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SHORT COMMUNICATION

Full migration routes of two Little Egrets (*Egretta garzetta*) display breeding and wintering site fidelity

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ORNITHOLOGICAL SCIENCE

Abstract Our study provides the first GPS tracking data of Little Egret *Egretta garzetta* from an East Asian population. Our two main objectives were to reveal the migratory route and migratory strategy of Little Egret, and to study inter-annual breeding and wintering site fidelity. Our data, from an adult and a juvenile, suggest that this species is a short-distance high-speed migrant using few or no stopover sites. Both individuals displayed high breeding and wintering site fidelity. They also used very small winter home ranges, probably associated with high prey availability in aquaculture ponds.

Key words East Asia, GPS tracking, Little Egret, Migration, Site fidelity

The Little Egret *Egretta garzetta* has a large global range across tropical and warm temperate regions of Asia, Africa, Europe and Australia (del Hoyo et al. 2020), and since the 1990s it has also colonized the Caribbean (Hayes & White 2001). The species' ecology has been well studied, as has its distribution, spatial ecology and foraging behavior (e.g.,, Wong et al. 2000; Hayes & White 2001; Katz et al. 2013; Pang et al. 2020). Previous studies of the species' migratory behavior, based on ringing recoveries or observations, have shown that Palaearctic breeders exhibit partial migration to the Mediterranean region, tropical Africa and the Oriental region (Kushlan & Hancock 2005; Londei 2010; del Hoyo et al. 2020). However, our understanding of the Little Egret's migratory behavior in East Asia is incomplete and, given its wide distribution, studies on populations here are needed.

In East Asia, the Little Egret's migration ecology has not previously been studied. In Hong Kong, the species is present year-round, with annual influxes during spring and autumn. It has been speculated that local breeders in Hong Kong migrate south to winter and that winter visitors migrate into Hong Kong from the north (Carey et al. 2001). Tracking the migratory movements of Little Egrets can enhance our knowledge of migration ecology, including the species' migration route, and it's breeding and wintering site fidelity.

In this study, we used GPS transmitters to study the migratory behavior of the Little Egret in Hong Kong over two years, hoping to document the full migratory route of birds wintering in Hong Kong and breeding in Anhui Province, China, and to elucidate the species' breeding and wintering site fidelity.

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MATERIALS AND METHODS

1) Study area

This study was carried out in the Inner Deep Bay of the Hong Kong Special Administrative Region, China. The area consists of tidal mudflats, coastal mangroves and human-influenced wetlands, including tidal shrimp ponds, drainage channels and commercial fishponds. The commercial fishponds form a continuous wetland habitat of approximately 460 ha. The ponds contain polycultures of commercial freshwater fish including Grass Carp *Ctenopharyngodon idellus*, Grey Mullet *Mugil cephalus* and Tilapia *Oreochromis* sp. and provide important foraging habitat for egrets, especially when the water level is lowered for fish-harvesting (Young 1998; Pang et al. 2020).

2) Bird capturing and data logger deployment

On 29 January 2018, we captured two wintering Little Egrets by using clap-nets (1.5 m in diameter) at a fishpond in the Mai Po Inner Deep Bay Ramsar Site, Hong Kong (22°28′29″N, 114°01′32″E) (Table 1). We determined the age of the birds based on morphology (Baker 2016). Their sex was not determined. A solar-powered GPS-UHF data logger [model PICA (5.5 g in weight), Ecotone Telemetry, Poland], was attached to each bird using Teflon tape forming a backpack harness. The combined weight of the data loggers and harnesses was <3% of the birds' weight. The location error of the data loggers, based on field testing, was 20 m (Table 1). Both birds were released within two hours of being captured. Given that Little Egrets are rarely active at night, we programmed the data loggers to record data, including GPS coordinates and speed, hourly from 0500 to 1900 every day. However, both individuals initiated migration at night, so any displacement between 0500 to 1900 of the previous day was assumed to be the result of migratory movement. Data, stored on the loggers, were downloaded remotely every two weeks using a hand-held base station with a unidirectional antenna. We were not able to recapture the birds to remove the data loggers after data collection; however the harnesses were expected to wear and detach after the experiment. All procedures were approved by the Agricultural Fisheries and Conservation Department of the Hong Kong Government [permit number: (43) in AF GR CON 09/51 pt.6].

3) Analysis of location data

In order to document their migration, and because the maximum daily movements of Little Egrets on the breeding and wintering grounds were shorter than 10 km, we defined commencement of migration as the day on which birds moved more than 10 km from their wintering or breeding grounds.

The end of migration was defined as the day on which they made only short distance flights (<10 km daily movements) for more than three consecutive days (van der Winden et al. 2010; Ye et al. 2018).

