The first population assessment of the Critically Endangered giant ibis *Thaumatibis gigantea* in Lomphat Wildlife Sanctuary, Cambodia

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Paper submitted 19 January 2020, revised manuscript accepted 19 May 2020.

មូលន័យសង្ខេប

សត្វត្រយ៉ងយក្ស *Thaumatibis gigantea* ដែលជាបក្សីជំនាញរស់នៅក្នុងព្រៃល្បោះស្ងួត មានការថយចុះខ្លាំង និងគួរឱ្យកត់សម្គាល់ទាំងចំនួន និងទីរបស់វា ដោយសារកត្តាបាត់បង់ទីជម្រក ការរំខាន និងការបរបាញ់។ ក្នុងពេលបច្ចុប្បន្នចំនួនសត្វត្រយ៉ងយក្សពេញវ័យមានមិនដល់២០០ក្បាលផង ហើយការស្វែងយល់ពីចំនួនប្រជាសាស្ត្ររបស់សត្វត្រយ៉ងយក្សដែលនៅសេសសល់នេះ គឺមានសារៈសំខាន់ខ្លាំងដើម្បីធ្វើការអភិរក្សពួកវា។ យើងបង្ហាញពីការប៉ាន់ប្រមាណនូវចំនួនប្រជាសាស្ត្រនៃត្រយ៉ងនេះនៅក្នុងដែនជម្រកសត្វព្រៃលំផាត់ជាលើកដំបូងតាមរយៈការអង្កេតតាមដានសំបុករបស់វានៅកំឡុងរដូវបន្តពូជចាប់ពីឆ្នាំ២០១៥-២០១៨ និងការអង្កេតនៅតាមត្រពាំងទឹកនារដូវប្រាំងក្នុងឆ្នាំ២០១៩។ ជាទូទៅទាំងចំនួននៃការកត់ត្រាជារួម និងចំនួនរបស់សត្វត្រយ៉ងយក្សដែលគណនាពីការអង្កេតនៅតាមត្រពាំងមានកំរិតខ្ពស់នៅកំឡុងខែមករា និងកុម្ភៈ ហើយការកត់ត្រាតាមរយៈសំលេងវាមានការកើនឡើងនៅក្នុងខែកុម្ភៈ។ មានសំបុកសត្វត្រយ៉ងយក្ស សរុបចំនួន៣១ ត្រូវបានរកឃើញ និងអង្កេតតាមដាននៅក្នុងកំឡុងពេលនៃរដូវបន្តពូជរវាងឆ្នាំ២០១៥-២០១៨។ អត្រាញាស់ជោគជ័យមានប្រមាណ៩០% ជាមួយនឹងចំនួនកូនសត្វត្រយ៉ងយក្សញាស់ជាមធ្យម ១,៥៣ក្បាល/សំបុក ហើយចំនួនកូនសត្វត្រយ៉ងយក្សញាស់ជាមធ្យម ១០.២៥ក្បាល/ឆ្នាំ។ យ៉ាងហោចណាស់មានសត្វត្រយ៉ងយក្ស (ដែលរួមទាំងសត្វពេញវ័យ និងកូនសត្វដែលបានញាស់) ចំនួន១៣ក្បាល ៨ក្បាល ៣១ក្បាល និង៥១ក្បាល ត្រូវបានកត់ត្រានៅតាមសំបុកក្នុងពេលអង្កេតតាមដានក្នុងឆ្នាំ២០១៥ ឆ្នាំ២០១៦ ឆ្នាំ២០១៧ និងឆ្នាំ២០១៨រៀងៗខ្លួន ដែលឱ្យជាមធ្យមមានសត្វត្រយ៉ងយក្ស ចំនួន២៥.៧៥ក្បាល/រដូវបន្តពូជ។ សត្វត្រយ៉ងយក្សពេញវ័យមានចំនួនប្រហាក់ប្រហែលគ្នារវាងការអង្កេតនៅតាមត្រពាំងទឹក និងការអង្កេតតាមដានសំបុក។ លទ្ធផលបង្ហាញថា ការអង្កេតនៅតាមត្រពាំង និងការអង្កេតតាមដានសំបុក ជាវិធីសាស្ត្រមានសារៈសំខាន់ដែលអាចប្រើប្រាស់ដើម្បីប៉ាន់ប្រមាណចំនួនសត្វត្រយ៉ងយក្សបាន។ វិធីសាស្ត្រនេះអាចអនុវត្តបានលុះណាមានបុគ្គលិកទីវាលដែលមានបទពិសោធន៍ និងទទួលបានការបណ្តុះបណ្តាលគ្រប់គ្រាន់។

