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DISTRIBUTION, STATUS, AND ECOLOGY OF THE WATER MONITOR (*VARANUS SALVATOR*) ON HAINAN ISLAND, AND THE ROLE OF FOLKLORE IN ITS CONSERVATION

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Abstract.—The Water Monitor (*Varanus salvator*) is the most widespread yet one of the most heavily exploited reptiles in the world. Though *V. salvator* is still abundant in most parts across its wide range, this large lizard is now extremely rare in China and is considered critically endangered in the country. In China, *V. salvator* is restricted to the international border areas of Guangxi and Yunnan Province, as well as Hainan Island. Little information is available about the distribution and status of the species in China and no ecological study has been undertaken to date, undermining effective protection effort for such imperiled species in China. In this study, we present a summary on the past and present distribution of the species on Hainan Island based on our field survey and literature/media review, and we conducted an ecological study in a remote village of western Hainan where local taboos preserve a small breeding population of *V. salvator*. Our findings show that *V. salvator* was once quite common and widespread in Hainan, but severe hunting and habitat loss in the lowlands have collectively driven a dramatic decline of the species. Luckily, remnant populations are surviving in some remote and/or protected areas of the island. Our limited data suggested the basic ecology of Hainan's Water Monitor is similar to those reported elsewhere. Threats to the species and relevant conservation recommendations for this island population are also discussed.

Key Words.—China; monitor lizard; natural history; population; reptile; taboos

INTRODUCTION

The Water Monitor (*Varanus salvator*) is the second-largest lizard species in the world, measuring up to over 2.5 m in total length (Bennett 1995; Koch et al. 2007). It has the widest distribution of all extant varanids, occurring across South and Southeast Asia, and is considered a morphologically and genetically polytypic species (Ast 2001; Koch et al. 2007 2013; Bennett et al. 2010). Five subspecies are currently recognized based on morphological studies: the nominotypic subspecies *V. s. salvator* is restricted to the type locality Sri Lanka; *V. s. andamanensis* from the Andaman Islands in the Gulf of Bengal; *V. s. macromaculatus* is widely distributed across Northern India, Southeast Asia including the Greater Sunda and their satellite islands; *V. s. bivittatus* occurs on Java and the Lesser Sunda Islands of Indonesia; and *V. s. zieglerei* is known from Obi and the surrounding islands in Indonesia (Koch and Böhme 2010; Koch et al. 2013).

The extensive range of Water Monitor is due to its tremendous adaptability; its diverse diet including carrion, human leftovers, and live prey ranging from mollusks to mammals, and its wide habitat breadth of city parks, farmland, wetlands, and mangroves to pristine inland forests (Bennett 1995; Shine et al. 1998; Uyeda 2009; Bennett et al. 2010; Uyeda et al. 2012).

Although predominantly a lowland species, it has been recorded in areas up to 1,800 m elevation (Bennett et al. 2010). Despite being one of the most heavily exploited reptiles in the world (Luxmoore and Groombridge 1990; Koch et al. 2013), it is still widespread and abundant in most parts across its huge range and is therefore classified as Least Concern by the International Union for Conservation of Nature Red List, but the current global population trend of the species is unknown (Bennett et al. 2010).

China is the northeastern distributional limit of the species, with records from the tropical and subtropical provinces of Guangdong, Guangxi, Yunnan, and Hainan Island (Zhao et al. 1999). Based on the latest taxonomic study, the population in China belongs to the subspecies *V. s. macromaculatus* (Koch et al. 2013). Recent research showed that records from Guangdong Province were of escaped and/or released animals, and the confirmed natural range of Chinese *V. salvator* is thus restricted to the international border areas of Guangxi and Yunnan provinces, as well as Hainan Island (Wang et al. 2017).

In China, *V. salvator* is extremely rare and remnant populations are confined to Yunnan Province and Hainan Island (Rao and Yang 1996; Yang and Rao 2008; Shi et al. 2011; Lau and Chan 2013; Yang et al. 2017). There have been no unequivocal reports from Guangxi for nearly two decades (Zhou et al. 2004), indicating

the Guangxi population is close to local extinction, if the species is still extant. The principal threat to this adaptable species in China is hunting for the exotic food trade, while habitat destruction of its preferred lowland wetlands also exacerbates its decline (Rao and Yang 1996; Xu et al. 2006; Yang et al. 2017). Consequently, *V. salvator* has been classified as Critically Endangered by the China Species Red List and is listed as Class I Key Protected Species in China, the same statutory status as the Giant Panda (*Ailuropoda melanoleuca*; Jiang et al. 2016).

Despite its endangered status in China, basic information on the distribution, status, and ecology of the insular population of *V. salvator* on Hainan Island remains undocumented except a handful of distribution records (Zhao et al. 1999; Shi et al. 2011; Lau and Chan 2013). Updated information on the current distribution and status, as well as the ecology of *V. salvator* is necessary to enhance its protection, both at regional and national levels. During our field survey on Hainan Island, we discovered a small breeding population of native *V. salvator* near a remote village, which is effectively protected by the local Li minority villagers due to local traditional taboos. In this study, we reviewed the change in distribution and status of *V. salvator* in Hainan, studied the basic ecology of the discovered population, and investigated how local folklore/taboo contribute to the conservation of a widely hunted species in China. We identified major threats to the species in Hainan and provided recommendations for its conservation.

