FACTORS INFLUENCING DISTRIBUTION AND HABITAT UTILISATION OF *LEPTOPTILOS JAVANICUS* IN AND AROUND BARANDABHAR CORRIDOR FOREST, CHITWAN, NEPAL

Yureshiya Wagle, Bishnu P. Bhattarai*, Jagan N. Adhikari

Tribhuvan University, Nepal
**e-mail: bishnu.bhattarai@cdz.tu.edu.np*

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The globally Vulnerable wetland-dependent bird species *Leptoptilos javanicus* was once thought to avoid farmlands, but recent studies in lowland Nepal showed that the species uses farmlands extensively for foraging and breeding. Identifying whether this preference of *L. javanicus* to these habitats is common throughout Nepal is essential to understanding the conservation needs of the species. This study aimed to explore the seasonal distribution and habitat utilisation by *L. javanicus* in and around the Barandabhar Corridor Forest by using 220 randomly selected squares within a 500 × 500 m^2 grid. We visited centroids of each selected square to collect data on *L. javanicus* distribution, habitat types, and probable causes of disturbance in two seasons (rainy: August – September 2019 and winter: December – January 2019–2020). A total of 64 observations of *L. javanicus* (n = 29 in winter, n = 35 in rainy) were made. *Leptoptilos javanicus* were seen in more squares outside the Protected Area (65.2%) during the rainy season. Variables that negatively influenced *L. javanicus* sightings were distance to the road (few individuals seen close to the road), distance to the village (few individuals seen close to settlement), and areas under human disturbance (only few individuals seen in areas with more livestock and people) during both seasons. The farmlands around the Barandabhar Corridor Forest hosted many individuals of *L. javanicus* and are a new location in lowland Nepal with a resident population of this species. Past assumptions regarding *L. javanicus* conservation require revision, and including a focus on farmlands is an important requirement in Nepal's conservation planning.

Key words: bird conservation, Chitwan National Park, Lesser adjutant, paddy fields, point count, wetland birds

Introduction

The Lesser adjutant, *Leptoptilos javanicus* (Horsfield, 1821), is a large wading bird of the Ciconiidae family with an estimated global population of 5000–10000 individuals (BirdLife International, 2017). Farmlands, grasslands, marshes, water holes, lagoons, flood plains, dams, flooded pastures, rivers, streams, lakes, and ponds are habitats used by this species (del Hoyo et al., 2020). They also use undisturbed moist forests with tall trees for breeding and roosting (Hancock et al., 2010).

Leptoptilos javanicus is assumed to be declining globally and nationally in Nepal with suspected causes being habitat loss and degradation, illegal hunting, human activities such as timber, firewood, grass collection, livestock grazing (Inskipp et al., 2016; BirdLife International, 2017). The stork is categorised as «Vulnerable» by IUCN (BirdLife International, 2017) and in the Nepal's National Red Data Book (Inskipp et al., 2016). However, the National Parks and Wildlife Conservation Act of 1973 in Nepal (NPWC Act, 1973) has yet to list this species as a nationally protected bird species (DNPWC, 2020).

Several recent studies have focused on *Leptoptilos javanicus* and other Ciconidae species, primarily in the eastern and central parts of Nepal, both in protected forested areas and in agricultural landscapes (Bhattarai, 2012; Adhikari et al., 2019; Koju et al., 2019; Kittur & Sundar, 2020). There are, however, many other areas thought to be within the distribution range of the species in Nepal that remain unexplored. According to recent studies in central Nepal, *L. javanicus* populations were healthy on farmlands with fields that have multiple crops throughout the year, interspersed with natural wetlands and human settlements (Koju et al., 2019; Sundar et al., 2019; Khatiwada et al., 2021).

Our study has focused on the areas inside and farmlands adjacent to Barandabhar Corridor Forest, which is one of the Important Bird and Biodiversity Areas (NP02-IBAs) in Nepal (Baral & Inskipp, 2005). There is currently

no detailed research on *Leptoptilos javanicus* from this area. This corridor forest has a mix of wooded areas and agricultural land providing a good place to understand whether *L. javanicus* uses forested areas or agricultural areas more when both these land uses are present. There are no empirical estimates of *L. javanicus* distribution or habitat use from within protected forest areas to contrast against information from outside Protected Areas to understand which of these different areas are used more by *L. javanicus*. Such a comparison is necessary before assumptions regarding *L. javanicus* reliance on protected forested regions can be thought to be accurate. This research aimed to (1) determine the seasonal distribution of *L. javanicus* in the study area, (2) identify the seasonal use of one area by *L. javanicus*, and (3) examine the relation of *L. javanicus* with various environmental variables.