CITATION: Pin C., Bou V., Eames, J.C., Samorn V. & Thol S. (2020) The first population assessment of the Critically Endangered giant ibis *Thaumatibis gigantea* in Lomphat Wildlife Sanctuary, Cambodia. *Cambodian Journal of Natural History*, **2020**, 7–14.

Abstract

The Critically Endangered giant ibis *Thaumatibis gigantea* is a dry forest specialist whose range and population has declined dramatically due to habitat loss, human disturbance and hunting. Less than 200 mature individuals of the species are now thought to exist and understanding the status of remaining populations is crucial to their conservation management. We provide a first estimate for giant ibis populations in Lomphat Wildlife Sanctuary, based on nest monitoring during the 2015–2018 breeding seasons and waterhole surveys in 2019. Overall detections and numbers of individuals recorded at waterholes were high in January and February 2019, and most of our call detections occurred in the latter month. A total of 31 nests were found and monitored over the 2015–2018 breeding seasons. Nest success rates were high at 90% and on average, 1.53 chicks fledged per nest and 10.25 chicks fledged per year. At least 13, 8, 31 and 51 giant ibises (including adults and fledged chicks) were recorded at nests monitored in 2015, 2016, 2017 and 2018 respectively, giving an average of 25.75 giant ibises per breeding season. Numbers of mature giant ibises estimated from nest monitoring and waterhole surveys were comparable. Our results suggest that both survey methods can be used to estimate populations of the species, provided field surveyors have adequate training and experience.

Keywords Call detections, giant ibis, sight detections, waterholes.

Introduction

The Lower Mekong Ecoregion is one of the most important 200 ecoregions for global biodiversity (Olson & Dinerstein, 1998; Wikramanayake *et al*., 2002). The eastern and northern plains landscape of Cambodia supports the largest extent of lowland dry deciduous forest in Southeast Asia (Wikramanayake *et al*., 2002) and are recognized as having high value for biodiversity conservation (Tordoff *et al*., 2005). This landscape is home to a wide range of wildlife including globally threatened mammals and bird species (Gray *et al*., 2012; O'Kelly *et al*., 2012). During the dry season, water availability within the landscape is mainly limited to perennial rivers and waterholes ("trapeang" in Khmer). These water sources form an essential part of the dry deciduous forest and are used by several globally threatened large mammals and large birds (Keo, 2008; Wright *et al*., 2012a; Pin *et al*., 2018).

The national bird of Cambodia, the Critically Endangered giant ibis *Thaumatibis gigantea*, historically ranged across Thailand, Cambodia, Lao PDR and Vietnam but has declined dramatically in numbers and range due to habitat loss, disturbance, and poaching (Thewlis & Timmins, 1996). The remaining global population is estimated to be around 190 mature individuals (BirdLife International, 2018) and confined to the eastern and northern plains of Cambodia (Keo, 2008; Gray *et al*., 2014; Ty *et al*., 2016; Pin *et al*., 2018). A few individuals may also remain in Vietnam and Lao PDR, but the species is considered extinct in Thailand (BirdLife International, 2018).

The Critically Endangered status and lack of knowledge of giant ibis have prompted several studies in recent years. These include studies of its ecology, conservation (Keo, 2008; Wright *et al*., 2012a) and behaviour (Pin *et al*., 2018). All of the remaining populations known are in protected areas. The first study to determine the size of such a population occurred in the Prey Siem Pang Khang Lech Wildlife Sanctuary in Stung Treng Province (Ty *et al*., 2016), which estimated 49.5 ± 10 mature birds remained at the site. Using the waterhole survey methodology developed by Ty *et al*. (2016), combined with nest monitoring, the aim of our study was to determine the population of giant ibises in Lomphat Wildlife Sanctuary in Ratanakiri Province.

