Ruddy Shelduck *Tadorna ferruginea* home range and habitat use during the non-breeding season in Assam, India

TSEWANG NAMGAIL[1,2]*, JOHN Y. TAKEKAWA[1],
BALACHANDRAN SIVANANINTHAPERUMAL[3],
GOPALA AREENDRAN[4], PONNUSAMY SATHIYASELVAM[3],
TAEJ MUNDKUR[5], TRACY MCCRACKEN[6] & SCOTT NEWMAN[6]

[1]U.S. Geological Survey, Western Ecological Research Center, San Francisco Bay Estuary Field Station, 505 Azuar Drive, Vallejo, California 94592, USA.
[2]Moss Landing Marine Laboratories, 8272 Moss Landing Road, Moss Landing, California 95039, USA.
[3]Bombay Natural History Society, Mumbai 400 001, India.
[4]World Wildlife Fund-India, 172 B, Lodhi Estate, New Delhi 110003, India.
[5]Wetlands International, NL-6700 AL Wageningen, Netherlands.
[6]EMPRES Wildlife, Health and Ecology Unit, Animal Production and Health Division, Food and Agriculture Organisation of the United Nations, Rome, 00153, Italy.
*Correspondence author. E-mail: tnamgail@usgs.gov

Abstract

India is an important non-breeding ground for migratory waterfowl in the Central Asian Flyway. Millions of birds visit wetlands across the country, yet information on their distribution, abundance, and use of resources is rudimentary at best. Limited information suggests that populations of several species of migratory ducks are declining due to encroachment of wetland habitats largely by agriculture and industry. The development of conservation strategies is stymied by a lack of ecological information on these species. We conducted a preliminary assessment of the home range and habitat use of Ruddy Shelduck *Tadorna ferruginea* in the northeast Indian state of Assam. Seven Ruddy Shelducks were fitted with solar-powered Global Positioning System (GPS) satellite transmitters, and were tracked on a daily basis during the winter of 2009–2010. Locations from all seven were used to describe habitat use, while locations from four were used to quantify their home range, as the other three had too few locations (< 30) for home range estimation. A Brownian Bridge Movement Model (BBMM), used to estimate home ranges, found that the Ruddy Shelduck had an average core use area (*i.e.* the contour defining 50% of positions) of 40 km^2 (range = 22–87 km^2) and an average home range (95% contour) of 610 km^2 (range = 222–1,550 km^2). Resource Selection Functions (RSF), used to

describe habitat use, showed that the birds frequented riverine wetlands more than expected, occurred on grasslands and shrublands in proportion to their availability, and avoided woods and cropland habitats. The core use areas for three individuals (75%) were on the Brahmaputra River, indicating their preference for riverine habitats. Management and protection of riverine habitats and nearby grasslands may benefit conservation efforts for the Ruddy Shelduck and waterfowl species that share these habitats during the non-breeding season.

Key words: Brahminy Duck, Brownian Bridge, Central Asian Flyway, habitat, home range, India.

The Indian sub-continent is an important non-breeding (wintering) ground for many migratory waterfowl in the Central Asian Flyway (Alfred & Nandi 2000). Because of its latitudinal and climatic extent, the sub-continent provides a diversity of wetland habitats for migratory birds (Ali & Ripley 1978). These wetlands have been degraded due to rapid economic development, increasing human population and associated over-exploitation of resources (Islam & Rahmani 2004). Consequently, the populations of several duck species are declining in India, particularly in areas where they congregate in large numbers during the non-breeding season (Islam & Rahmani 2004; Wetlands International 2006). The Pink-headed Duck *Rhodonessa caryophyllacea* is already extinct in India, last reported in the 1960s, and several others are threatened with extinction (Kumar *et al.* 2005).

Information on the distribution, abundance and diversity of waterfowl in India is being generated through the annual monitoring programme under the Asian Waterbird Census (Li *et al.* 2009). But there has been little effort to understand their spatio-temporal resource utilisation, largely due to the difficulty associated with tracking these highly mobile birds. Such studies are, however, crucial for understanding their ecology, spread of avian diseases and for developing conservation strategies for their long-term survival. Capitalising on modern satellite telemetry techniques, we studied the home range and habitat use of the Ruddy Shelduck *Tadorna ferruginea*.

