A second population assessment of the Critically Endangered giant ibis *Thaumatibis gigantea* in Siem Pang Wildlife Sanctuary, Cambodia

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Paper submitted 25 December 2020, revised manuscript accepted 18 March 2021.

មូលន័យសង្ខេប

ត្រយ៉ងយក្ស *Thaumatibis gigantea* ជាបក្សីដ៏កម្រជិតផុតពូជបំផុត ដែលចំនួនសត្វពេញវ័យនៅសេសសល់មានតិចជាង ២០០ក្បាល ក្នុងនោះវត្តមានរបស់វាភាគច្រើនមាននៅកម្ពុជា។ ការយល់ដឹងពីទំហំ និងបម្រែបម្រួលនៃចំនួនរបស់បក្សីប្រភេទនេះ គឺពិតជាសំខាន់ណាស់ក្នុងការគ្រប់គ្រង និងអភិរក្សប្រកបដោយភាពជោគជ័យ។ យោងតាមការស្រាវជ្រាវនៅតាមត្រពាំងពីខែកុម្ភៈ ដល់ខែមេសា ឆ្នាំ ២០២០ និងការស្វែងរកនិងពិនិត្យតាមដានសំបុកប្រចាំឆ្នាំពីខែមិថុនា ដល់ខែ កញ្ញា ក្នុងអំឡុងពីឆ្នាំ ២០១៣ ដល់ ២០២០ ធ្វើឱ្យយើងអាចផ្តល់ទិន្នន័យប៉ាន់ប្រមាណចំនួនត្រយ៉ងយក្សជាលើកទី២ នៅក្នុងដែនជម្រកសត្វព្រៃសៀមប៉ាង។ ជាមធ្យមមានត្រយ៉ងយក្សចំនួន ៥០.៦ក្បាល ត្រូវបានរកឃើញក្នុងខែនីមួយៗពីការស្រាវជ្រាវនៅតាមត្រពាំង ហើយចំនួនដែលរាប់ឃើញច្រើនជាងគេ (៥៨ក្បាល) គឺស្ថិតក្នុងខែមីនា។ សំបុកសរុបចំនួន ៧៨សំបុក ត្រូវបានរកឃើញក្នុងអំឡុងរដូវបង្កាត់ពូជសរុបទាំង ០៨រដូវ ចាប់ពីឆ្នាំ២០១៣ ដល់ ២០២០។ ចំនួនសំបុកដែលត្រូវបានរកឃើញជារៀងរាល់ឆ្នាំមានការកើនឡើង ហើយ ៧៤%នៃសំបុកទាំងនោះទទួលបានជោគជ័យ។ កូនត្រយ៉ងយក្សចំនួន ៨៣ក្បាលបានហើរចេញពីសំបុកក្នុងអំឡុងពេលនៃការសិក្សានេះ ដោយគិតជាមធ្យមមានកូនចំនួន ១.០៦ក្បាល បានហើរចេញពីក្នុងមួយសំបុក (សម្រាប់សំបុកទាំងអស់) និងចំនួន ១.៤៣ក្បាល បានហើរចេញពីក្នុងមួយសំបុក (ចំពោះសំបុកដែលជោគជ័យ)។ លទ្ធផលរកឃើញនេះបង្ហាញថា មានត្រយ៉ងយក្សពេញវ័យយ៉ាងតិចចំនួន ៥៣ក្បាល (២៦គូ) មានវត្តមានក្នុងដែនជម្រកសត្វព្រៃសៀមប៉ាង តែយ៉ាងណាក្តី ចំនួនជាក់ស្តែងរបស់វាអាចមានចំនួនច្រើនជាងនេះ ព្រោះការសិក្សានេះធ្វើឡើងបានតែ២៥%នៃទីជម្រកសមស្របទាំងអស់របស់វាតែប៉ុណ្ណោះ។ ការរកឃើញនេះប្រហែលគ្នាទៅនឹងការប៉ាន់ប្រមាណទិន្នន័យត្រយ៉ងយក្សដែលត្រូវបានស្រាវជ្រាវកាលពីឆ្នាំ២០១៤ ហើយទិន្នន័យនេះចង្អុលបង្ហាញថាចំនួនត្រយ៉ងយក្សអាចនឹងមានវត្តមានថេរ ក្នុងដែនជម្រកសត្វព្រៃសៀមប៉ាង។ មូលហេតុដែលធ្វើឱ្យសំបុកត្រយ៉ងយក្សបរាជ័យនៅមិនទាន់ត្រូវបានគេដឹងនៅឡើយ។ អត្រារស់រានមានជីវិតរបស់កូនត្រយ៉ងយក្សក្រោយពីហើរចេញពីសំបុក និងសមាមាត្រប្រចាំឆ្នាំនៃសត្វត្រយ៉ងយក្សជំទង់ដែលអាចបង្កាត់ពូជនៅក្នុងចំនួនរបស់វានៅក្នុងតំបន់នេះក៏នៅមិនទាន់ត្រូវបានគេដឹងនៅឡើយទេ។ ការសិក្សាស្រាវជ្រាវបន្ថែមតាមរយៈការបំពាក់ឧបករណ៍តាមដានទៅលើសត្វត្រយ៉ងយក្សជំទង់ អាចជួយបំពេញចន្លោះខ្វះខាតនៃចំណេះដឹងទាំងនេះបាន។