Material and Methods

Study site

Barandabhar Corridor Forest (BCF) is the only remaining wildlife corridor of central Nepal linking the lowland Chitwan National Park (CNP) in the south and the highland Mahabharat Range foothills up to Annapurna Conservation Area (ACA) in the north (Adhikari et al., 2018). BCF is a 29-km long forest patch of 87.9 km^2. It is rich in biodiversity and is a part of the Terai Arc Landscape (TAL; Thapa, 2011) and also serves as a highly potential alternative habitat for wildlife to move up to Mahabharat foothills (Fig. 1), mainly during the rainy season. It is situated in the tropical inner Terai lowlands of the south-central part of Nepal. BCF has a subtropical climate with an average maximum and minimum temperature of 30.8°C and 17.8°C respectively during 1989–2018 (DHM, 2019; Adhikari et al., 2020). December to February is regarded as winter and the temperature reduces to a minimum of 6°C, while March to July is regarded as summer with temperatures rising up to 43°C. July to September is considered as the rainy season and the average annual rainfall was 1980 mm (average of 1989–2018 data: DHM, 2019; Adhikari et al., 2020).

Three heavily populated and farmer-oriented municipalities surround the vicinity of BCF named Ratnanagar Municipality in the east, Kalika Municipality in the north-east and Bharatpur Metropolitan City in the west (Fig. 1). The major crops of the study area were rice (*Oryza sativa* L.) in the rainy season, maize (*Zea mays* L.), wheat (*Triticum aestivum* L.), pea (*Pisum sativum* L.), and vegetables in winter and summer. Farmers planted rice in both seasons on the irrigated field of some parts of our study area. Trees were scattered in the fields, and supported roosting and nesting birds.

Data collection

The BCF and farmlands found within 1 km of the forest boundary were digitised using Google Earth Pro (Lisle, 2006). A grid of 500 m × 500 m squares was overlaid over this area in ArcGIS 10.7 (Esri, California, USA). We included farmlands located within 1 km from the forest line as there were very few unspoiled pieces of land beyond that line that were not urbanised. The cropping patterns and soil textures of the farmlands were not uniform and the farmlands in the north-eastern parts of the study area were drier than farmlands on other locations. For the intensive research, the study area was divided into 1148 squares, and 220 (21%) of these were randomly selected for data collection. Among the focal squares, 72 were in farmlands and 148 were inside the forest. Habitats of the study area were classified as wetlands, grasslands, forests, and farmlands (Table 1). The co-ordinates of centroids of the focal squares selected for sampling were extracted and uploaded in GPS (Garmin e-Trex10) so as to easily reach these locations for observations.

Table 1. Description of different habitat types in the Barandabhar Corridor Forest, Nepal

Habitat types	Description
Wetlands	Rivers, lakes, irrigation canals, ponds, marshy lands, puddles
Grasslands	Grasslands, grasslands along with some scattered shrubs
Forests	All types of forest, that included tree species such as *Shorea robusta* C.F.Gaertn., *Terminalia elliptica* Willd., *Adina cordifolia* (Roxb.) Brandis, *Bombax ceiba* L., *Senegalia catechu* (L.f.) P.J.H.Hurter & Mabb., *Dalbergia sissoo* Roxb. ex DC., *Mallotus nudiflorus* (L.) Kulju & Welzen, *Litsea doshia* (D.Don) Kosterm., *Litsea monopetala* (Roxb.) Pers.
Farmlands	All crop lands, associated with human settlements