Ruddy Shelduck, also known as Brahminy Duck, is a culturally important species in the Indian sub-continent, especially in the Himalayan region (Ali 1996). It is considered sacred in Buddhism, and features in many Himalayan folklores and epic stories. The species is a symbol of fertility in Hinduism. It is known in Sanskrit as Chakravaka, a symbol of conjugal love and fidelity (Śarmā 1964). Because of these socio-cultural significances, it is tolerated in much of its breeding range, and nests are found close to houses. It receives socio-religious protection in some Buddhist parts of Asia, but such socio-cultural protection is diminishing due to cultural erosion.

Within India, Ruddy Shelduck breed in Ladakh (Pfister 2004), Arunachal Pradesh (Choudhury 2000) and Sikkim (Ganguli-Lachungpa 1990) and occur on lakes, rivers and other water bodies during the non-

breeding season (Ali & Ripley 1978). The largest non-breeding aggregation (about 6,000 birds) in India was recorded at the Chilika Lake in Orissa (Balachandran *et al.* 2005). Elsewhere the birds breed in Pakistan, Nepal and Bhutan, and it is a non-breeding species in Bangladesh and Sri Lanka (BirdLife International 2010). Thus, the Ruddy Shelduck is a widespread species; a total of 62,762 individuals were counted between 2002–2004 at 337 sites across south Asia (Li *et al.* 2009).

Globally, the species is widely distributed over Asia, Europe and Africa (BirdLife International 2010). The populations in Asia are predominantly migratory, moving latitudinally on a broad front, while those in the Western Palearctic are sedentary or dispersive (BirdLife International 2010). It occurs in many Central Asian countries, both during the breeding and non-breeding season (Kuchin *et al.* 2000; Kreuzberg-Mukhina & Lanovenko 2001). Given such a wide distribution, the Ruddy Shelduck has been categorised as a species of "least concern" on the IUCN Red List of Threatened animals (IUCN 2008). However, its population is declining, especially in the western Palearctic (Madge & Burn 1988; Delany *et al.* 2008; BirdLife International 2010). The species is included in the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA).

Ruddy Shelduck is of great epidemiological significance, and was involved in the large outbreaks of the highly pathogenic Avian Influenza H5N1 virus at Qinghai Lake, where the virus was first detected (Takekawa *et al.* 2010). Over 140 Ruddy Shelduck died during the first reported outbreak at this lake in 2005 (Liu *et al.* 2005; Chen *et al.* 2006). The species moves far and wide between the breeding and wintering areas (Popovkina 2006), and thus could spread avian diseases. Therefore, resource utilisation distribution of the species is crucial for understanding the epidemiological dynamics in areas where it comes in contact with domestic poultry. This paper presents preliminary information on the home range and habitat use of individual Ruddy Shelducks in Assam, India, to shed light on the role of waterfowl in spreading avian diseases.

Methods

Study area

The Deepor Beel Bird Sanctuary (26°07'00"N, 91°40'29"E) is a 900 ha site near the Brahmaputra River, southwest of Guwahati City in northeast India (Fig. 1). The Beel (meaning lake in Assamese) is a freshwater lake with abundant aquatic vegetation, including Water Hyacinth *Eichhornia crassipes,* Water Lettuce *Pistia stratiotes,* Duck Weed *Ottelia alismoides* and Common Duckweed *Lemna minor* (Islam & Rahmani 2004). The main sources of water to the lake are the Basistha and Kalamoni Rivers, which then drain into the Brahmaputra River, some 5 km from the reserve. Deepor Beel is important for migratory waterfowl during the non-breeding season with about 150 species of birds (including 16 species of Anatidae) recorded on the lake (Islam & Rahmani 2004) and is designated as a Ramsar Site and as an Important Bird Area (IBA; Islam & Rahmani 2004).
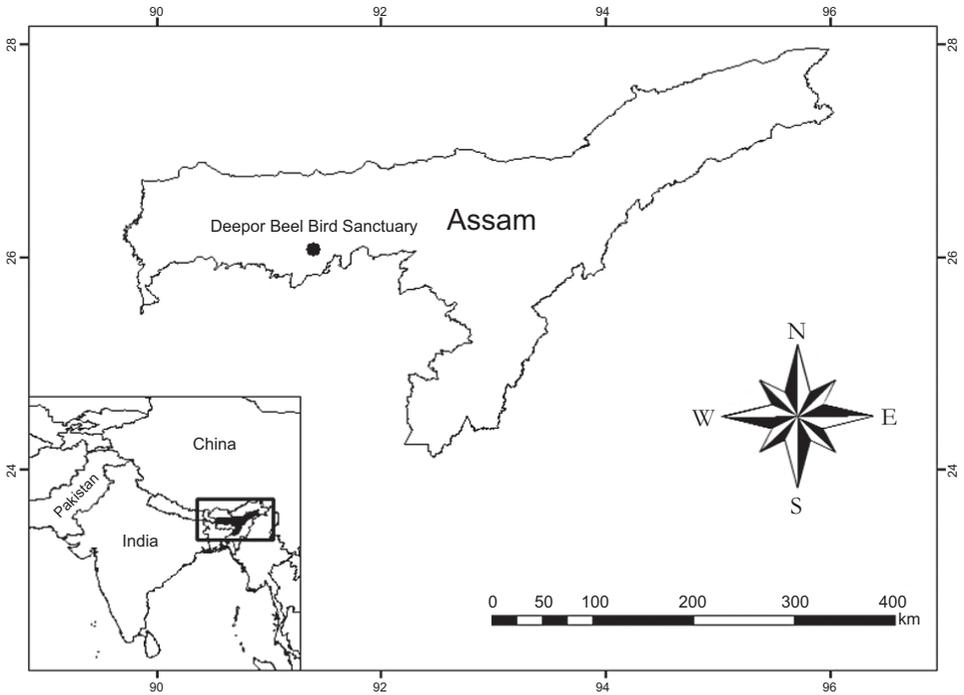
Figure 1. Map of India indicating the location of Assam in northeast India and the Deepor Beel Bird Sanctuary.