CITATION: Eang S., Vann V. & Eames, J.C. (2021) A second population assessment of the Critically Endangered giant ibis *Thaumatibis gigantea* in Siem Pang Wildlife Sanctuary, Cambodia. *Cambodian Journal of Natural History*, **2021**, 12–20.

Abstract

The Critically Endangered giant ibis *Thaumatibis gigantea* numbers fewer than 200 mature individuals that mainly occur in Cambodia. Understanding the size and trends of remaining populations of the species are crucial to its successful conservation management. Based on waterhole surveys in February–April 2020 and annual nest searches and monitoring in June–September of 2013–2020, we provide a second estimate for giant ibis populations in Siem Pang Wildlife Sanctuary. On average, 50.6 giant ibises were detected each month in our waterhole surveys and most birds (58) were detected in March. A total of 78 nests were located over the eight breeding seasons in 2013–2020. Numbers of nests found each year increased and 74% of all nests proved successful. This led to 83 chicks fledging during the study period, giving a mean figure of 1.06 chicks fledged per nest for all nests and 1.43 for successful nests alone. Our results indicate a minimum of 53 mature giant ibises (26 pairs) occur in Siem Pang Wildlife Sanctuary, although the actual population could be larger as only 25% of suitable habitats at the site were sampled. This is similar to a comparable estimate made in 2014 and suggests giant ibis populations may be stable in Siem Pang Wildlife Sanctuary. While encouraging, the reasons for failures of giant ibis nests remain incompletely known. The post-fledging survival rate of juvenile giant ibises also remains unknown, as does the proportion of juveniles annually recruited into the local breeding population. Studies that deploy tracking devices on juvenile birds could help to reduce these knowledge gaps.

Keywords Auditory detections, giant ibis, visual detections, waterholes.

Introduction

The giant ibis *Thaumatibis gigantea* is the largest species in the worldwide ibis family Threskiornithidae and is listed as Critically Endangered by the IUCN (BirdLife International, 2018). Its taxonomic position in a monotypic genus further increases its conservation importance. The giant ibis has an extremely small population estimated at 194 individuals which has undergone an extremely rapid decline as a result of hunting, disturbance and lowland deforestation. It is likely to continue to decline rapidly owing to on-going deforestation and human disturbance (BirdLife International, 2018). The range of the species has also contracted resulting in its extinction in Thailand and near extinction in Laos and Vietnam, such that recent records from the latter countries probably refer only to spill-over from Cambodia (Eames *et al*., 2003). As a result, the species may be considered as confined to Cambodia for conservation purposes. The latter population is currently confined to protected areas in northern and eastern Cambodia including the Chhep, Kulen Promtep, Siem Pang, Lomphat, Phnom Prich, Seima and Srepok wildlife sanctuaries (Loveridge & Ty, 2015).