We identified stopover sites during migration based on birds remaining for more than 12 hours (usually several days) at suitable wetland foraging sites on coasts or inland (van der Winden et al. 2010; Rappole 2013; Ledwoń & Betleja 2015), and situated geographically between the breeding and wintering grounds. Diurnal stops, differed from stopover sites and were defined as locations where birds paused during daytime for less than 12 h between nocturnal flights, usually in non-typical foraging habitats (Ledwoń & Betleja 2015).

We defined the breeding grounds based on diurnal activity during which birds moved back-and-forth between a foraging area, usually wetland, and a nesting area, usually woodland (Kushlan & Hancock 2005). Such movement could imply nest-building, incubation or chick-rearing activities, though such movements were anticipated to become more obscure as their offspring matured.

4) Home range analysis

The home ranges of the Little Egrets were calculated as the 50% (core area) and 90% (overall home range) utilization distribution (UD), using the fixed Kernel Density Estimation (KDE) method (Worton 1989; Seaman & Powell 1996). We used the h_{ref} kernel density estimators for the calculation (Calenge 2011). We then assessed the spatial overlap patterns of each bird across years, in order to examine their degree of foraging and breeding site fidelity, by using the Utilization Distribution Overlap Index (UDOI) (Fieberg & Kochanny 2005). This index takes into account the intensity of use within a home range, which is regarded as more suitable than conventional home range indices such as the home range overlap proportion (García-Rodríguez & Puig-Montserrat 2014). We calculated the UDOI of the breeding and wintering grounds of two Little Egrets over two years. Normally UDOI values fall between 0 and 1, where 0 means no overlap between UDs and 1 indicates complete overlap. However, values can be higher than 1 when the two UDs are not uni-

Table 1. Summary of information obtained from two migratory Little Egret individuals captured in Hong Kong.

ID	Age	Body weight (g)	Capture date	Last transmission	Days of tracking	GPS locations
PIC05	Juvenile	392	29 Jan 2018	8 Feb 2019	376	3,003
PIC09	Adult	478	29 Jan 2018	16 Dec 2019	687	9,221

formly distributed and have a high degree of overlap (Zengeya & Murwira 2016; Cecere et al. 2018). The analyses were performed using the package adehabitatHR (Calenge 2011) in software R version 3.6.3 (R Core Team 2013) and the maps were produced using QGIS 3.6.1 (QGIS Development Team 2016).

RESULTS

We tracked the annual movements of two migratory Little Egret: PIC05 (juvenile) for 376 days and PIC09 (adult) for 687 days. Data loggers were attached during winter and both birds migrated away from their wintering grounds (Inner Deep Bay, Hong Kong) in spring. Their departure dates were 45 days apart. PIC09 left on 28 March 2018 and PIC05 on 12 May 2018. In 2019, PIC09 commenced spring migration on 27 March. In autumn, PIC09 began its migration on 29 July 2018 and 3 Aug 2019, whereas PIC05 started later, in the evening, on 5 October 2018.

Both PIC05 and PIC09 visited breeding grounds in Anhui Province, China. During the 2018 spring migration, PIC05 migrated 1,141 km over 86 hours. It spent 70 days on its breeding grounds. Then, from 22 July 2018, it travelled 321 km to the northeast, to coastal Lianyungang, Jiangsu (Fig. 1a). It spent 74 days there before commencing its autumn migration, during which it travelled 1,451 km over 73 hours. Also in spring 2018, PIC09 travelled 985 km over 72 hours (Fig. 1b). In spring 2019, it traveled 1,014 km over 69 hours (Fig. 1c). It spent 120 days on its breeding grounds in 2018, and 126 in 2019. In autumn 2018, PIC09 travelled 1,044 km over 60 hours, and in autumn 2019 it flew 1,043 km over 204 hours. During the 2019 autumn migration, it stopped for 132 hours near a reservoir in Jiangxi Province, before continuing to its wintering grounds (Fig. 1c). PIC09 spent 238 days over the 2018/2019 winter in the Inner Deep Bay area.

The average travelling speeds of PIC05 were 29.2 (±17.79) km/h in spring and 42.2 (±16.1) km/h in autumn, while those of PIC09 were 34.6 (±28.9) km/h in spring 2018 and 44.7 (±18.2) km/h in spring 2019. PIC09 travelled at a speed of 31.6 (±16.7) km/h in autumn 2018 and 5.2 (±8.8) km/h in autumn 2019.

The home ranges of the two birds differed considerably in size on both the breeding and wintering grounds (Table 2). On the wintering grounds, juvenile PIC05 had a larger home range (mean 95% home range=24.45 km^2; mean 50% home range=3.46 km^2) than adult PIC09 (mean 95% home range=2.84 km^2; mean 50% home range=0.27 km^2). On the breeding grounds, PIC05 again had a larger home range size (mean 95% home range=120.23 km^2; mean 50% home range=18.86 km^2) than PIC09 (mean 95% home range=2.97 km^2; mean 50% home range=0.21 km^2).