The sanctuary also supports critically endangered birds including the Oriental White-backed Vulture *Gyps bengalensis,* Slender-billed Vulture *Gyps tenuirostris* and several species classed by the IUCN as "endangered" and "vulnerable", such as the Greater Adjutant *Leptoptilos dubius* and Lesser Adjutant *Leptoptilos javanicus* (IUCN 2008). Deepor Beel has one of the largest populations of Ruddy Shelduck in Assam; Barman *et al.* (1995) recorded 769 individuals in the sanctuary in the winter of 1991/92. The species has often been observed along the Brahmaputra River and its tributaries (Choudhury 2000). Land in the vicinity was cultivated intensively for rice

production, especially in the winter when part of the Beel dries out.

Capture, marking and satellite tracking

Ruddy Shelduck were captured with indigenous mesh nets and monofilament leg nooses at Deepor Beel in December 2009, as part of a disease surveillance study. They were placed in bamboo holding cages and processed (biometrics recorded included mass, flat wing chord and tarsus). Capture, handling and marking procedures were approved by the U.S. Geological Survey's (USGS) Western Ecological Research Animal Care and Use Committee (ACUC), following protocols identical to those used

by the University of Maryland Baltimore County Institutional ACUC (Protocol EE070200710). The sex and age of each bird, determined by cloacal eversion and plumage, were also recorded. Shelducks were fitted with 22 g solar-powered GPS Platform Terminal Transmitters (PTT-100; Microwave Telemetry Inc., Columbia, MD, USA) which were programmed to record GPS location data every two hours. The birds were also fitted with metal rings. The transmitters were attached dorsally between the wings with teflon harnesses (Bally Ribbon Mills, Bally, PA, USA), which included breast and body loops connected along the keel. Location data were uploaded to satellites every two days (CLS America Inc., Maryland, USA). The weight of the transmitter and harness (about 25 g) was within the recommended weight limit of 3% of the birds' body mass (Kenward 2001).

Home Range

Home ranges of the marked birds were quantified using a Brownian Bridge Movement Model (Horne *et al*. 2007). This method is suitable for vagile animals like birds which tend to have multiple centres of activities. Unlike the kernel density estimate, this model deals with the issue of serial auto-correlation and unequal time intervals between locations in a straightforward manner (Horne *et al*. 2007). Furthermore, instead of assuming independence between animal locations, Brownian Bridges explicitly incorporate the time between locations into the model. The home range analyses were carried out in ArcMap version 9.3 (Environmental Systems Research Institute, Inc., Redlands, CA, USA) and

Animal Space Use 1.3 Beta. Movement rates of the birds were calculated by dividing the distance between two consecutive locations by the time between those locations, and averaging them over the study period. Models were run using the Universal Transverse Mercator (UTM) grid system.