A ten-year action plan for the giant ibis has been published for the period 2015–2025 (Loveridge & Ty, 2015). The third objective of this plan specifies the need to "develop a unified census method", "conduct census of priority sites" and "identify and map priority sites within protected areas to inform site management plans" (Loveridge & Ty, 2015). The first systematic population assessment for giant ibises comprised a survey (rather than a census) undertaken in Siem Pang Wildlife Sanctuary (SPWS) (Ty *et al*., 2016). The authors estimated 49.5 ± 10 mature birds occurred at the site, but did not qualify the basis for their error margin. The same methods were later employed at Lomphat Wildlife Sanctuary where 40 giant ibises were estimated to occur (Pin *et al*., 2020). No error margin was provided for the latter. We report here on a waterhole (trapeang) survey undertaken at SPWS in 2020 and evaluate the breeding success of giant ibises at the site between 2013–2020 to determine if any changes have occurred in its populations.

Methods

Our study was conducted in SPWS which encompasses 1,337 km^2 in Stung Treng Province, northeast Cambodia (140°10'N, 106°13'E; Fig 1). The sanctuary combines the former Siem Pang and Prey Siem Pang Khang Lech wildlife sanctuaries and was designated on 6 November 2019. The site is contiguous with the Xe Pian National Protected Area (Laos) and the Virachey and Veun Sai-Siem Pang national parks in Cambodia and forms part of a 11,217 km^2 network of protected areas in Laos, Cambodia and Vietnam, one of the largest nominally protected landscapes in the Mekong basin (Loveridge *et al*., 2018). The conservation importance of SPWS is well documented and the site supports populations of seven Critically Endangered taxa comprising five bird species, one mammal species and one reptile species (BirdLife International, 2012; Ty *et al*., 2016; Loveridge *et al*., 2017, 2018). Approximately half of the site consists of deciduous dipterocarp forests which include over 200 waterholes and stretches of riverine forest that provide