MATERIALS AND METHODS

Hainan Island.—Hainan is a large tropical island in China, similar in size to Taiwan with an area of 33,920 km². Hainan has a cone-shaped topography, with a thin strip of coastal plains rising gradually to a mountainous center towards the southwest. The tallest mountain, Mt. Wuzhishan, reaches 1,867 m elevation and 80 additional peaks exceeding 1,000 m can be found in the mountainous interior. There are no natural, lentic habitats of any size but numerous river systems drain the hilly terrain, with 154 independent rivers draining into the sea. These rivers, together with thousands of man-made wetlands, waterways, and reservoirs, created about 1,200 km² of inland waters. Surface water area of the numerous reservoirs measure about 567 km² and make up most of the lentic freshwater habitats. The Hainan coastline measures 1,528 km with about 2,016 km² of coastal wetlands under the Ramsar Convention (convention on wetlands of international importance) definition.

Over 100 islets can be found along the eastern, southeastern, and southern coastline, most of which are uninhabited (Jiang 2015; Fig. 1). Hainan has a

tropical monsoonal climate, with a prominent rainy season between May and October when 80–90% of the annual rainfall is received (Wang 2014). The average annual precipitation is 1,500–2,000 mm and can be as high as 2,500 mm in central and eastern districts, and as low as 900 mm in the southwest. The annual average temperature is 23°–27° C throughout most of the island, and temperatures are lower towards the central mountainous district, and higher towards the west and the south (Wang 2014).

Hainan Island has diverse ecosystems ranging from mangrove to primary rainforest and is part of the Indo-Burma biodiversity hotspot (Myers et al. 2000). Since World War II, however, the natural forests of the island has been dramatically reduced (Zhang and Zhu 2012). The island has been settled by the Li minority ethnic group for at least 3,000 y, and the Han Chinese arrived on the island over 2,000 y ago. The official census in 2019 reported a resident human population of nearly 9.45 million, with an annual growth rate of 6.76%. Major human settlements are found along the coastal plains and alluvial valleys in the mountainous areas, with the capital city Haikou being most populous. With such long history of human settlement, the lowland vegetation has been greatly modified, and forests of most open valleys and gentle slopes of the mountains have also been cleared (Lin et al. 2017). Due to continuous habitat loss and severe hunting, the wildlife of the island, particularly large animals, such as the Hainan Gibbon (*Nomascus hainanus*) and Eld's Deer (*Rucervus eldii*), have suffered precipitous population declines over the last half-century (Zeng et al. 2005; Zhang et al. 2010; Chan et al. 2020).

Literature and media review.—Although records of wild-living *V. salvator* of unknown provenance were occasionally reported in Hainan (as well as elsewhere in China), there has always been an illegal trade of varanids. Specimens have occasionally escaped and, if confiscated by the authorities, they were sometimes released. To avoid overestimating its distribution and status, we crosschecked the location of each report and rejected those in which *V. salvator* were encountered at highly questionable locations such as city centers, suggesting escapes from the wildlife trade, and if from a rural landscape or protected areas, whether a confiscation release took place in the last decade.

Two authoritative monographs (Zhao et al. 1999; Shi et al. 2011) provide summaries of distribution records for *V. salvator* in Hainan. We used keywords 巨蜥 (Water Monitor) and 海南 (Hainan) to search the full text of Chinese publications in the China Academic Journals Full-text Database (CJFD) via China National Knowledge Infrastructure (CNKI; <http://www.cnki.net/>). We also conducted a media search for the occurrence