Habitat use

GPS locations of seven Ruddy Shelducks recorded over a period of five months in the non-breeding period (December–April) were analysed to describe habitat use by the birds. Habitat type for each bird location was determined by overlaying the location layer on the habitat layers such as land cover (ARC/INFO, Redlands, California, USA). Land cover data were grassland (wooded grassland and grassland), woodland (evergreen needle-leaf forest, evergreen broad-leaf forest and deciduous broad-leaf forest, as well as mixed forest), shrubland (areas with woody plants lower than 5m, including both closed and open shrubland) and water (major rivers, minor rivers and lakes). Distances from the birds' locations to linear features (roads and streams) were also calculated to see how the birds use space with respect to these features. We also determined the birds' habitat use in terms of vegetation cover by using the Normalised Difference Vegetation Index (NDVI) as a proxy, which complemented the habitat analysis with land cover. NDVI takes values between –1 and 1. Although, negative values (–0.5 to –1) correspond to water, sand or barren areas, and very high values (approaching 1) correspond to temperate and tropical rainforests, we did not use this variable to make such distinctions, which were addressed

by using the land cover types. For estimating the proportions of available habitat, we generated random locations within the area and then assigned them to different habitat characteristics (*e.g.* grassland, cropland), following Marcum & Loftsgaarden (1980), as described earlier for habitat use.

Once the habitat characteristics of the birds and the random locations were known, habitat selection was assessed by estimating selection ratios (ratio of the proportion of habitat use and available) for different habitat units. The selection ratio of a habitat unit is proportional to the probability of that unit being utilised by the birds (Manly *et al.* 1993). For statistical analyses, habitat variables were grouped into distinct categories (*e.g.* a bird's distance to a road was classed as being < 2 km, 2–4 km, 4–6 km or >6 km; upper bound inclusive), and the selection ratio ($\hat{w}_i$) for each category was calculated as $\hat{w}_i = o_i / \pi_i$, where o_i is the proportion of used units in category i, and π_i is the proportion of available resource units in category i. Subsequently, the standard error of a selection ratio was calculated as *s.e.* $(\hat{w}_i) = \hat{w}_i \sqrt{\{1/u_i - 1/u_+ + 1/m_i - m_+\}}$, where u_i is the used resource units in category i, u_+ is the total number of used units sampled, m_i is available resource units in category i and m_+ is the total available units in category i.

To test for habitat selection statistically, a modified χ^2 (log-likelihood Chi-square statistic) was calculated as $\chi_L^2 = 2 \sum \{u_i \log_e \{u_i / E(u_i)\} + m_i \log_e \{m_i / E(m_i)\}\}$, where $E(u_i)$ is the expected value of u_i, and $E(m_i)$ is the expected value of m_i, based on the null hypothesis that there was no selection. If the value of the calculated chi-square test for a certain habitat exceeded the percentage points of the chi-squared distribution with the same degrees of freedom as used habitat (*i.e.* habitat selection occurred), simultaneous Bonferroni-adjusted 100 $(1 - \alpha)$ % confidence intervals were calculated for each habitat category (to locate significant differences) as $\hat{w}_i \pm Z_{\alpha/(2I)}$ *se* $(\hat{w}_i)$, where $_I$ is the number of habitat categories and *s.e.* $(\hat{w}_i)$ is the standard error of the selection ratio. A habitat was used selectively if the confidence interval for that habitat excluded 1. A habitat was preferred if the confidence interval was > 1, and avoided if < 1 (Manly *et al.* 1993).

Results

Home Range

Ruddy Shelducks were tagged with PTTs in December 2009. Location data for only four individuals were used to estimate home ranges, as the other three had too few locations (< 30) for estimating any meaningful non-breeding home range for these birds. The number of locations from the four individuals ranged from 262–1,282 (Table 1). Their average core use area (50% contour) was 40 km² (range = 22–88 km²), while their average home range (95% contour) was 610 km² (range = 222–1,551 km²). Three individuals (#95381, 95385 and 95386) had their core use areas along the Brahmaputra River (Fig. 2). They overlapped in their home ranges, yet had distinct core use areas (Fig. 2). On average, Ruddy Shelduck moved a distance of 0.62 km/h. Their movement rate ranged between 0.57 and 1.26 km/h (Table 1).

Table 1. Home range (95% contour, in km²), core use area (50% contour, in km²) and movement rate (km/h) for Ruddy Shelduck marked with satellite transmitters in India (December 2009–April 2010).