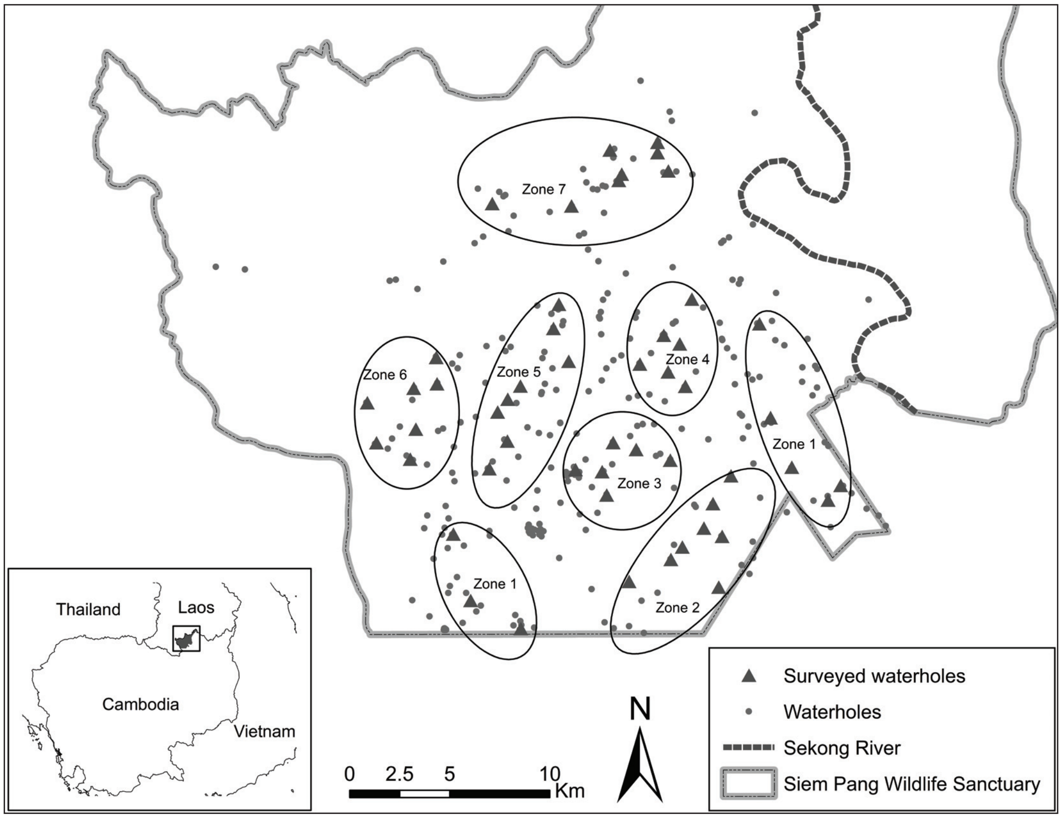

Fig. 1 Location of Siem Pang Wildlife Sanctuary and waterhole zones selected for giant ibis surveys in 2020.

suitable habitat for giant ibises. The local climate is monsoonal with a pronounced wet and dry season, which occur from May to October and from November to April, respectively. Detailed accounts of the biodiversity, vegetation and climate of SPWS are provided by BirdLife International (2012) and Ty *et al*. (2016).

Waterhole surveys

Our survey was based on observations at waterholes (Fig. 1) and adopted the methods developed by Ty *et al*. (2016). Waterholes provide important foraging habitats for giant ibises, especially during the dry season (Keo, 2008). The survey was conducted from the 17th to the 23rd day of each month in February–April 2020. A team of ten surveyors familiar with giant ibis were trained in the survey protocol and GPS and compass use. Training was not provided in distance estimation and surveyors estimated their distance to calling birds based on their personal experience.

To maximize detections, we focused on surveying waterholes that were visited by giant ibises between 2015 and 2019. Following Ty *et al*. (2016), we did not attempt to survey all known waterholes at SPWS since these number over 200. Rather, we identified 76 waterholes where at least one detection of giant ibis occurred during the dry seasons (January–April) of 2015–2019. Fifty-one of these waterholes were randomly selected for survey, similar to the sample size of 49 waterholes selected by Ty *et al*. (2016). To facilitate the field survey, each waterhole was assigned to one of seven zones. Each zone was located at least 3 km from its nearest neighbour and included six to eight waterholes (Fig. 1).

A single zone was surveyed over the course of one day by the field team and overall, each waterhole was visited once each month by observers in pairs or individually. Giant ibis frequently call from their roosts at SPWS from 0500 to 0600 hrs, then cease calling and travel to foraging sites around 0600 hrs (Ty *et al*., 2016). Because disturbance caused by human activity generally begins around 0700 hrs (Ty *et al*., 2016), our counts were confined to 0530–0700 hrs to coincide with calling activity during the least disturbed period of the day. To avoid disturbance, our observers approached waterholes slowly and chose concealed vantage points affording a clear view of the entire waterhole before 0530 hrs. Data recorded on visual detections of giant ibises comprised: number of