Data on *Leptoptilos javanicus* were collected twice: first during August – September 2019 representing the rainy season, and second during December – January (2019–2020) representing the winter season. We visited the square at the same time (06:00 to 12:00) in both seasons to reduce potential bias due to the time of day. Within a 100-m radius of the centroid of each grid, we searched for *L. javanicus* and also recorded environmental factors. The radius of the circle is adequate for the data collection of such a large bird (Thompson & Schwalbach, 1995). In open areas *L. javanicus* was easily visible, but inside the forest it was more difficult to observe the species within the circle. We therefore restricted analyses to observations seen within 100 m. Therefore, data from both the forest areas and agricultural areas were comparable. The number of *L. javanicus* individuals was recorded at each point by spending 20 min., of which the first 5 min. were used for acclimatisation and the other 15 min. were used for data collection. If wetlands were present at the sampling location, one point of the shore area was selected for data collection. Number of *Leptoptilos javanicus* seen, disturbance factors (number of people, number of livestock, distance to road and distance to village) and habitat type were recorded. We categorised the habitat types depending upon the dominant land use around count locations. The nearest distance to settlements, roads, water resources, was measured as Euclidian distance in metres using the GPS points from ArcGIS 10.7.

Data analysis

The collected data were entered into MS-Excel and further statistical analyses were performed in R software version 4.0.0 (R Core Team, 2020). The distribution of the *Leptoptilos javanicus* was prepared using ArcGIS 10.7. Habitat utilisation of *L. javanicus* was identified coarsely on the basis of frequency of occurrence and abundance of its individuals. The habitats were categorised on the basis of land use and land cover, environmental variables such as distance from the water source, distance from the village, distance from the road, number of livestock and number of people. We used the zero-inflated function since most of the visited grids did not have *L. javanicus* and distribution of the dependent variable was therefore non-normal (Shapiro-Wilk normality test $W = 0.402$, $p = 0.001$). We used the «pscl» package (Jackman, 2020); the zero-inflated generalised linear model (GLM) function was used to determine the coefficients, standard errors, and p-values at a 95% confidence level for all relationships between the presence of *L. javanicus* and variables.

Results

Among 220 surveyed squares in the grid, *Leptoptilos javanicus* was present in 41 (18.6%). *Leptoptilos javanicus* was recorded from 23 squares in the rainy season (10.5%) and 18 squares in the winter season (8.2%). Only one square had *L. javanicus* in both seasons (Fig. 1).

Distribution of Leptoptilos javanicus

No records were found from the squares located in the farmlands of the drier north-west region of BCF. In the rainy season, of the 23 squares with *Leptoptilos javanicus*, 15 sightings (65.3%) were in farmlands and eight (34.7%) ones in other habitats (wetland: 17.4%, grassland: 13.0%, forest: 4.4%) (Fig. 1). In the winter season, of the 18 squares with *L. javanicus* sightings, 14 (77.8%) were from various habitats (wetland: 11.1%, grassland: 5.5%, forest: 61.1%) of BCF, and four (22.2%) from farmlands (Fig. 2).

Factors affecting Leptoptilos javanicus sightings

During the rainy season, distance to water was the only variable, with which *Leptoptilos javanicus* presence showed a statistically significant relationship (Table 2). A higher number of *L. javanicus* individuals was seen closer to water.

During the winter, the presence of *Leptoptilos javanicus* was significantly influenced by the distance to water (negatively) and the distance to a road (positively) (Table 3). The use of various habitats by *L. javanicus* is illustrated in Fig. 3.

Discussion

Distribution

In our study area, *Leptoptilos javanicus* was relatively rare with the highest frequency of occurrence outside forests in farmlands. Research on *Ciconia episcopus* (Boddaert, 1783) conducted in Myanmar also found that this species was seen more outside than inside Protected Areas (Win et al., 2020). *Ciconia episcopus* is another species that was assumed to require forested areas, but like with *L. javanicus*, research in south Asia and Myanmar is showing the assumptions to be wrong. Our study provides additional primary information that suggests that *L. javanicus* is able to use agricultural areas much more than forested areas.