Methods

Study area

Lomphat Wildlife Sanctuary (LWS) covers 2,525 km^2 and is located in the eastern plains landscape of Cambodia (centred on 13.2°N, 106.5°E) (Fig. 1). Despite designation as a wildlife sanctuary, the landscape of LWS has been degraded by an economic land concession for agricultural development, and by illegal land encroachment (Hor *et al*., 2014; Chanrith *et al*., 2016). The sanctuary borders Srepok Wildlife Sanctuary to the southeast and O'Yadav National Park to the east and largely supports deciduous dipterocarp forests dominated by Dipterocarpaceae, mostly comprising *Shorea siamenis*, *S. obtusa*, *Dipterocarpus tuberculatus*, *D. obtusifolius* and *D. intricatus* (McShea *et al*., 2011). The area experiences a monsoon tropical climate with two distinct seasons: a rainy season with most rainfall occurring between May to October, and a dry season from November to April (Thoeun, 2015). During the dry season, the area experiences frequent

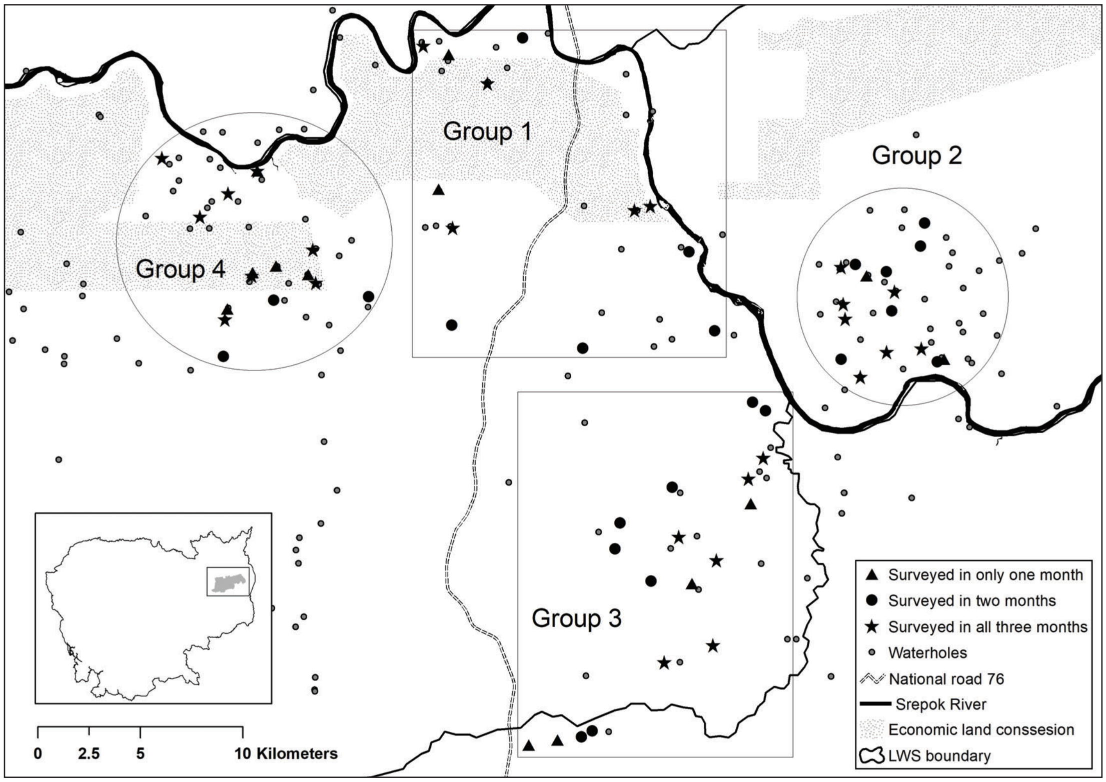

Fig. 1 Waterhole groups selected for giant ibis surveys in Lomphat Wildlife Sanctuary during the 2019 dry season (January–March). The inset shows the location of the wildlife sanctuary in Cambodia.

forest fires which create an open understory and reduce canopy cover (McShea *et al*., 2011; Ratnam *et al*., 2016).