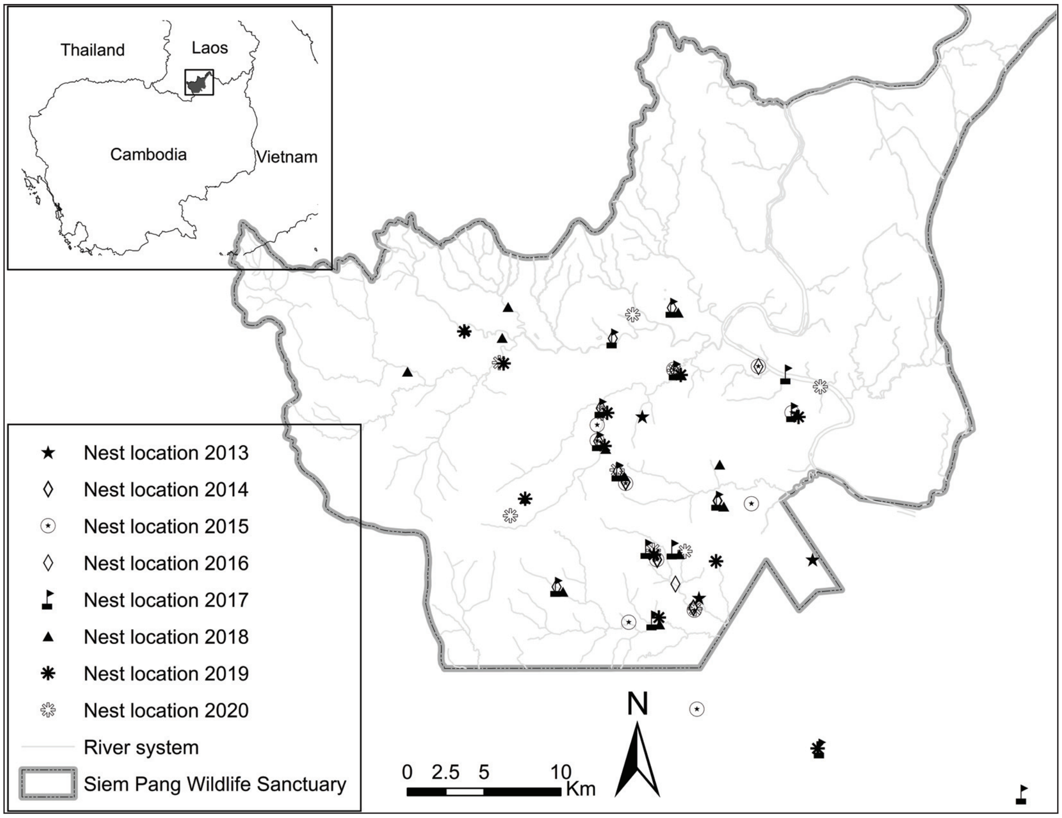

Fig. 2 Locations of giant ibis nests monitored during the 2013–2020 breeding seasons in Siem Pang Wildlife Sanctuary.

individuals observed; time of observation; duration of stay at waterhole; and entrance and exit direction, time and flight height. The identity of any birds flushed on approach to a waterhole was also noted. Data recorded on auditory detections comprised the time, direction and bearing of call and estimated distance from the observer.

Nest monitoring

The third objective of the action plan for giant ibis advocates research efforts including nest monitoring to inform conservation actions (Loveridge & Ty, 2015). Nest monitoring for giant ibises in SPWS predates this guidance, having begun in 2013. More specifically, we undertook searches for giant ibis nests from June to September each year in 2013–2020.

Giant ibises begin mating in May and June and build nests from late June until early August (Keo, 2008). Our surveys were divided into two phases. Because giant ibises show high fidelity to their nest sites (BirdLife International, unpublished data), the first phase involved checking nest locations found in the previous season, whereas the second phase comprised searches for new nests in new areas. During the first phase, we first checked the locations of nests from the previous season every two weeks to minimize disturbance. This was undertaken from June to July each year and once confirmed, the nests were observed for at least 30 minutes once a fortnight from incubation onwards. This monitoring increased to one visit per week from the beginning of the hatching period until fledging in an attempt to determine the dates of both. Information on human disturbance and predation events were also recorded. Nests were considered successful if their chicks fledged and failures if they did not.