The wintering home range (kernel utilization distribution) of PIC05 (UDOI=1.32) and PIC09 [UDOI=0.49 (between 2017/2018 and 2018/2019), 2.37 (between 2018/2019 and 2019/2020), and 0.65 (between 2017/2018 and 2019/2020)] showed a high degree of overlap across years (Fig. 2). PIC09 utilized the same breeding area in mainland China in both 2018 and 2019 (UDOI=0.66).

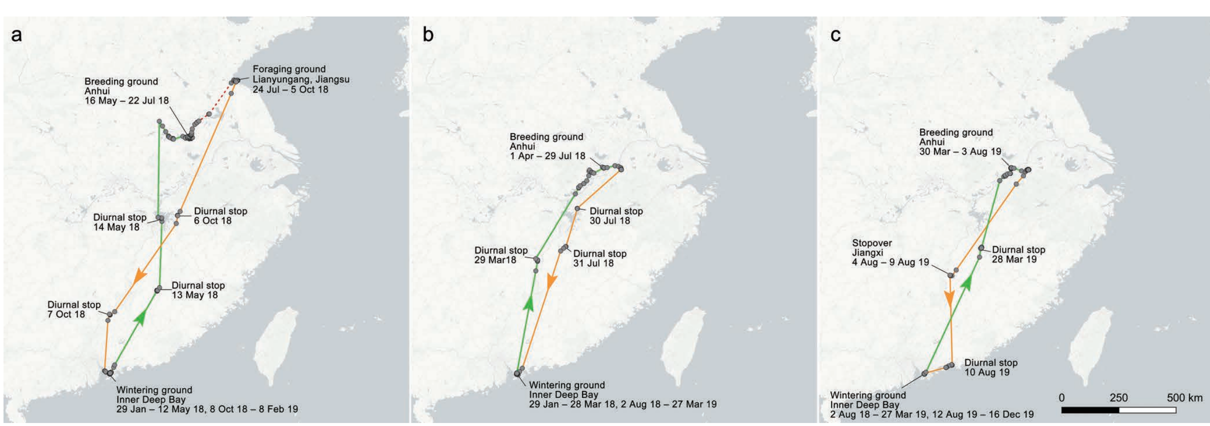

Fig. 1. Migration routes of two Little Egrets. Spring migration is indicated in green; autumn migration is indicated in orange and pre-migratory dispersal is indicated in red. a, movement of PIC05 from 29 January 2018 to 8 February 2019; b, movement of PIC09 from 29 January 2018 to 31 December 2018; and c, movement of PIC09 from 1 January 2019 to 16 December 2019.

Table 2. Kernel utilization distribution (KUD) of two Little Egrets wintering in Hong Kong, China and breeding in Anhui Province, China, in 2018 and 2019.

ID	Area	Year	95% KUD (km^2)	50% KUD (km^2)
PIC05	Wintering	2017/2018	24.77	2.74
		2018/2019	24.13	4.18
	Mean		*24.45*	*3.46*
	Breeding	2018	*120.23*	*18.86*
PIC09	Wintering	2017/2018	6.56	0.73
		2018/2019	0.57	0.02
		2019/2020	1.39	0.06
	Mean		*2.84*	*0.27*
	Breeding	2018	3.43	0.07
		2019	2.50	0.35
	Mean		*2.97*	*0.21*