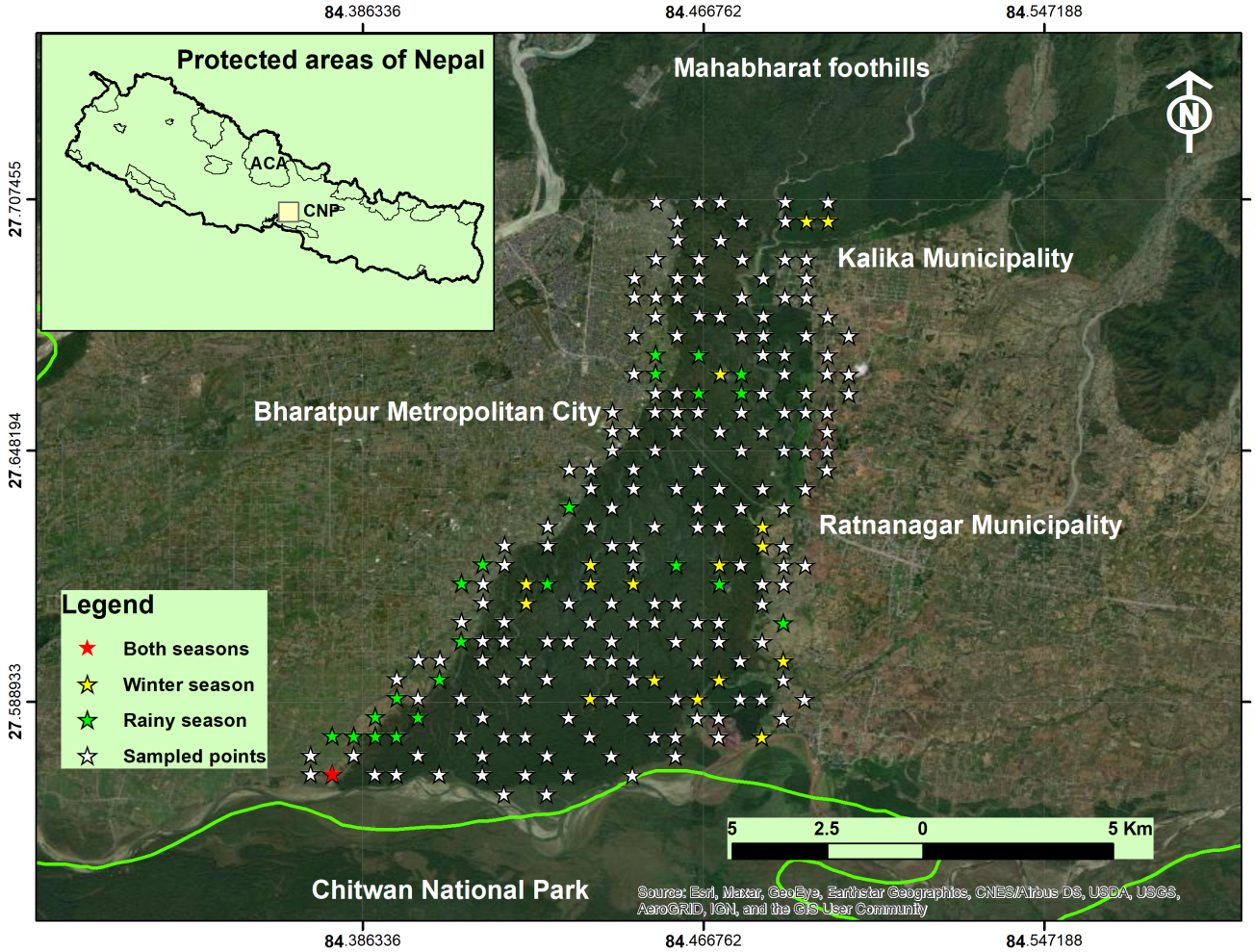

Fig. 1. Distribution of *Leptoptilos javanicus* in study area in lowland Nepal. Designations: CNP – Chitwan National Park, ACA – Annapurna Conservation Area.

Table 2. Zero-inflated GLM model showing the effects of various environmental factors on presence of *Leptoptilos javanicus* in rainy season in the Barandabhar Corridor Forest, Nepal

Model	Estimate	Standard error	z value	p-value
Intercept	0.23	0.357	0.646	0.518
Distance to water sources	-0.019	0.005	-3.941	**< 0.0001**
Distance to village	0.01	0.0003	0.912	0.362
Distance to road	0.02	0.0003	1.75	0.061
Number of people present	-0.097	0.293	-1.514	0.081
Number of livestock present	-0.026	0.313	-0.804	0.386

Note: Value marked in bold is statistically significant at $p < 0.05$.