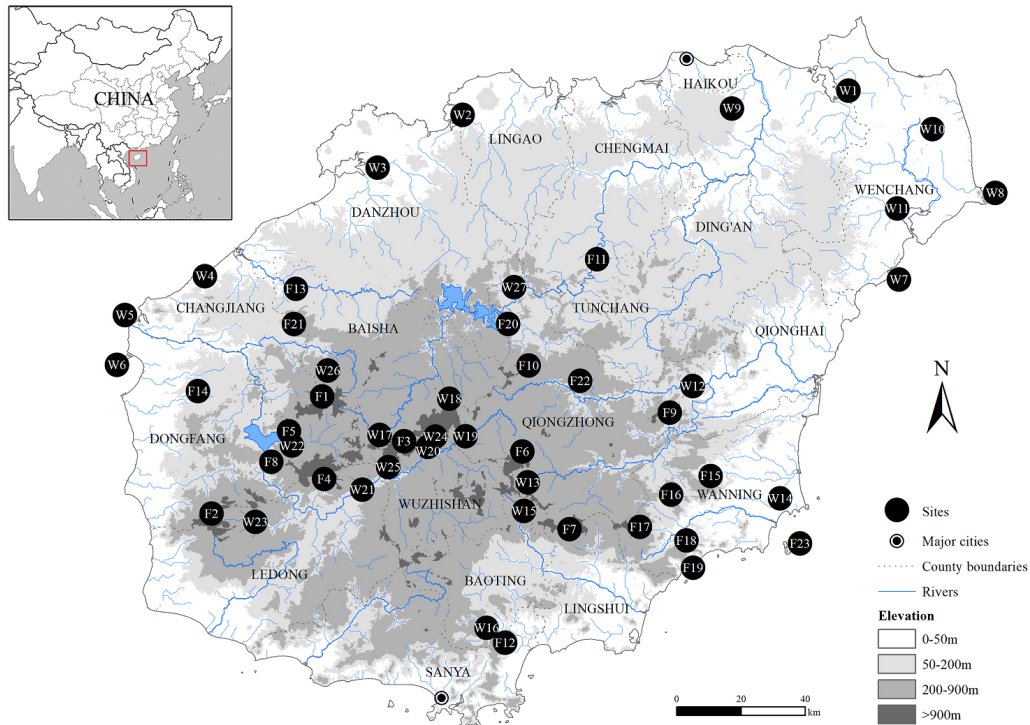


FIGURE 1. Surveyed localities (solid black circles) by the authors and colleagues from Kadoorie Farm and Botanic Garden between 1998 and 2020 on Hainan Island, China. Abbreviations are NNR = National Nature Reserve and NR = Provincial Nature Reserve. Forest sites surveyed were F1: Bawangling NNR, F2: Jianfengling NNR, F3: Yinggeling NNR, F4: Jiayi NR, F5: Exianling NR, F6: Wuzhishan NNR, F7: Diaoluoshan NNR, F8: Houmiling NR, F9: Huishan NR, F10: Limushan NR, F11: Nanweiling, F12: Ganzaling NR, F13: Bangxi NR, F14: Datian NNR, F15: Jianling NR, F16: Shangxi NR, F17: Nanlin NR, F18: Jiaxin NR, F19: Qingpilin NR, F20: Fanjia NR, F21: Baomeiling NR, F22: Wanling, and F23: Dazhou Island National Nature Reserve. Wetland sites surveyed were W1: Dongzhaigang, W2: Houshui Bay, W3: Yangpu Bay & Danzhou Bay, W4: Haiwei, W5: Changhuajiang River Estuary, W6: Beili Bay (including Sigeng), W7: Huiwen, W8: Tongguling NNR, W9: Mission Hills golf complex, W10: Longma, W11: Qinglangang, W12: Dongtai Farm, W13: Shijie, W14: Xiaohai Lagoon, W15: Bacun, W16: Yanoda, W17: Nankai, W18: Hongxin, W19: Nanping, W20: Maoxin, W21: Nanpen, W22: Nanrao, W23: Chahe, W24: Qingjie, W25: Bulun, W26: Nancha, and W27: Songtao.

of *V. salvator* on Hainan Island in Google, Baidu, Sina Weibo, and Wechat, which are the leading global and national search engines and social media networks, using the same Chinese keywords. We checked all returned results and only accepted those believed to be of wild origin with the same criteria. Because poaching remains as the major threat to *V. salvator* in China, and there were cases of poaching following locality data given in scientific publications (Stuart et al. 2006; Yang and Chan 2015), we refrained from disclosing the exact locations of recent records and listed our distribution data to a more general geographical area, either a township or a protected area of several hundred square kilometers.

Island-wide field and interview surveys.—Since the late 1990s, we have been conducting a series of rapid biodiversity surveys throughout Hainan Island, covering all counties and major habitats of the island. Although these surveys were not targeting *V. salvator*, one of the focal taxon groups surveyed was

herpetofauna, and the survey team consisted of several experienced herpetologists. During these rapid surveys, we conducted non-random transects, including both diurnal and spotlighting transects. Forest trails, quiet forest roads, watercourses and farmlands were walked by two or three experienced field biologists at a slow pace (under 1 km/h) to maximize encounter rate of target species. We covered elevations between sea level to the summit of Mt. Wuzhishan at 1,867 m, during both the cold-dry and wet-warm seasons. Carcasses, tracks, feeding signs, and droppings that could be confidently identified were also recorded. Additionally, the second author spent several months surveying rivers, streams, and marshes throughout the island for an ichthyological study during 2005–2010 and paid particular attention to the presence of *V. salvator*. We conducted surveys for this lizard across the island (Fig. 1) and results of some surveys have been published (e.g., Kadoorie Farm and Botanic Garden [KFBG] 2001, 2002, 2003; Jiang et al. 2013; Lu et al. 2015). In addition to field data collection, we also conducted *ad hoc* interviews