Searches for new nests were undertaken from July to September each year. Adult giant ibises are more conspicuous during this period as they are active and frequently call. Following Ty *et al.* (2016), listening posts were employed to search areas of suitable habitat for nests which comprised habitats in the vicinity of waterholes, rivers and streams (Fig. 2) (Keo, 2008; Wright *et al.*, 2012). Searches were conducted over five- to seven-day periods by a team of seven or more trained observers. These were split into groups of two or three observers and each group surveyed separate locations with a ≥ 2km radius from 0500 hrs every day to ensure detection of giant ibis calls made from their roosts. The direction and distance of each calling bout was noted by the observers, who then progressively navigated towards the calling bird. In each instance, observers took care not to disturb either member of the pair and remained alert to alarm calls. Upon finding a nest, the observers recorded its location and estimated the height and identity of the nest tree. Once confirmed, all new nests were monitored as previously outlined.

Data analysis

Waterhole surveys: Following Ty *et al*. (2016) and Pin *et al*. (2020), we screened our data to remove potential double-counts of the same individual in vocal and sight detections as follows: 1) when birds were observed flying from the same direction as previously detected calling birds, one of the detections was excluded; 2) vocal detections of individual birds by the same observers within a 45° radius were considered the same individual unless they occurred at the same time. Potential double counts of individual birds moving between waterholes on the same morning (as suggested by their timing) were also excluded. More specifically, we first considered the time a bird was sighted at a given location, the time it departed for another location and the bearing on which it departed. If a bird was then observed flying from the direction in which one had already been recorded, this record was excluded from the count for the new location.

Following these adjustments, a maximum monthly count was calculated for each zone following Ty *et al*. (2016) by summing the number of unique individuals recorded by visual and auditory detections. A minimum monthly count was also calculated for each zone which was based on auditory detections alone (as these provided higher counts). The actual estimate of monthly detection for each zone was taken as the mid-point between these two figures in providing a conservative estimate combining both types of detections (Ty *et al*., 2016).

Nest monitoring: Following Pin *et al.* (2020), we summed the number of nests found each year, distinguishing the number of successful nests, the number of fledged chicks recorded at each nest, and the total number of giant ibis recorded (including adults and young seen at nests). We estimated the total number of giant ibis recorded by summing the number of fledged chicks and adults seen at nests during the monitoring period. The average number of chicks per nest was estimated by dividing the total number of fledged chicks by the total number of successful nests (Pin *et al*., 2020).

Results

Waterhole surveys

Following removal of 36 potential double-counts from our data for February, 41 from March and 43 from April, our minimum and maximum counts for giant ibises were 41 and 51 in February, 48 and 58 in March and 30 and 43 in April, respectively (Table 1). Our monthly population estimates were consequently of 46 giant ibises in February, 53 in March and 36.5 in April. Total numbers of visual detections were similar between months, whereas figures for auditory detections were similar in February and March but lower in April. The mean monthly total for detections (auditory and visual) was 50.6 birds. The greatest number of giant ibises were recorded at waterholes in zone seven (Fig. 1).

Nest monitoring

A total of 78 giant ibis nests were found and monitored during the study period (Table 2, Fig. 3). The number of nests found each year increased from two in 2013 to a maximum of 16 in 2018 and decreased in 2019 and 2020. Fifty-eight (74%) of the 78 nests were successful and a total of 83 chicks fledged over the study period. An average of 1.06 fledged chicks per nest was recorded for all nests monitored, whereas the equivalent figure for successful nests only was 1.43. On average, 7.25 of the 9.75 nests found each year were successful, with 10.5 chicks fledging per study year.

Twenty-six percent of nests were not successful, mostly for unknown reasons. One chick was found dead in a nest, whereas another was found dead under the nest tree. Broken eggs were found under a nest tree on six occasions, whereas bad weather (wind and rain) caused nest failure on one occasion and disturbance from nearby logging on two occasions. Predation was not observed but claw marks made by the Southeast Asian monitor lizard *Varanus nebulosus* were observed on a nest tree on two occasions (Mem Mai pers. obs.). A party of long-tailed macaques *Macaca fascicularis* were also observed 70 m from a failed nest on another occasion. The best documented case of nest destruction by another species involved a juvenile slender-billed vulture *Gyps tenuirostris* which nested in the same tree as a giant ibis nest at Jong Brolay Kondal (14°10′35″N, 106°16′5″E) in August 2020. The fledged juvenile returned to the nest tree to roost on 3 August, but did so in the giant ibis nest, resulting in its destruction (Fig. 4).