Lomphat Wildlife Sanctuary supports a suite of globally threatened species including mammals such as banteng *Bos javanicus*, gaur *B. gaurus*, Asian elephant *Elephas maximus*, Eld's deer *Rucervus eldii*, sambar *Rusa unicolor*, and large-bodied birds such as red-headed vulture *Sarcogyps calvus*, giant ibis, white-shouldered ibis *Pseudibis davisoni*, sarus crane *Antigone antigone*, lesser adjutant *Leptoptilos javanicus* and Asian woolly-neck *Ciconia episcopus* (BirdLife International Cambodia Programme, unpublished data; Tordoff *et al*., 2005; Goes, 2009; Sum *et al*., 2011; Gray *et al*., 2012; Wright *et al*., 2012b; Clements *et al*., 2013; Wright *et al*., 2013b).

Waterhole surveys

The giant ibis is a large-bodied dry forest specialist which forages extensively at waterholes, abandoned paddy fields, and occasionally at rivers during the dry season (Keo, 2008; Wright *et al*., 2012a; Pin *et al*., 2018). As such, we decided to conduct our surveys for giant ibis at waterholes.

All of our team members were trained in data collection prior to the waterhole survey, including the use of GPS devices and compasses (to record bearings to giant ibises seen and heard), and in filling out the datasheets. We also played audio recordings of calls of giant ibis and other bird species to ensure team members could accurately distinguish giant ibis calls. Recorded distances between observers and calling giant ibises were based on the presumption and experience of each listener, rather than formal measurement.

Our study was conducted over three months from January to March 2019. Counts were undertaken between the 21st and 26th days of each month. We employed the survey method developed by Ty *et al*. (2016) to ensure our data set would be comparable. This method combines visual and auditory detections at waterholes. As giant ibis generally produces loud, long, and well-patterned calls, we were able to record auditory detections. Auditory detections were records of any giant ibis calls (beyond visual detections) made during survey hours, including calls made at roost sites while preparing to fly to foraging sites and call produced while traveling.