Table 3. Zero-inflated distribution GLM model showing the effects of various environmental factors on abundance of *Leptoptilos javanicus* in winter season

Model	Estimate	Standard error	z value	p-value
Intercept	0.131	0.457	0.452	0.623
Distance to water sources	-0.029	0.024	-1.578	**0.043**
Distance to village	0.021	0.003	0.712	0.461
Distance to road	0.021	0.001	1.321	**0.05**
Number of people present	-0.065	0.324	-1.114	0.09
Number of livestock present	-0.035	0.213	-1.804	0.06

Note: Values marked in bold are statistically significant at $p < 0.05$.

More individuals of *Leptoptilos javanicus* were seen during the rainy season than in winter. During the rainy season, *L. javanicus* was seen more regularly on farmlands in the CNP buffer zone, where the species had previously been observed (Poudyal, 2010; Bhattarai et al., 2021). However, during the winter season *L. javanicus* was found to be largely using forest areas while also using other habitats (Fig. 2). This variation in habitat use by season is possible due to different levels of food availability in farmlands and other habitats, but also may be linked to the birds' habit of nesting late in the monsoon and in early winter (Sundar et al., 2019). A careful study on breeding habitat requirements of *L. javanicus* in our study area can shed more light on this aspect.

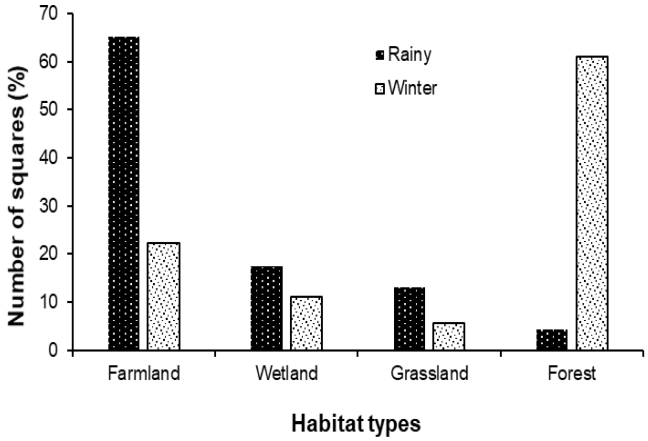

Fig. 2. Sightings of *Leptoptilos javanicus* in number of squares in various habitat types in two seasons in the Barandabhar Corridor Forest, Nepal.

Fig. 3. *Leptoptilos javanicus* reported in various areas in the Barandabhar Corridor Forest, Nepal. Designations: a) foraging in grassland; b) foraging in farmland (paddy field); c) using trees inside the forest; d) foraging in wetlands.

The geographical distribution pattern of *Leptoptilos javanicus* revealed more birds using the southern portion of BCF rather than the northern portion. We cannot confidently explain why this difference exists, and studies to measure food availability are needed to explain our findings.

Habitat utilisation

The observed parameters varied significantly depending on location and season, suggesting that *Leptoptilos javanicus* may modify its behaviour in response to aspects such as water availability and roads. Change of foraging inten-

sity in response to changing weather and crops have previously been observed in *L. javanicus* (Sundar et al., 2019). Our study underscores seasonal variation of behaviour of *L. javanicus* in another part of lowland Nepal, though we are unable to point out the exact reasons why these changes took place. Our study shows that *L. javanicus* was resident in the study area. In the two seasons, there were considerable differences in the areas used by *L. javanicus*. It is possible that the extent of available habitats influenced these changes. Flooded rice fields were mostly used by *L. javanicus* during the rainy season. Similar results were documented in a study conducted at CNP where Poudyal (2010) identified paddy fields as important feeding areas for this species. The choice of paddy fields by *L. javanicus* during the rainy/pre-breeding season may be due to availability of food on the flooded plains. The farmlands chosen for foraging were close to roads, villages, and water sources. Disturbance factors such as distance to roads appear to negatively impact the presence of *L. javanicus* in the study area in the rainy season. Similar findings were made previously by Bhattarai et al. (2021) in Chitwan National Park of Nepal. Karki & Thapa (2013) also reported a negative relationship of *L. javanicus* in eastern Nepal with human settlements and roads. Bhattarai (2012) reported that *L. javanicus* used paddy fields located nearer to the forest or Protected Areas with an abundant supply of water resources.