Table 1 Corrected figures for visual and auditory detections of giant ibises in Siem Pang Wildlife Sanctuary in February–April 2020.

Zone	No. of waterholes	February		March		April	
		Visual Detections	Auditory Detections	Visual Detections	Auditory Detections	Visual Detections	Auditory Detections
1	8	2	0	0	4	2	4
2	7	2	10	0	6	1	4
3	7	0	2	3	2	0	4
4	6	0	5	3	7	2	5
5	8	0	9	4	8	3	7
6	7	1	3	0	5	3	0
7	8	5	12	0	16	2	6
subtotal	**51**	**10**	**41**	**10**	**48**	**13**	**30**
Total		**51**		**58**		**43**	

Table 2 Summary of nest monitoring results for giant ibises in Siem Pang Wildlife Sanctuary, 2013–2020.

Breeding season	Nests found	Successful nests	No. of adults	No. of chicks fledged	Total individuals
2013	2	1	4	1	5
2014	4	3	8	4	12
2015	11	6	22	6	28
2016	9	9	18	16	34
2017	15	13	30	19	49
2018	16	12	32	16	48
2019	11	7	22	11	33
2020	10	7	20	10	30
Total	**78**	**58**	**156**	**83**	**239**

Discussion

Our study is the second attempt to determine the population size of giant ibises in SPWS. The first attempt was undertaken in 2014 and provided a minimum population estimate of 49.5 ± 10 adults (Ty *et al.*, 2016). Unlike a similar study in Lomphat Wildlife Sanctuary (Pin *et al.*, 2020), total numbers of adult giant ibis derived from our waterhole surveys and nest monitoring differed markedly. For example, the results of our waterhole survey suggest a minimum of 53 ± 5 mature giant ibises (26 pairs) occurred at SPWS in 2020. This figure is similar to the 2014 estimate of 49.5 birds (Ty *et al*., 2016). In contrast, our nest monitoring data for the same year suggested a minimum population of 20 adults and 10 fledglings, giving a total of 30 individuals. This is based on ten nests being found and assumes the species is monogamous.

During our study design, we selected waterholes known to be frequented by giant ibises due to time and resource constraints. This would bias any attempt to extrapolate our results to larger areas. Notwithstanding this, since we only sampled 51 of the 200 waterholes

Fig. 3 Giant ibises nesting in Siem Pang Wildlife Sanctuary, 29 July 2014 (© Jonathan Eames).

Fig. 4 Juvenile slender-billed vulture in giant ibis nest, Siem Pang Wildlife Sanctuary (© BirdLife International/Mem Mai).

currently known in SPWS, our population estimate would likely have been higher had all of the waterholes were sampled. This also seems probable considering over 3,023 incidental sightings of giant ibises were made in SPWS between 2013 and 2019, an average of 36 sightings per month (BirdLife International, unpublished data).

The timing of our waterhole survey differed slightly from Ty *et al*. (2016) who undertook their field work in January–March and obtained the highest count in February. Our field work was conducted in February–April and obtained the highest combined count in March. Notwithstanding this, our visual detections were highest in April 2020 when the rains began. These precipitated the first yearly emergence of large numbers of frogs which may have stimulated giant ibis activity. This raises the possibility that the February–April might be a more appropriate survey period. Increases in the number of observers and waterholes sampled would likely also lead to a greater proportion of the population being detected. One difficulty experienced with the survey method was distance estimation. As this becomes increasingly subjective beyond 100 m, it would be worth including training and ground-truthing for distance estimation in preparations for future surveys.

The number of nests we found each year differed greatly, ranging from a low of two nests in 2013 to a high of 16 nests in 2018 (Table 2). As the survey team remained largely unchanged during the study period, our team members became more familiar with nest searches and the ecology and breeding behaviour of giant ibises. Similar to the findings of Pin *et al*. (2020) in Lomphat Wildlife Sanctuary, we believe this likely contributed to improved levels of nest detection over time.