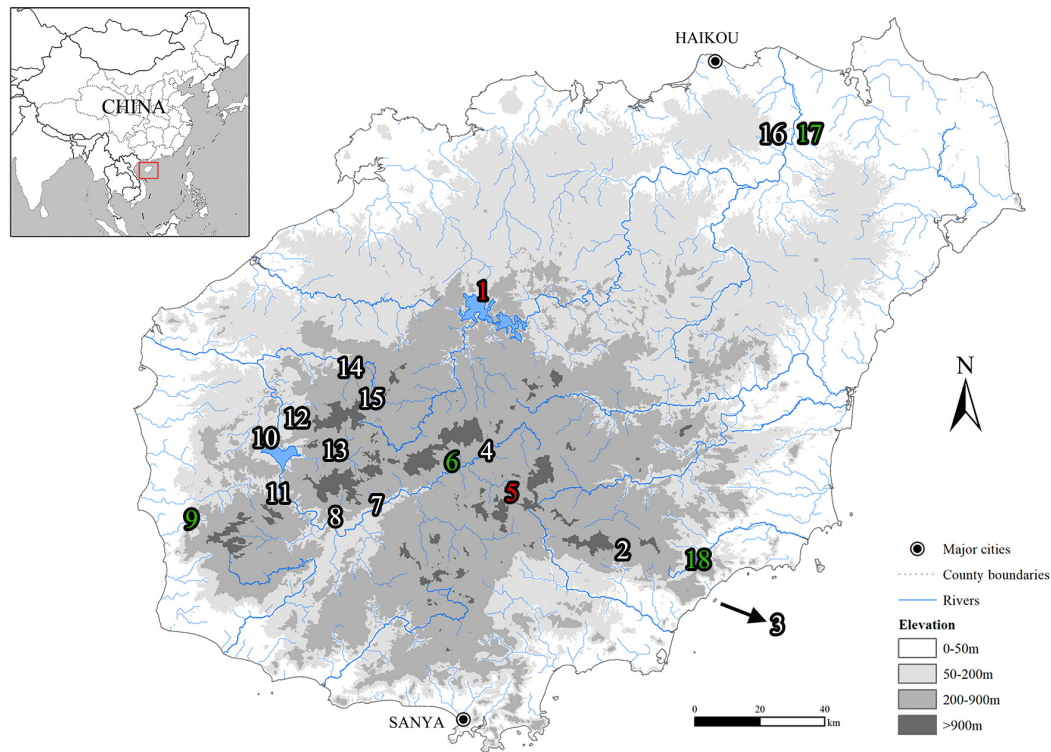


FIGURE 2. Confirmed historical and recent records of Water Monitors (*Varanus salvator*) on Hainan Island, China, based on literature and media reviews, as well as island-wide field/interview surveys conducted by Kadoorie Farm and Botanic Garden. Sites are 1: Nanfeng Town; 2: Dali Town; 3: Boundary Island; 4: Shiyun Town; 5: Shuiman Town; 6: Maoyang Town; 7: Wanchong Town; 8: Baoyou Town; 9: Banqiao Town; 10: Donghe Town; 11: Jiangbian Town; 12: Qicha Town; 13: Wangxia Town; 14: Jinbo Town; 15: Qingsong Town; 16: Longtang Town; 17: Yunlong Town; and 18: Nanqiao Town. Localities with recent records (2011–2020) are in white, those between 2001–2010 are in green, and records from over two decades ago are in red. See Table 1 for detailed data sources of these records.

during these surveys with local forest users and hunters on the presence/absence and status of a selection of threatened species known from Hainan, including *V. salvator* and, if locally extirpated, the approximate year of last sighting. *Varanus salvator* is the only varanid on Hainan Island (Shi et al. 2011), and the next largest lizard on the Island is Reeves' Butterfly Lizard (*Leiolepis reevesii*) with the maximum recorded snout-vent length of 138 mm (Shi et al. 2011). Therefore, we are confident that the interviewees could not have confused the Water Monitor with any other lizard species of the island. These data were collated for the island-wide distribution database.

Natural history field study in Z village.—With concern over poaching, we referred the site of this breeding population protected by local taboos as Z village in this paper. Z village is a small remote village in Baoyou town of Ledong county in the west of Hainan (Fig. 2). The village has about 200 households with a human population of about 1,200, and all residents are of the Li ethnic minority group which make up 15% of the population of Hainan. The village has a typical rural village layout at an elevation of 150–210 m elevation,

with densely packed houses surrounded by a mix of paddy fields, vegetable gardens, fishponds, and natural groves at the village periphery. A small tree-lined river, measuring about 6–16 m wide, and its tributaries, crisscross the agricultural landscape, which is where *V. salvator* were frequently encountered. Z village has a tropical monsoon climate with an average annual temperature of 23°–25° C; average lowest temperature can be down to 6.8° C and the highest up to 35.9° C (Tan 1981; Wang 2014). The rainy season is from May to October with an average annual precipitation of 1,400–1,800 mm, which largely coincides with the typhoon season from late July to mid-October (Tan 1981; Wang 2014).

Between 2012 and 2016, we established a Water Monitor Patrol Team in Z village. We selected and trained six villagers to conduct regular patrol, to study the basic ecology of the species, and to identify and remove threats to its survival. We divided the lowland areas of Z village (about 3 km²) into six grids, and we selected a transect of 2 km inside each grid that covered different habitats including streams/rivers, agricultural lands, fishponds, irrigation pools and ditches, and human settlements. Each patrol team member was equipped with binoculars and/or a long-zoom camera, and

repeatedly walked the transect in the morning (0700–1200) and afternoon (1400–1800). Field patrols/surveys were conducted on Saturday of each week between July 2012 and June 2016. Due to the lack of manpower, we were not able to conduct fieldwork in adjacent natural hillside forest. When *V. salvator* was encountered, we marked down the age class of the animal, date, time, location, macro- and micro-habitats of the site, and followed the lizard for as long as possible to record its behaviors. We also collected reliable reported sightings of *V. salvator* with detailed information from villagers. For age class categorization, we classified brightly colored/boldly patterned individuals with a total length of < 50 cm as juveniles, specimens with a total length of 50–100 cm as sub-adults, and lizards with a total length of over 100 cm as adults (Andrews 1995; Shine et al. 1996, 1998).

Varanus-related folklore survey.—Folklore, especially taboos, have proven to be an effective conservation tool for many species that are otherwise hunted/harassed on a community level (Uyeda et al. 2016; Bhattacharya and Koch 2018). To understand how local beliefs and taboos contribute to the preservation of such a widely hunted and critically endangered species in China, we randomly interviewed 56 villagers 8–86 y old in Z village 25–26 July 2012. They were interviewed with a semi-structured questionnaire on their traditional beliefs, customs, stories, attitudes, and knowledge towards *V. salvator*. Questions were open-ended to encourage participants to express their perspectives and attitudes freely (see Appendix 1 for an English translation of the questionnaire).