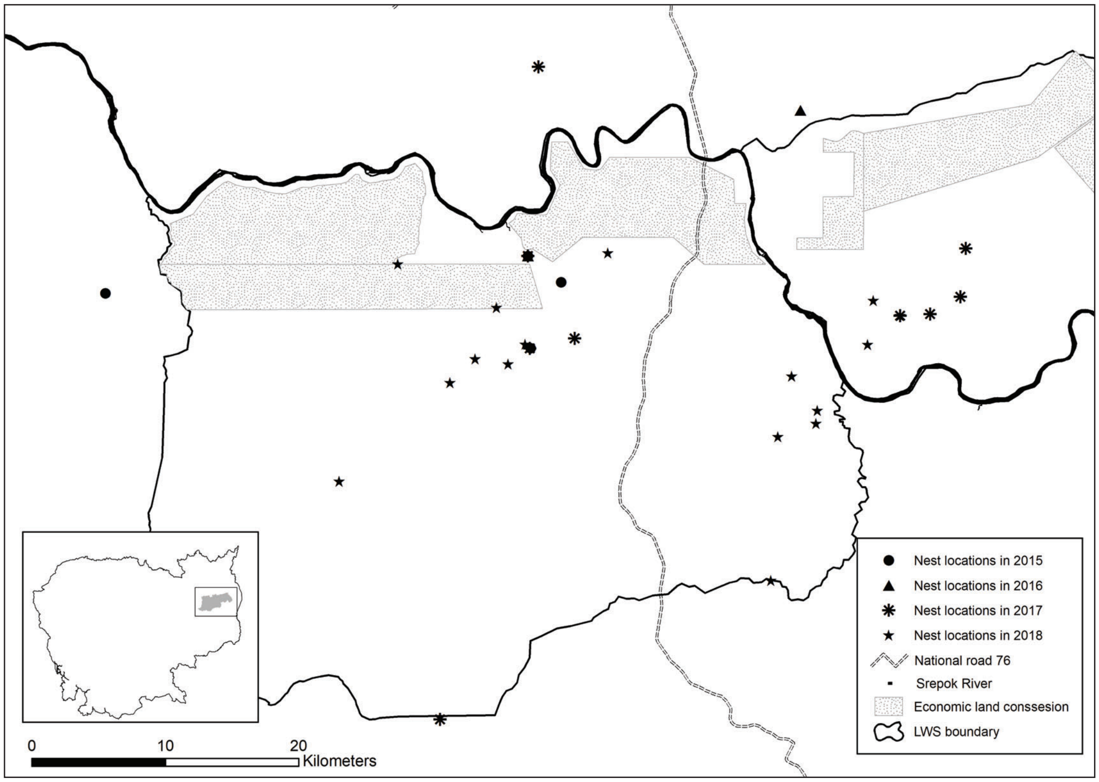

Fig. 2 Locations of giant ibis nests monitored in Lomphat Wildlife Sanctuary during the 2015-2018 breeding seasons.

To maximize detections of giant ibis, we focused on surveying waterholes that had been used by the species in previous years and recent months. These were identified using information and incidental encounters generated by field staff and local community members and accounted for ≈25% of all known waterholes in LWS (49 of ≈200). Our survey team comprised 14 people (six community members and eight BirdLife International staff). Due to personnel limitations, our study waterholes were divided into four groups which were surveyed on different days by dedicated surveyors (Fig 1). To maximise the number of waterholes surveyed simultaneously, one or two team members were assigned to survey a given waterhole at a time. We surveyed 41 waterholes in January, 49 waterholes in February and 48 waterholes in March. As the distance between each group of waterholes was greater than 4 km (Fig. 1), we assumed that giant ibis detections in different waterhole groups were independent of one another. The average distance between nearest-neighbour waterholes was 1,510 m (range 151–6,483 m). Each waterhole was surveyed once per day by surveyors who waited in concealed positions to avoid disturbing the birds. The survey was conducted between 05:00 and 08:00 hrs each day and the distance and bearing to each giant ibis detected was recorded.

Nest monitoring

Monitoring and protection of bird nests from poaching and predation is an important method for improving the reproduction success of birds, especially globally threatened species (Clements *et al*., 2009; Clements *et al*., 2013; Wright *et al*., 2013a). Monitoring of giant ibis nests in LWS began in 2015 and continued as of early 2020.

Nest searches were undertaken to determine the reproductive success of giant ibises in LWS and produce a distribution map of their nests to assist conservation efforts at the site. These were conducted during the breeding seasons of 2015–2018. As giant ibises generally start to mate in May and June and begin nest building in late June until early August in the wet season (Keo, 2008), our nest searches were undertaken in two phases. During the first phase (May & June), we checked areas where giant ibis nests had been registered during the previous breeding season to document whether these were still used by the species. In our experience, this approach is very effective for finding giant ibis nests when time and personnel are limited. During the second phase (July to mid-August), we searched for new nests in other areas and these searches were guided by the known ecology of the species and information provided by local people and protected area staff. As the ability and experience of team members improved over time, we retained the most experienced individuals and assigned small groups (two people/group) to search different locations so as to maximize the chance of nest detection. Nest searches were conducted for at least seven consecutive days per field trip to maximise the area covered.

We searched the same area each year to permit comparisons of numbers of nests found between the breeding seasons of 2015–2018 (Fig. 2). Our searches focused on the preferred foraging habitats and nesting sites reported for giant ibis, including rivers, streams and waterholes (Fig. 3) (Keo, 2008; Wright *et al*., 2012a). These included listening posts at waterholes and searches along rivers and streams and within a 2 km radius of each waterhole to detect giant ibises by sight and calls. Upon detection, the bearing and distance of each giant ibis from the observer was first recorded. Team members then navigated to the giant ibis and searched for its nest. Once located, each nest was visited for half an hour once every fortnight until it had fledged or failed. The arrival and departure times of surveyors were recorded, as were the activities of birds and signs of predators in the vicinity of a nest. Nest protection efforts were not undertaken due to resource limitations.

Data analysis

Waterhole surveys: We screened our data to remove potential double counts of the same individual in vocal and sight detections, as follows: 1) when sighted birds were observed flying from the same direction as calling birds previously detected, 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 (Ty *et al*., 2016). 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 data screening, we estimated monthly population counts from sightings and call detections at each waterhole and derived overall monthly population counts by summing these. Our population figure represents a minimum population estimate and differs from the number of detections which represents the number of occasions we recorded giant ibis (from sightings or call detections) on a given day. Thus, if two or more giant ibises were sighted or heard at the same location, these were considered one detection. As such, the number of detections does not represent the number of giant ibis.