PTT	Sex	Weight (g)	Start date	End date	Number of locations	50%	95%	Movement rate (km/h)
95381	Female	1,250	14/12/2009	27/04/2010	1,282	22.1	365.8	0.57
95383	Female	1,100	14/12/2009	03/03/2010	262	19.5	222.1	0.32
95385	Female	1,265	13/12/2009	01/04/2010	358	31.0	312.5	0.30
95386	Male	1,310	14/12/2009	12/02/2010	309	87.7	1,551.6	1.26

Habitat use

A total of 596 locations from seven individuals were included in the habitat analysis. Ruddy Shelduck used the areas close (< 2 km) to the Brahmaputra River (riverine wetlands) more than expected considering availability (χ_L^2 = 243.3, P < 0.001), and avoided habitats far (> 4 km) from the river (Table 2). Ruddy Shelduck also selected areas far (> 6 km) from roads (χ_L^2 = 236.2, P < 0.001). They used aquatic habitats more than expected (χ_L^2 = 223.1, P < 0.001) but avoided woods and cropland habitats (Table 2). Shrub and grassland areas were used in proportion to their availability. Distribution in relation to NDVI data indicated that the Ruddy Shelduck avoided areas with dense vegetation (NDVI = 1.0; χ_L^2 = 60.8, P < 0.001).

Discussion

Home Range

The home range analyses showed that the tagged Ruddy Shelduck largely occurred along the Brahmaputra River and that they used the riverine wetlands extensively (Fig. 2). The average core use area of the Ruddy Shelduck was 40 km² while the average home range was 610 km², which is large compared to home ranges of similarly-sized ducks such as Mallard *Anas platyrhynchos* during the non-breeding season (1.84 km²; Legagneux *et al.* 2009). Its home range is also significantly larger than those of the geese – Giles (2010) reported wintering home ranges of 12–19 km² for PTT-marked Canada Geese *Branta canadensis*.

The large home range of the Ruddy Shelduck could be attributed to low quality of wetland habitats in the study area during the non-breeding season (Islam & Rahmani 2004), which may require them to visit more areas to obtain necessary resources (see Schoener 1968). Assam is one of the more heavily cultivated states in India (Deka *et al.* 2006), and since the Ruddy Shelduck appeared to avoid croplands, suitable habitat for the ducks may be highly fragmented
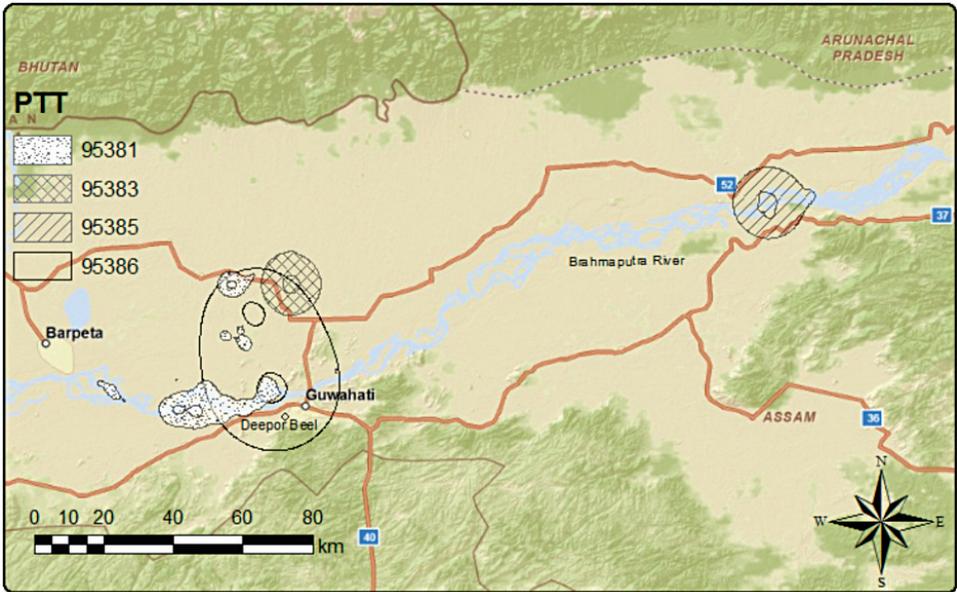
Figure 2. Home range (95% contour) and core use area (50% contour; inner circle) of four Ruddy Shelducks in Assam, India (December 2009–April 2010) determined from a Brownian Bridge Movement Model.

(Rahmani & Islam 2008). Discrepancies in home range in relation to habitat quality and landscape configuration have also been reported in other bird species; for instance, birds maintain larger territories in deserts than in wooded areas (Miller 1931; Doucette 2010).