RESULTS

Distribution.—Our literature search yielded 267 items via CNKI and we only retained records documenting native Monitor Lizard. Due to its rarity and low density, we were able to trace only five confirmed locality records documenting wild *V. salvator* in Hainan from formal publications: Swinhoe (1870) first reported the presence of Monitor Lizard from Hainan Island based on a skin and a foot procured from local market without locality information; Schmidt (1927) reported five specimens collected by C.H. Pope in 1922–1923 from Nam Fong, Nodua (now under the large reservoir Songtao); subsequent domestic researchers documented four more localities in Hainan: Dali town (Li 1958), Maona village of Shuiman town (Zhao et al. 1999), Boundary Island (Shi et al. 2011), and Wanchong Town (Lau and Chan 2013). There was a record from Ganzaling Nature Reserve in Sanya City, southern Hainan in the early 2000s (Chen et al. 2008). Although the Reserve supports suitable lowland habitats

such as forest, marshy ponds, and perennial streams, this particular population originated from non-native traded animals confiscated by the Hainan authorities in 2001 (Xu et al. 2006). These confiscated lizards were transferred to a captive breeding facility in the Reserve and some escaped into the wild, and apparently bred with a juvenile specimen collected from the wild (pers. obs.). None have been detected in recent years, however, indicating this introduced population has probably died out (Xu et al. 2006; Jiancai Chen, pers. comm.). Therefore, literature search only yielded five confirmed township level localities from Hainan Island: Nanfeng town, Dali town, Shuiman town, Boundary Island, and Wanchong Town.

The four online sources returned 11,533 items related to Water Monitor and Hainan (6,180 from Google, 5,260 from Baidu, 80 from Sina Weibo, and 13 from Weixin), but only seven independent news reports regarding Water Monitor found in Hainan were retained. Among the seven cases, four were from urban areas in Haikou City, Changjiang City, Qionghai City and Dongfang City, and we rejected these records. We therefore retained three sightings from remote villages and a nature reserve from media sources: Donghe Town, Longtang Town and Jianfengling Nature Reserve in Banqiao Town. Except for the above-mentioned localities based on literature and media review, we confirmed an additional 11 new localities based on our island-wide field and interview surveys (Fig. 2, Table 1). Collectively our literature (*sensu lato*) and field research yielded 18 township level occurrence records of native *V. salvator* in Hainan, with 16 of them from the last two decades (Table 1).

Folklore and taboos.—This large lizard is well-known among rural villagers throughout Hainan; in the Li minority dialect *V. salvator* is called *Guy* in English transliteration, while the other major minority group of Hainan, the Miao (= Hmong in Southeast Asia), call it *Mung-yak*. For some tribes of the Li minority group, *V. salvator* is generally regarded as a taboo animal, bringing bad luck to whoever hunts or hurts it, or even just directly speaks out its local name *Guy*. Any violators must ask the village witch doctor to perform a sacred ritual to avoid negative consequences.

Varanus salvator ranged near homes in Z village and were commonly regarded as poultry-raiding/aquaculture pests. During the interview survey, all 56 respondents in Z village said they know of the local belief that monitors are taboo animals, and people cannot hunt, hurt, or even touch them. Of the respondents, 84% (n = 47) had a negative feeling towards the species and would not like to encounter one, while only 5.4% (n = 3) believed the monitors will bring good luck if encountered. The rest (10.6%) had no superstition on the species. Although 37.5% of respondents (n = 21) were unhappy with the

TABLE 1. Distribution records of Water Monitors (*Varanus salvator*) on Hainan Island, China, based on literature and media reviews, as well as island-wide field/interview surveys conducted by Kadoorie Farm and Botanic Garden. Exact locality information on unpublished recent records from the last decade were withheld for conservation reason. Abbreviations are NNR = National Nature Reserve and NR = Provincial Nature Reserve, ca. = approximately.

City or County	Township	Location	Sources	Elevation
Danzhou City 儋州市	Nanfeng Town 南丰镇	Nanfeng Village 南丰村	Schmidt 1927	ca. 190 m
Lingshui County 陵水县	Dali Town 大里乡	Diaoluoshan NNR 吊罗山	Li 1958; this study (last field observation in 2017)	ca. 160 m
	—	Boundary Island 分界洲岛	Shi et al. 2011	< 100 m
Wanning City 万宁市	Nanqiao Town 南桥镇	Jiaxin NR 加新保护区	This study (interview data, last seen in 2008)	< 200 m
Qiongzong County 琼中县	Shiyun Town 什运乡	Changhua River 昌化江	This study (last field observation in 2011)	ca. 250 m
Wuzhishan City 五指山市	Shuiman Town 水满乡	Maona village 毛纳村	Zhao et al. 1999	ca. 570 m
	Maoyang Town 毛阳镇	—	This study (interview data, last seen in 2004)	ca. 250 m
Ledong County 乐东县	Wanchong Town 万冲镇	Yinggeling NNR 鹦哥岭	Lau and Chan, 2013	ca. 200 m
	Baoyou Town 抱由镇	Z Village; Jianfengling NNR 尖峰岭	This study (last field observation in 2020) This study (interview data, last seen in 2008)	150–210 m
Dongfang City 东方市	Banqiao Town 板桥镇	Jianfengling NNR 尖峰岭	Newspaper 2009	ca. 100 m
	Donghe Town 东河镇	Exianling Village 俄贤村	Newspaper 2019; This study (last field observation in 2019)	ca. 150 m
	Jiangbian Town 江边乡	—	This study (interview data, last seen in 2013)	ca. 155 m
Changjiang County 昌江县	Qicha Town 七叉镇	—	This study (last field observation in 2019)	ca. 105 m
	Wangxia Town 王下乡	Bawangling NNR 霸王岭	This study (interview data, last seen in 2013)	230–300 m
Baisha County 白沙县	Jinbo Town 金波乡	Bawangling NNR 霸王岭	This study (interview data, last seen in 2015)	350–400 m
	Qingsong Town 青松乡	—	This study (interview data, last seen in 2018)	300–480 m
Haikou City 海口市	Longtang Town 龙塘镇	Sanlian Village 三联村	Newspaper 2019	ca. 40 m
	Yunlong Town 云龙镇	—	This study (interview data, last seen in 2004)	ca. 40 m

presence of *V. salvator* in their village, 51.8% (n = 29) accepted these animals and were willing to live with the species in the future; and the rest remained neutral towards the presence of the species. It can be interpreted that the local people were ambivalent towards monitors, they neither worship nor detest *V. salvator*, but it is a general taboo to hurt or hunt monitors otherwise it brings bad luck or bodily harm. Interestingly, although they have existing folklores that monitors are taboo animals and should not be hurt or hunted, a few villagers also mentioned that the monitor lizard can be used. There are some well-known folklores regarding the monitors in Z village (Table 2).