During the course of our study, we detected breeding of giant ibises outside of the typical nesting season. In 2016 and 2017 for instance, a giant ibis nest along the Sekong River fledged young in early December. Additionally, a pair of giant ibises were observed building a nest next to the O'Lao'k Stream in early October 2020. If successful, this nest would have fledged in January 2021. As such, continuation of nest searches through October each year might increase the number of nests found in future surveys.

We recorded a nest success rate of 74% (58 of 78 nests) which is lower than the 90% rate (28 of 31 nests) documented at Lomphat Wildlife Sanctuary by Pin *et al*. (2020). The reasons for this difference are not clear. Pin *et al*. (2020) recorded an average figure of 1.53 chicks fledging per nest whereas our average figures were 1.06 for all nests and 1.43 for successful nests alone. These differences cannot be explained by differences in conservation effort between the sites because nest protection efforts were not undertaken at Lomphat Wildlife Sanctuary (Pin *et al*., 2020) whereas the use of nest guardians ceased at SPWS in 2016.

Although 83 giant ibises successfully fledged during our study at SPWS, the causes of nest failures remain incompletely known. Nest predation by common palm civets *Paradoxurus hermaphroditus* and/or yellow-throated martens *Martes flavigula* was reported on two occasions in 2004 (Keo, 2008). However, no supporting evidence was provided and Southeast Asian monitor lizards were not considered. The latter species is widespread in the deciduous dipterocarp forests at SPWS, an accomplished tree-climber and its close relative, the water monitor lizard *Varanus salvator,* is known to feed on birds and their eggs (Das, 2010). Southeast Asian monitor lizards are targeted by human hunters at SPWS and it is possible that this hunting pressure may have contributed to successful fledging of giant ibis chicks by reducing local populations of the lizard. While less than ideal, this possibility might be preferable on balance, considering Southeast Asian monitor lizards are widely distributed in the region and regarded as Least Concern, whereas giant ibises are largely confined to Cambodia and Critically Endangered.

The post-fledging survival rate of juvenile giant ibises remains unknown at SPWS, as does the proportion of juveniles annually recruited into the local breeding population. This is unlikely to be optimal however. For example, a juvenile giant ibis was found in a weakened state near Trapeang Daikla (14°11′44′′N, 106°14′2′′E) on 16 November 2020. This was easily captured by hand and taken into care and was later reported to be underweight, dehydrated and suffering from a feather louse infestation and possibly avian malaria (BirdLife International, unpublished data). The bird has since recovered (Christel Griffoen, pers. comm.).

Two large groups of giant ibises were observed during the study period which were unprecedented. A flock of 15 giant ibises was recorded at Veel Kreel (14°10′34′′N, 106°13′22′′E) on 4 July 2018. As this date appears too early for flocks of post-breeding adults and young, they could potentially have been non-breeding birds. Additionally, a flock of 14 giant ibises was recorded at O'Sangke (14°16′19′′N, 106° 3′25′′E) on 21 September 2018. This date is late enough to include post-breeding adults and juveniles, although the age of first breeding and whether giant ibises breed annually remains unknown. The deployment of tracking devices on juvenile birds would help to fill this knowledge gap and is recommended in the action plan for giant ibises (Loveridge & Ty, 2015). It would also help to determine whether giant ibises are truly monogamous (currently assumed to be the case), their degree of fidelity to nest sites and provide an indication of territory sizes, none of which are currently known.

Acknowledgements

Our study was undertaken under the framework of a memorandum of understanding between the Cambodian Ministry of Environment and BirdLife International. Our studies were supported financially by the BirdLife Species Champions Giant Ibis Transport Co. Ltd. and Stephen Martin, Fondation Segré, Rising Phoenix Co. Ltd. and the John D. and Catherine T. MacArthur Foundation. We are also grateful to our following field staff for data collection: Mem Mai, Loun Bunpeang, Mem Samphorn and Vann Kosal.

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