During winter, *Leptoptilos javanicus* used fewer farmlands than forests. Our finding was similar to data of Gunarathne et al. (2014) in Kumana National Park (Sri Lanka) and found *L. javanicus* near water bodies associated with forests having large trees. In both seasons, the presence of *L. javanicus* was not significantly affected by livestock and humans. This suggests that these Ciconidae birds are used to farmers and livestock, who do not harm the birds in Nepal. More careful studies are needed to fully understand the relationships between *L. javanicus* and human activities in Nepal.

Conclusions

The research focuses on the factors affecting occurrence, distribution and habitat utilisation of *Leptoptilos javanicus* in and around the Barandabhar Corridor Forest and makes an addition to the sparse research on *L. javanicus* from Central Nepal. There was a large number of sightings of *L. javanicus* closer to water sources. Human disturbance factors such as distance to the road, distance to the village and presence of people and livestock negatively influenced the sightings of *L. javanicus* during both seasons. The study confirms existing evidence that this large wetland-dependent bird uses both protected forests and unprotected farmlands. Hence, integrating agricultural landscapes in ongoing attempts to preserve forested Protected Areas will aid conservation of large wetland-dependent birds in central Nepal.

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ФАКТОРЫ, ВЛИЯЮЩИЕ НА РАСПРОСТРАНЕНИЕ И ИСПОЛЬЗОВАНИЕ МЕСТООБИТАНИЙ LEPTOPTILOS JAVANICUS НА ТЕРРИТОРИИ И ЗА ПРЕДЕЛАМИ ЛЕСНОГО КОРИДОРА БАРАНДАБХАР (ЧИТВАН, НЕПАЛ)

Ю. Вагле, Б. П. Бхаттарай*, Дж. Н. Адхикари

Университет Трибхувана, Непал
**e-mail: bishnu.bhattarai@cdz.tu.edu.np*

Ранее считалось, что глобально уязвимый (VU) вид *Leptoptilos javanicus*, связанный с водно-болотными угодьями, избегает сельскохозяйственных земель. Однако недавние исследования в низменной части Непала показали, что этот вид широко использует сельскохозяйственные угодья для добычи питания и размножения. Определение того, распространена ли эта приуроченность *L. javanicus* к данной среде обитания на всей территории Непала, имеет большое значение для понимания необходимости сохранения этого вида. Это исследование было направлено на изучение сезонного распространения и использования среды обитания *L. javanicus* в лесном коридоре Барандабхар и вокруг него с использованием 220 случайно выбранных квадратов сетки с ячейками размером 500 × 500 м^2. Мы посетили центроиды (центральные части) каждого выбранного квадрата сетки, чтобы собрать данные о распространении *L. javanicus*, типах местообитаний и возможных причинах беспокойства в течение двух сезонов (сезон дождей: август – сентябрь 2019 г. и зима: декабрь – январь 2019–2020 гг.). Всего проведено 64 наблюдения *L. javanicus* (n = 29 зимой, n = 35 в сезон дождей). Особи *L. javanicus* были отмечены на большем количестве площадей за пределами особо охраняемой природной территории (65.2%) в сезон дождей. Переменными, которые негативно повлияли на обнаружение *L. javanicus*, оказались расстояние до дороги (т.е. редкие наблюдения рядом с дорогой); расстояние до населенного пункта (т.е. редкие наблюдения вблизи поселения); районы, измененные человеком (лишь несколько особей было зарегистрировано в районах с большим количеством домашнего скота и людей) в течение обоих сезонов. Сельскохозяйственные угодья вокруг лесного коридора Барандабхар стали местом обитания большого числа особей *L. javanicus* и являются новым местообитанием в низменной части Непала, где обитает постоянная популяция этого вида. Предыдущие предположения относительно путей сохранения *L. javanicus* требуют пересмотра, и включение акцента на сельскохозяйственные угодья является важным требованием при планировании сохранения *L. javanicus*.

Ключевые слова: водно-болотные виды, национальный парк Читван, рисовые поля, сохранение птиц, точечный учет, яванский марабу