Natural history.—All respondents in Z village reported that they have seen the monitors and the animals were usually encountered, in descending frequency order, at the following habitats: watercourses and riparian belts, fish ponds, natural groves, rubber

plantation, paddy field, settlement area, and on the road. Between July 2012 and June 2016, we obtained 40 direct sighting records during fieldwork: 19 were from watercourses, seven from fish ponds, five from rubber plantations, three from paddy field, two from irrigation pool in farmland, two from ditches in village and two found inside settlement area (Appendix 2). Based on our field and interview data, *V. salvator* in Z village prefer riverine habitat and also forage in paddy fields and fishponds. Of our sighting records, 75% were directly associated with aquatic habitats in concordance with studies elsewhere (Bennett 1995; Bhattacharya and Koch 2018). The remaining microhabitats where *V. salvator* have been recorded are all within 300 m from water sources.

According to interview and field observations, monitors in Z village mainly prey on crabs, fishes, frogs, snails, and rats, and also scavenge on carcasses. Most villagers reported that monitors also prey on domestic

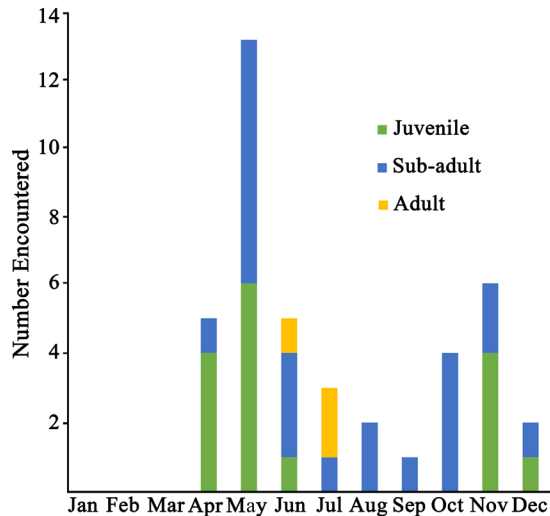


FIGURE 3. Number of individuals of Water Monitors (*Varanus salvator*) encountered by the patrol team in Z village, Hainan Island, China, in different months from 2012–2016.

animals, including chicken, ducks, and even piglets. We had one observation of predation attempt on a domestic animal during our study: a juvenile monitor preying on a duckling in the morning of 3 June 2014; the duck was injured but escaped. We also observed a sub-adult monitor scavenging on the carcass of a medium-sized pig discarded on the riverbank in the morning of 15 October 2015. Elsewhere, *V. salvator* is widely reported to scavenge at garbage dumps in human settlements (Uyeda 2009; Kulabtong and Mahaprom 2014), but this feeding behavior was neither reported by villagers nor observed in our field surveys. Although *V. salvator* preys on domestic animals and we received complaints from villagers of fish and chicken loss, we did not observe any obvious human-monitor conflicts. Owing to the local taboos, villagers do not harass or kill monitors even when poultry or fish predation was found.

Most villagers said *V. salvator* can be seen year-round except for the coldest time in December and January, and encounter rates were highest between March and May, which are the transitional period from the dry to wet season. Of our 40 direct sightings, the highest number was 13 in May and the lowest was one in September (Fig. 3, Appendix 2). Most of the recorded lizards in April and May were juveniles and the rest were sub-adults. Between June and October, we only had one record of a juvenile, while sub-adults and adults were usually encountered. In November, most records were of juveniles (Fig. 3). The monitors were rarely spotted during the dry winter from December to February, although we had one record of a juvenile in early December. We did not observe or receive reports of any mating or egg-laying events in Z village, so the breeding season of *V. salvator* in Hainan cannot be ascertained, as incubation period of the species is



FIGURE 4. (Top). An adult Water Monitor (*Varanus salvator*) from the main river of Z village, Hainan Island, China. (Photographed by Gang Lu). (Bottom). A juvenile *V. salvator* by a small stream in Z village. (Photographed by Jian-Huan Yang).

highly variable (Andrews and Gaulke 1990; Bennett 1995). Although we only conducted diurnal survey, we recorded a juvenile monitor sleeping on tree branches at night and local interviewees rarely reported seeing active monitors at night. The species is rarely reported to be active at night (Uyeda et al. 2013), and we therefore believe *V. salvator* in Hainan is predominantly diurnal as reported elsewhere (Traeholt 1997). The earliest time we recorded *V. salvator* was at 0820 on 12 October 2015, and the latest was at 1815 on 9 September 2015. They were most frequently detected 1000–1200 (48.4% of all records) and 1700–1800 (19.4% of all records).

Most villagers claimed that juveniles and sub-adults prefer farmland and village areas, while most adults disperse into adjacent hillside forests and are seldom seen. Our field survey seems to support this claim: 92.5 % of our direct sighting records were juveniles and sub-adults, and only three adults were encountered (Appendix 2). We did not conduct fieldwork in the hillside forests, and we are unable to confirm if the adults indeed spend most time in natural forests away from human settlements.