Fig. 3 A pair of giant ibises foraging at a waterhole during the study in Lomphat Wildlife Sanctuary (© Thol S.).

Fig. 4 A pair of giant ibises nesting in a dipterocarp tree (*Shorea obtusa*) during the 2018 breeding season (© Sar S.).

Nest monitoring: Each nest was observed for 30 minutes once every two weeks to record its progress, including incubation and feeding activity of chicks, until fledging or failure (Fig. 4). Nests whose chicks hatched and fledged were regarded as successful. Failed nests were those abandoned by the giant ibis due to predation by small carnivores (i.e. common palm civet *Paradoxurus hermaph-*

roditus), human disturbance (i.e. poaching, felling of nest tree) and/or natural causes.

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 ibises recorded (including adults and young seen at nests). We estimated the total number of giant ibis 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 with the total number of successful nests.

Results

Waterhole surveys

Over the course of the study, 37 detections of giant ibises (eight sightings and 29 call detections) were recorded in January, 40 (seven sightings and 33 call detections) in February, and 18 (eight sightings and ten call detections) in March (Table 1). Total numbers of sight-based detections were similar between the three study months, whereas the highest number of call detections occurred in February. The overall number of giant ibises encountered was 62 in January, 60 in February and 29 in March.

Following data screening to remove possible double counts, 28 detections were removed from our data for January, 24 from February and ten from March. The estimated number of individual giant ibises was 34 in January, 36 in February and 19 in March (Table 1). The greatest number of giant ibises were recorded in waterhole group 3, with 31 individuals.

Nest monitoring

A total of 31 giant ibis nests were discovered and monitored over the course of our study (Table 2). The number of nests we found increased significantly in 2017 and 2018 (nine nests and 16 nests, respectively) despite similar search effort in the same areas in previous years.

Nest success rates were high at 90% (28 of 31 nests). The average number of fledged chicks per nest was 1.53 (range 1.25–2.00) and 10.25 chicks fledged each year on

Table 1 Numbers of sightings and call-based detections of giant ibis across four groups of waterholes in Lomphat Wildlife Sanctuary in January–March 2019. Figures in parenthesis are numbers of birds recorded before removal of double counts.

Water hole group	January 2019				Febuary 2019				March 2019			
	No. of detections			Estim. birds	No. of detections			Estim. birds	No. of detections			Estim. birds
	Sighting	Calls	Total		Sighting	Calls	Total		Sighting	Calls	Total	
1	1	0	1 (3)	**3**	0	3	3 (4)	**2**	3	1	4 (10)	**4**
2	3	7	10 (11)	**8**	2	13	15 (20)	**11**	3	4	7 (8)	**6**
3	2	9	11 (17)	**13**	3	12	15 (22)	**15**	1	2	3 (3)	**3**
4	2	13	15 (31)	**10**	2	5	7 (14)	**8**	1	3	4 (8)	**6**
Total	**8**	**29**	**37 (62)**	**34**	**7**	**33**	**40 (60)**	**36**	**8**	**10**	**18 (29)**	**19**

Table 2 Results of nest monitoring during the 2015–2018 breeding seasons for giant ibis in Lomphat Wildlife Sanctuary.

Breeding season	Nests found	Successful nests	Mature birds per nest	No. of chicks fledged	Total giant ibis count
2015	4	4	2	5	13
2016	2	2	2	4	8
2017	9	9	2	13	31
2018	16	13	2	19	51

average in 2015–2018. At least 13, 8, 31 and 51 giant ibises (including adults and fledged chicks) were recorded at nests in 2015, 2016, 2017 and 2018 respectively, giving an average of 25.75 giant ibises per breeding season. Our figures indicate at least 32 adult giant ibises (two adults/ nest x 16 nests) were present in LWS in 2018 (Table 2).

Discussion

Our study is the first attempt to estimate populations of the giant ibis in Lomphat Wildlife Sanctuary. In combining sightings and call detections, our survey method is a simple, inexpensive and useful approach for determining populations of the species at the site.