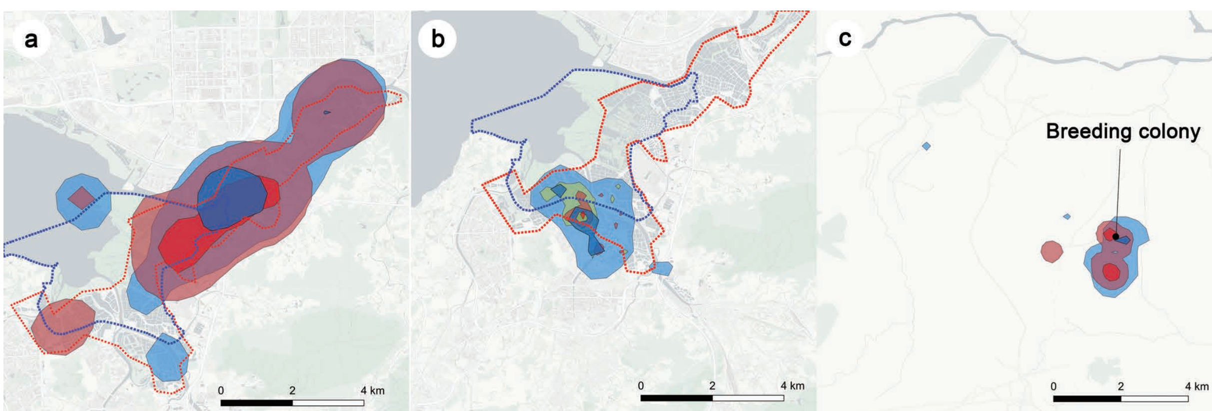

Fig. 2. Kernel utilization distribution of two Little Egrets. a, 95% (lighter shading) and 50% (darker shading) home ranges of PIC05 on the wintering grounds in 2017/18 (blue) and 2018/19 (red); b, 95% and 50% home ranges of PIC09 on the wintering grounds in 2017/18 (blue), 2018/19 (red) and 2019/20 (yellow); c, 95% and 50% home ranges of PIC09 on the breeding grounds in 2018 (blue) and 2019 (red). The fishpond area in the Inner Deep Bay area is indicated with a red dashed line and the Mai Po Inner Deep Bay Ramsar Site is indicated with a blue dashed line.

DISCUSSION

1) Migratory route and migratory strategy

We documented the migratory route of Little Egret in East Asia for the first time. Both study individuals migrated to Anhui Province, China (breeding grounds) in spring from Hong Kong (wintering grounds). Their migration routes (mean=1,159 km) were considerably shorter than those of Grey Heron *Ardea cinerea* (Ye et al. 2018: ca. 3,000 km) and Purple Heron *A. purpurea* (van der Winden et al. 2010: 3,309–5,571 km), but were comparable with Black-crowned Night Heron *Nycticorax nycticorax* (Ledwoń & Betleja 2015: ca. 1,000 km). Our data indicate that Little Egret follows direct migratory routes with few stopovers.

Among the six migration journeys recorded for the two egrets, only one involved a stopover, during which PIC09 rested for 132 hours at a reservoir in Jiangxi Province, China, during autumn migration 2019. This strategy is similar to that of Grey Heron (van der Winden et al. 2010; Ye et al. 2018), but differs from other species, such as Black-crowned Night Heron (Ledwoń & Betleja 2015) and Chinese Egret

E. eulophotes (Zhang et al. 2018).

2) Potential effects of age

Adult and juvenile birds may display varying migratory strategies and movements (Newton 2008). In this study, we found that the migratory movement of two Little Egret differed in three major ways. First, the juvenile, PIC05, dispersed northward in summer 2018; it departed the breeding grounds in Anhui, China and flew 321 km to a coastal area (22.1% of the autumn migration distance of the same year). Adult PIC09, made no such movement. PIC05's relatively short stay of just 70 days in Anhui Province might suggest that it was not mature enough to breed, or that it attempted to breed but failed. Second, juvenile PIC05's home ranges on both the breeding and wintering grounds, were larger than those of adult PIC09 (Table 2). These differences may be associated with the exploration of new foraging areas by juveniles (Hjertaas 1979; Kim et al. 2015), leading to the pre-migratory dispersal and larger home range sizes exhibited by PIC05. Third, juvenile PIC05 began its migration more than 40 days later in spring and more than 60 days later in autumn than adult PIC09. This delayed onset of migration may be related to young, inexperienced birds requiring longer to feed and obtain sufficient energy reserves before migration (Newton 2008). Given the small sample size of this study, further research is necessary to elucidate the generality of the differences between individuals, and between adults and juveniles.

3) Breeding and wintering site fidelity

The two Little Egret individuals showed fidelity to wintering sites in consecutive years, which is common in various families and groups of birds, ranging from ardeids [e.g., Reddish Egret *E. rufescens*: Koczur et al. (2018)], other waterbirds [e.g., Black Stork *Ciconia nigra*: Bobek et al. (2008)], to raptors [e.g., Osprey *Pandion haliaetus*: Washburn et al. (2014)] and passerines [e.g., Whinchat *Saxicola rubetra*: Blackburn & Cresswell (2016)]. Winter site fidelity is regarded as advantageous for birds because of its association with site familiarity and greater foraging efficiency, thereby promoting survival (Brown & Long 2007). The site fidelity we found in Little Egret, on both its breeding and wintering grounds, is probably explained by their colonial behavior, which may reduce the need for dispersal for increased breeding success (Becker et al. 2008). Furthermore, both Little Egret individuals displayed high winter site fidelity in fishpond areas and had very small home ranges. A small home range is likely to indicate reliable and sufficient food resources suitable for supporting minimized daily energy expenditure during winter (Newton 2008; Bengtsson et al. 2014). This suggests that commercial fishponds, though artificial, may provide stable food resources for birds, which is advantageous for them in prolonging their premigratory fattening period, as they travelled shorter distances during the non-breeding seasons (Young 1998; Pang et al. 2020).

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