Threats.—Most respondents said that the local population of monitors is declining. Based on our personal observations as well as reports from villagers,

TABLE 2. Some well-known folklores regarding Water Monitors (*Varanus salvator*) in Z village, Hainan Island, China, directly quoted from interviewees.

“If you try to hunt/kill a monitor but failed, that the animal was injured but escaped, the animal will take revenge and you will die very soon”
“If any part of your body was hit by the monitor’s tail, the affected part will shrink slowly”
“If a monitor entered your house, you must ask the local witch doctor to perform a sacred ritual; otherwise your family will have big troubles soon”
“If your snare caught a monitor by accident, no matters how badly decayed the monitor body is, even with only bones left, you still need to eat the remains; otherwise you will die soon”
“If you accidentally injured a monitor, you must ask the local witch doctor to perform a sacred ritual to offset your guilt; otherwise you will die soon”
“The tail is very poisonous; you will get seriously injured if touched”
“If you got bitten by a monitor, you will die soon”.
“Its gall-bladder can be used for the treatment of eye diseases, and it is very effective”
“The gall-bladder wine is very good to your health”. This refers to an alcoholic tonic prepared by mixing the monitor gall bladder with rice wine, which is similar to “snake wine” in China and Southeast Asia

the majority of villagers strongly believe in the traditional taboos and would not hunt or harm the monitors, but a few villagers no longer hold the local beliefs and would try to catch the lizards for food. There were occasional reports of poachers from outside catching the lizards in Z village. In addition to poaching, the loss of paddy fields and natural groves due to changes in crop species and the expansion of monoculture plantations of Pará Rubber Trees (*Hevea brasiliensis*), banana (*Musa* spp.), and Areca Palms (*Dyopsis lutescens*), is also reducing area of prime habitat for *V. salvator*. Incompatible human activities, such as overfishing, hunting of frogs for food and the increased use of agricultural chemicals, also deplete the food base for monitors directly and indirectly.

DISCUSSION

Unlike their counterparts outside China, *Varanus salvator* is evidently very rare in Hainan now and no longer able to survive near busy cities, with few records from the last decades (see Li 1958; Zhao et al. 1999; Lau and Chan 2013; this study). We believe island-wide hunting together with lowland habitat degradation has driven the species to the current precarious status (Xu et al. 2006; Jiang et al. 2016). Over a century ago, Swinhoe (1870) noted that *V. salvator* appeared to be common in the interior of Hainan and was eaten by the Chinese, but since his time, the monitors must have been extensively hunted as most village elders interviewed in different parts of the island claimed that monitors used to be quite common decades ago. Respondents to our surveys in their thirties and forties, however, also reported

monitors were still regularly seen near their villages when they were young, indicating this habitat generalist survived into the 1980s and 1990s over a much wider area, despite the high rate for human consumption. We believe the loss of extensive lowland habitats with little human harassment also acted synergistically to trigger a dramatic decline of the species in the past two decades.

It is interesting to note that *V. salvator* of Hainan appears to prefer inland areas in the western half of the island, with very few records from coastal plains and none from mangroves, unlike its conspecific in Southeast Asia, which is commonly found in mangroves and other coastal wetlands. Swinhoe (1870), as well as numerous subsequent western naturalists who spent considerable amount of time in the coastal plains, reported the species was to be found in the interior, and the clusters of recent records from our island-wide survey also support their observations. Our result suggests there are other remnant populations surviving in remote pockets of the island; however, the current population status of these remnant populations is not known. With improved anti-poaching enforcement effort and conservation awareness in Hainan, these relict populations are key to population recovery of this adaptable and fecund species (Shine et al. 1998; Stanner 2010; Uyeda et al. 2012; Kulabong and Mahaprom 2014). Our study did not systematically cover the whole island and its offshore islets, and it is imperative to conduct a comprehensive survey combining interview and field survey to fully investigate the present distribution and conservation hotspots of the species throughout Hainan Island.

At the onset of our study, almost half of the respondents in Z village were unaware that *V. salvator*

is listed as Class I key protected species and hunting or hurting monitors is prohibited by laws. The continual observance of local taboos against harming monitors by most residents is the sole reason for the existence of a breeding monitor population in Z village. Such legal illiteracy regarding wildlife protection is still common throughout rural China, especially around international border regions, where minority groups are living in relative isolation and Chinese language is not their mother tongue. Belief in traditional taboos is weakening amongst the younger generations, however, and better access to the outside world means traditional taboos are likely to be further degenerated, to the detriment of this monitor population. Therefore, there is an urgent need to instigate a conservation awareness program and publicity of relevant wildlife protection laws in rural Hainan. As an attempt to improve the situation, we engaged relevant government departments and local community to protect the monitor population by hiring residents as members of the Water Monitor Patrol Team and we delivered a series of outreach activities to enhance conservation awareness of local residents during our study period at Z village. This appeared to have a positive impact for the protection of the population of *V. salvator*.

Acknowledgments.—We thank all the respondents during our interviews. We are grateful to Shining Li, Shibai Xiao, Fanqiang Luo, Qing Chen, Zhihua Zhang, Wenyong Li for providing additional information on *Varanus salvator* in Hainan. Our colleagues Xi Zheng and Fei Li assisted in fieldwork and map preparation. We acknowledge the Forestry Department of Hainan Province and various nature reserves for granting permits for field survey (no permit numbers are provided by the permitting agencies).

