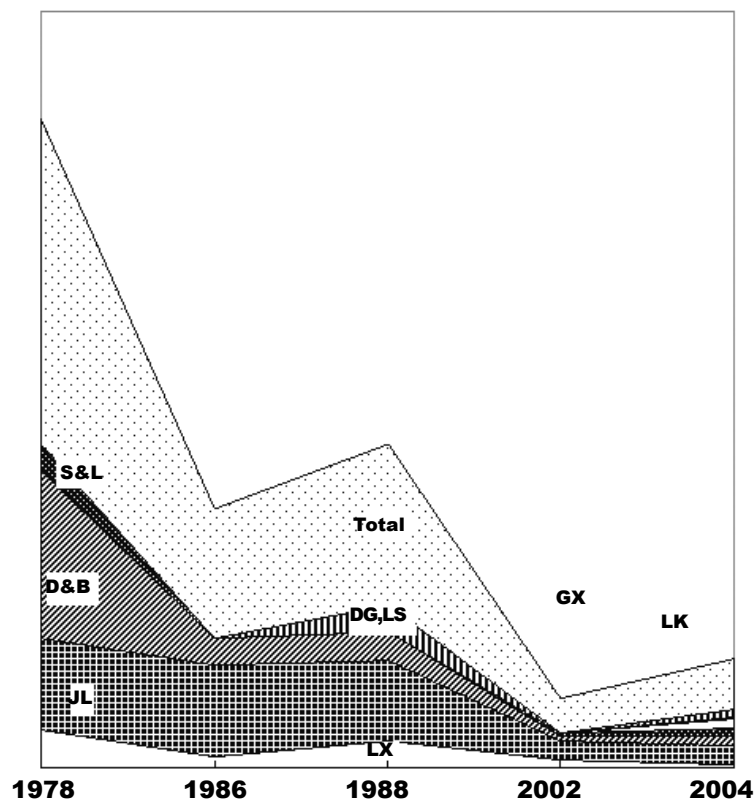


Fig. 2. Population decline in the Chinese crocodile lizard in China from 1978 to 2004: * Number of individuals in GX is too small to show. (For abbreviations see Method of survey in Material and methods.)

*Fig. 2. Descenso de la población del lagarto cocodrilo chino en China desde el año 1978 al 2004: * El número de individuos en GX es demasiado pequeño para ser representado. (Para las abreviaturas ver Método de reconocimiento en Material y métodos.)*

The survey transects were based on previous reports and local information, and some streams with crocodile lizards may not have been surveyed. In such case, the total population would be underestimated.

Total population of crocodile lizards in China

This survey indicates that crocodile lizard populations and habitat have changed greatly. In LX, where the Chinese crocodile lizard was first discovered by Ren Guorong in 1928, the 700 to 800 individuals in 1978 (Zeng, 2003) had decreased to 70 individuals in this survey, a 90% decline in population. Another important area is JL, which had 1700 individuals in 1978 (Zeng, 2003) and declined to 350 individuals in this survey, an 80% decline in population. LS and DG in Hexian County and D&B in Guiping County also suffered 70% population declines respectively (fig. 2). The complete population has decreased from 6,000 individuals in 1978 (Zeng, 2003) to 950 individuals in this survey. And the population in 1978 did not include the populations in LK and GX which had not been surveyed before 2004.

Additional information also supports the decline of crocodile lizard population observed during this survey. In DG of Hexian County, villagers said they could easily see many crocodile lizards ten years ago, but it was difficult to find them in recent years. In LK, local people also said that one could catch more than 50 individuals a day to make money five years ago, but this has been difficult in the last two years.

Measurements for conservation activities

In China, overexploitation is the most pervasive threat to vertebrates (Li & Wilcove, 2005); it is the same with the Chinese crocodile lizard. Illegal collectors encourage local people to hunt the animal; this is the main threat to the Chinese crocodile lizard. Therefore, punishing the illegal collection or "poaching" is an urgent need. If no one can illegally trade in the lizard, local people will not catch them. Educating local people to protect the animal is also important. In addition, the Chinese government should enact and enforce laws to ban the following activities: eating the Chinese crocodile lizard, using the animal for Chinese

medicine, and illegally trading this animal. If laws ban these activities and are enforced, the illegal hunting would cease accordingly.

More nature reserves should be set up in the habitat range. Among the eight areas of distribution, only three areas are included in current nature reserves. In the other five areas, most habitats had been destroyed heavily by human activities, such as forest cutting and ground vegetation replacement. Accordingly, the lizards in these streams have died or migrated due to lack of enough water. If nature reserves were set up in these areas, the forest could be protected or gradually restored and the habitats of the Chinese crocodile lizard could recover.

Based on the above conservation activities, Chinese crocodile lizards could be bred artificially in nature reserves and released back into nature to restore the wild populations. The Chinese crocodile lizard is a viviparous animal, different from many other lizards. It has a pregnancy of about nine months and gives birth once a year with an average of four young per litter (Tang & Zhang, 1986; Zhang, 2002). The survival rate in the first year of life can exceed 80% in captivity (Zhang, 2002). Chinese crocodile lizards have been bred successfully in Luokeng Nature Reserve. In 2006, one female gave birth to seven babies and another gave birth to one, suggesting that artificially breeding the crocodile lizard and then releasing the young back into nature is a good way to recover wild populations.

The Chinese crocodile lizard is classified as "vulnerable" (VU). However, this study indicates that the population size in LX, JL LS and DG and other habitats have all suffered more than 70% reduction. Accordingly, its conservation status should be promoted to "endangered level" (EN) (IUCN, <http://www.iucnredlist.org/info/categories>), in order to draw wider attention to the importance of conservation. Furthermore, conservation efforts for the entire population of the Chinese crocodile lizard should include populations in both China and Vietnam.

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