There was also individual variation in home ranges; the two heavier females had larger home ranges than did the lighter one. Although a positive correlation between body size and home range size has been reported for other species (McNab 1963; Nudds & Ankney 1982), our limited data did not allow such an inference. Furthermore, the home range of the male (#95386) was larger than that of the females. Although sexual differences in home ranges have been

reported in birds (Hingrat *et al.* 2004; Whitaker *et al.* 2007), we could not assess this effectively for Ruddy Shelduck due to the small numbers involved; this needs further future investigation with larger sample sizes. Two of the birds had more than one core use area, which could again be attributed to the fragmented nature of the habitat, forcing birds to move between productive habitats. Although the Ruddy Shelducks overlapped in their home ranges, they had distinct core use areas, suggesting that they have separate feeding areas.

Habitat use

The Ruddy Shelducks used riverine wetlands more than expected, and avoided cropland

Table 2. Estimated habitat selection indices for Ruddy Shelduck in Assam, India. $\hat{w}i$ = estimated habitat selection ratio; *s.e.*($\hat{w}i$) = standard error of selection ratio; $\hat{w}i$ (*l*) *and* $\hat{w}i$ (*u*) are Bonferroni-adjusted 95% lower and upper confidence limits, respectively.

Variable	Category	Selection	$\hat{W}i$	*s.e.* ($\hat{w}i$)	$\hat{w}i$ (*l*)	$\hat{w}i$ (*u*)
Distance to River	< 2 km	+	3.26	0.30	2.59	3.925
	2–4 km	0	0.78	0.15	0.44	1.124
	4–6 km	–	0.62	0.11	0.37	0.870
	> 6 km	–	0.40	0.03	0.33	0.474
Distance to Road	< 2 km	0	0.64	0.07	0.48	0.805
	2–4 km	0	0.80	0.09	0.59	0.983
	4–6 km	0	0.99	0.11	0.74	1.246
	> 6 km	+	1.51	0.12	1.24	1.781
Land-use	Water	+	5.88	0.95	3.77	8.00
	Woodland	–	0.53	0.07	0.38	0.68
	Shrubland	0	1.41	0.69	0.00 *	2.95
	Grassland	0	0.93	0.08	0.74	1.11
	Cropland	–	0.45	0.05	0.34	0.55
NDVI	< –0.5	0	7.33	4.49	0.00 *	17.398
	0.0	+	3.79	0.95	1.66	5.923
	0.5	0	0.93	0.03	0.87	1.001
	1.0	–	0.59	0.09	0.39	0.797

+ Use significantly more than expected; – Use significantly less than expected; 0 Use in proportion to habitat availability.
*A negative value was replaced with a zero since a proportion cannot take a negative value.
NDVI = Normalised Difference Vegetation Index

which was also reported in the only other study of the species' habitat use (Quan *et al.* 2001). Such a habitat use pattern of the Ruddy Shelduck suggests that there is less likelihood of exchange of pathogens between this species and domestic ducks, which are generally concentrated near croplands (Gilbert *et al.* 2007). Quan *et al.* (2001) found that Ruddy Shelducks avoided farmlands except during a brief period in the mid-winter when agricultural fields were more frequently irrigated, thereby providing

both water and forage for the birds. Agricultural fields were also reported as less important habitats for waterbirds in India (Sundar 2006) which face threats to their native habitats from reclamation of wetland areas for agriculture. Agriculture and associated habitat destruction have been recognised as some of the most important threats to birds across the world (BirdLife International 2008), and Assam is an agrarian state with almost 70% of the population relying on agriculture (Deka *et al.* 2006).

Conservation implications

Knowledge of spatial patterns in resource use of wildfowl is crucial not only for carrying out *in situ* management actions but also for understanding epidemiological dynamics in areas where wild birds come in contact with their domestic counterparts. Despite the death of hundreds of Ruddy Shelduck due to H5N1 virus, information on habitat utilisation and distribution of the species is lacking in areas where the disease has become a major health concern. Hitherto, only one study on its habitat use has been carried out in its breeding range in China, and there is no information on its home range and movement rate both in its breeding and non-breeding range. Our study indicates that riverine wetlands, grasslands and shrublands are important habitats for the Ruddy Shelduck. The species avoided croplands, suggesting that there is less likelihood of exchange of pathogens between Ruddy Shelduck and domestic ducks, which are often concentrated near cropland sites. The study also stresses the need for protecting riverine wetlands, grass

and shrublands for the long-term survival of the species.

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