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APPENDIX 1. Questionnaire about Water Monitors (*Varanus salvator*) in Z village, Hainan Island, China (English translation).

1. Interviewee's name/age/gender
2. Do you know monitor lizard? Have you ever encountered monitor lizard in Z village?
3. If yes, how often do you encounter a monitor lizard?
4. Where is monitor lizards most frequently seen? Do they wander into human settlements?
5. What is your perception on the population status of monitor lizard in the past decade? Increasing / declining / stable? And why (if reported increasing or declining)?
6. How many monitor lizards are living around the village area?
7. How big was the largest monitor lizard you have seen? (in cm and/or kg)
8. Are monitor lizards afraid of humans?
9. Are monitor lizards diurnal or nocturnal? What time (morning/afternoon/night) are they more active? What kind of weather (sunny/rainy days) are they usually encountered?
10. Which months are they more frequently seen? Will they hibernate in winter?
11. What do monitor lizards eat? Have you seen them preying on domestic animals, like chicken and ducks? Have you seen any natural predators of monitor lizard?
12. Have you ever seen any combating and/or mating behaviors of monitor lizards?
13. Have you ever seen their burrows/nests? If yes, where?
14. Which season (months) are hatchlings/juveniles more frequently seen? Will juveniles live in groups?
15. Have you seen and/or heard of any cases of human attacked by a monitor lizard? Do you know if there is any human-lizard conflict in the village?
16. Do you know of any local taboos about monitor lizards? If yes, could you please tell us in detail? Do you believe that?
17. What's your feelings/thoughts on monitor lizards? How do you feel when you see a monitor lizard? Do you think they will bring good or bad luck?
18. Are you happy that monitor lizards live in your village?
19. Have you heard of any monitor lizard sightings in other nearby village? If yes, where?
20. Do you know of any local/outside people hunting monitor lizards in Z village? Have you seen any lizard-hunting activities? If you saw it, what will you do?
21. Are there any utilizations of monitor lizard? If so, for what purposes?
22. Do you know that monitor lizard is a State Key Protected Species?
23. Have you heard of the Wildlife Protection Law of the country?
24. What can we do to protect the monitor lizards in Z village?

APPENDIX 2. Direct sighting records of Water Monitor (*Varanus salvator*) by the patrol team in Z village, Hainan Island, China, 2012–2016.

Date	Time	Age class	Habitat type	Observed behavior	Air temperature (° C)
2012/07/28	1722	Adult	River	Resting on dead tree	—
2012/11/03	1025	Juvenile	River	Swimming	—
2012/12/05	1025	Sub-adult	Riverine	Moving	—
2013/05/09	1145	Sub-adult	Riverine	Moving	—
2013/05/10	1104	Sub-adult	Riverine	Moving	—
2013/05/14	0850	Juvenile	River	Basking on dead tree	—
2013/05/15	1045	Sub-adult	Fishpond in village	Basking	—
2013/06/05	1025	Sub-adult	River	Basking on dead tree	—
2013/06/20	1030	Sub-adult	River	Swimming	—
2013/10/11	—	Sub-adult	Stream	Basking	—
2014/04/05	—	Two juveniles	Paddy field	Two juveniles resting together	—
2014/04/08	1733	Juvenile	Stream	Basking on dead tree	—
2014/04/09	1016	Juvenile	Stream	Basking on dead tree	—
2014/04/25	—	Sub-adult	Fishpond in paddy field	Moving	—
2014/05/06	1035	Juvenile	Fishpond in village	Basking	—

APPENDIX 2 (continued). Direct sighting records of Water Monitor (*Varanus salvator*) by the patrol team in Z village, Hainan Island, China, 2012–2016.

Date	Time	Age class	Habitat type	Observed behavior	Air temperature (° C)
2014/05/07	1100	Sub-adult	Irrigation pool in paddy field	Moving	—
2014/05/15	—	Sub-adult	River	Moving	—
2014/06/03	1000	Juvenile	Village	Preying on a duckling	—
2014/06/01	—	Sub-adult	Irrigation pool in paddy field	Moving	—
2014/07/16	0930	Adult	Paddy field	Moving	—
2015/05/13	Morning	Sub-adult	Ditch in village	Swimming	30.8
2015/05/14	1030	Juvenile	River	Basking on dead tree	34
2015/05/17	Morning	Juvenile	Fishpond in village	Moving	31.8
2015/05/20	0910	Juvenile	Fishpond in paddy field	Basking	30
2015/05/20	Morning	Juvenile	River	Basking on dead tree	34
2015/05/22	1016	Sub-adult	Fishpond in paddy field	Moving	34
2015/07/27	0900	Sub-adult	River	Climbing on tree truck	33
2015/08/04	1530	Sub-adult	Village	Moving	35
2015/08/24	1220	Sub-adult	River	Swimming	35
2015/09/09	1815	Sub-adult	River	Foraging	32
2015/10/12	0820	Sub-adult	Ditch in village	Resting	—
2015/10/14	1542	Sub-adult	River	Foraging	30
2015/10/15	1100	Sub-adult	Riverine	Scavenging on a dead pig	—
2015/11/13	1700	Sub-adult	Fishpond	Moving	29
2015/11/13	1730	Juvenile	Rubber plantation	Moving	31.2
2015/11/24	1710	Juvenile	Rubber plantation	Moving	29.3
2015/11/29	1425	Sub-adult	Paddy field	Basking	—
2015/11/30	Night	Juvenile	Rubber plantation	Moving	—
2015/12/05	1710	Juvenile	Rubber plantation	Moving	28.1
2016/06/06	1100	Adult	Rubber plantation	Moving	—