Our waterhole surveys suggest at least 36 mature giant ibises (the highest monthly count during the study) occur in Lomphat Wildlife Sanctuary. This figure is similar to the previous population estimate of 10–15 pairs derived from opportunistic sightings (BirdLife International, 2018). Due to resource limitations, we selected waterholes based on prior information to maximize our detections of giant ibis. While this could have biased our results, it is unlikely to have led to overestimation because potential double counts were carefully excluded from the survey data. However, as our study only sampled ≈25% of the waterholes known in LWS (49 of ≈200), our population estimate would likely have been much higher (approximately 30–40 pairs across LWS) if all of the known waterholes were included. For example, between 2015 and 2019, over 230 incidental sightings of giant ibis were recorded in various locations in LWS, including surveyed and un-surveyed waterholes, rice fields and grasslands (BirdLife International Cambodia Programme, unpublished data).

Obtaining sight-based detections of the giant ibis is challenging because it naturally occurs in low numbers and is very sensitive to the presence of humans. However, as the species generally produces a loud, long and well-patterned call which can be heard up to 2 km away (Ty, 2013), employing call detections in surveys generates more data per unit effort and improves population estimates. To ensure that data are reliable, training is important to ensure that field staff can accurately record the distance and bearing of calling birds. In our study, estimation of the distances to calling giant ibises was subjective, being based on the personal experience of each surveyor. Notwithstanding this, increasing the number of waterholes sampled and maximizing the number of experienced surveyors would help to minimize potential double counts and thereby improve the population estimates. As such, an expanded study using the same methods should be considered for medium and long-term monitoring of populations of giant ibis in LWS.

The aim of our study was to generate reliable information on the number of giant ibises (including fledged chicks and parents) in LWS. Four and two nests were found in 2015 and 2016 respectively, whereas nine and 16 nests were found 2017 and 2018 respectively. This increase was likely because our field team became more experienced. We suggest that nest monitoring can contribute to meaningful estimation of giant ibis populations. Notably, numbers of giant ibises estimated from waterhole surveys and nest monitoring were comparable (approximately 32 and 36 mature individuals, respectively), likely because both surveys mostly covered the same areas (Fig. 2). Our nest monitoring data also suggest that the reproductive success of giant ibis increased markedly during the study (Table 2). As such, LWS may support one of the few viable populations of the species in Cambodia. We also suggest that nest monitoring is appropriate for assessing populations of other large waterbird species, including sympatric white-shouldered ibis, lesser adjutant and Asian woollyneck.

Our study waterholes were distributed across different management zones in LWS: community/ sustainable use zones (including economic land concessions), conservation zones and core zones. During our surveys, we recorded several incidences of resource-competition between local people and wildlife at waterholes. For instance, domestic animals such as dogs and cattle were observed with people who were collecting water and catching fish, including eels, which are prey for giant ibis (Keo, 2008; Wright *et al*., 2012a). According to the protected areas law of 2008, local communities are allowed to access and use areas such as community and sustainable use zones in LWS. However, unchecked competition between humans and wildlife for resources could increase levels of disturbance to foraging giant ibis. Overall, LWS supports a wide range of globally threatened species including mammals and birds (Birdlife International Cambodia Programme, unpublished data; Tordoff *et al*., 2005; Goes, 2009; Sum *et al*., 2011; Gray *et al*., 2012; Wright *et al*., 2012b; Clements *et al*., 2013; Wright *et al*., 2013b). Despite its designation as a wildlife sanctuary, the biodiversity of LWS faces ongoing threats from agricultural development, illegal land encroachment (Hor *et al*., 2014; Chanrith *et al*., 2016) and wildlife poaching. Immediate action by the relevant government authorities, supported by partner NGOs, is needed to prevent the destruction of the protected area and its biodiversity.

Acknowledgements

Our research was undertaken with the permission of Ratanakiri Provincial Department of Environment and the Cambodian Ministry of Environment under the framework of an MoU between the latter and the BirdLife International Cambodia Programme. Our studies were financially supported by the Fondation Segré and the John D. and Catherine T. MacArthur Foundation. We are grateful to our field staff and the community protected area members who assisted data collection.

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