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# First Record of Autumn Migration of Juvenile Chinese Egrets *Egretta eulophotes* from South Korea Tracked with GPS Telemetry

**Seok-Jun Son[1,3], Sung-Kyung Lee[1], Jung-Woo Oh[1], In-Kyu Kim[2], Dal-Ho Kim[2], Bo-Ra Hyun[1] and Jung-Hoon Kang[1,*]**

[1]*National Research Institute of Cultural Heritage, Cultural Heritage Administration, Daejeon 35204, Republic of Korea*
[2]*Korea Institute of Environmental Ecology, Daejeon 34014, Republic of Korea*
[3]*Korea Institute of Wildlife Ecology, Daejeon 34388, Republic of Korea*

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**S-JS and J-HK conceived the idea and designed the study. S-JS, S-KL, J-WO, I-KK, D-HK, B-RH, and J-HK collected and analyzed data. S-JS wrote the manuscript.**

**Key words**
**Breeding sites, Chinese egrets, Home range, Migration route, Wintering sites.**

## ABSTRACT

Understanding bird migration strategies is crucial for identifying the habitat of birds. Recently, GPS tracking has been utilized to identify bird migration routes. The Chinese egret *Egretta eulophotes* is a migratory bird distributed in East Asia; most populations breed on uninhabited islands off the west coast of the Korean Peninsula. Location tracking devices were attached to two juvenile Chinese egrets from an uninhabited island in the Chilsan Archipelago off the west coast of the Korean Peninsula. GPS tracking was used to identify their autumn migration route and their home range and habitat type in breeding (post-fledging/pre-migration stages) and wintering sites (post-migration stage). The two egrets crossed the East China Sea to Taiwan. The signal for one bird was lost, whereas the other rested and then moved to the Philippines for winter. The home ranges of the two birds were reported using kernel density estimation (KDE). During the post-fledgling stage, the results showed KDE 95% (90.46 km$^2$) / KDE 50% (26.29 km$^2$) and KDE 95% (45 km$^2$) / KDE 50% (5.56 km$^2$). While during the pre-migration stage, it showed KDE 95% (34.40 km$^2$) / KDE 50% (8.84 km$^2$) and KDE 95% (43.98 km$^2$) / KDE 50% (5.92 km$^2$). In the Philippines wintering site (post-migration stage), the home range of the bird was KDE 95% (15.14 km$^2$) / KDE 50% (3.39 km$^2$). For the first time, we identified the autumn migration route and habitat home range type of juvenile Chinese egrets. Further investigation is needed to identify the migration routes and habitats of additional individuals and establish a management plan for the conservation of Chinese egrets' habitat.

## INTRODUCTION

Understanding the long-distance migratory strategies of birds is crucial for identifying their habitat and characteristics from an animal ecology perspective (Alerstam *et al*., 2006; Knudsen *et al*., 2011; Kays *et al*., 2015). Most studies on bird migration have been carried out through the observation of individuals with rings attached in the breeding or wintering sites (Melville *et al*., 1999; Yu, 2005; Gunnarsson *et al*., 2006; Bell *et al*., 2009; Newton, 2010; Lourenço *et al*., 2011; Lok *et al*., 2013; Pigniczki, 2017). In the last few decades, the development of GPS tracking has facilitated the identification of long-distance bird migration routes and other information such as migration timing, distance, and wintering sites (Higuchi and Pierre, 2005; Pavón *et al*., 2010; Ledwoń and Betleja, 2015; Pagel *et al*., 2020; Son *et al*., 2020).

The Chinese egret, *Egretta eulophotes* has a limited distribution in East Asia and is designated as vulnerable (VU) in the International Union for Conservation of Nature (IUCN) Red List (BirdLife International, 2016). In South Korea, the Chinese egret is designated as a Natural Monument (No. 361) and is a protected species (National Research Institute of Cultural Heritage, 2015). Most Chinese egrets breed on uninhabited islands off the west coast of the Korean Peninsula including Seomando, Hwangseodo, Mokdo, Napdaekiseom islet. They are also known to breed in China and Russia (Litvinenko and Shibaev, 2000; Yin and Lei, 2002; Guo-An *et al*., 2005; Kang *et al*., 2013), and during winter they mainly migrate to the Philippines, Malaysia, and Indonesia (BirdLife International, 2016). However, only a few studies related to breeding ecology and genetics have been conducted (Liang *et al*., 2010; Wang *et al*., 2011; Huang *et al*., 2012), and studies on habitat in the breeding and wintering sites

* Corresponding author: birdlife@korea.kr
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are insufficient. In particular, the migration route, stopover sites, and pre- and post-migratory habitat use of Chinese egrets are unknown. Accordingly, in this study, we used GPS tracking to identify the autumn migration route to the wintering sites of two juvenile Chinese egrets bred in 2019 in the Chilsan Archipelago, a large breeding site for Chinese egrets in South Korea. In addition, the habitat use pattern was examined through analysis of the home range pre- and post-migratory habitat. Our study provides novel data that will contribute to Chinese egret habitat conservation.

## MATERIALS AND METHODS

*Study area and fieldwork*

The study area is in the Chilsan Archipelago, in Songee-ri, Nakwol-myeon, Yeonggwang-gun, Jeollanam-do, South Korea (35°19′17.82″N, 126°16′31.35″E). To protect the breeding sites of the black-faced spoonbill *Platalea minor* and the Chinese egret, the entire island has been designated and managed as South Korea Natural Monument No. 389; it is a restricted area.

Before leaving the nest, two juvenile Chinese egrets were captured using a mist-net in the Chilsan Archipelago on June 27, 2019. A wildlife tracker (WT-300, GPS-Wideband Code Division Multiple Access telemetry system built-in Solar System; KoEco, Daejeon, South Korea) was then attached to the Chinese egrets. Following the measurement of their morphological characteristics and attachment of the tracking device and a ring, the captured Chinese egrets were released. The WT-300 tracking device attached in this study constituted less than 5% of the weight of each captured Chinese egret *i.e.,* less than 25 g and was attached to the back of the individuals using a harness made of teflon ribbon (Ueta *et al*., 2000). WT-300 is a device that receives and stores location information from GPS and then transmits it using a commercial mobile communication network through Wideband Code Division Multiple Access (WCDMA). GPS coordinates were received every 4 h and transmitted twice daily.

Permission was obtained in advance from the Cultural Heritage Administration to capture and attach a location-tracking device to Chinese egrets.

*Data analysis*

We defined the start and end day of migration as the date the individuals departed from and arrived at post-breeding/wintering sites. In addition, stopovers are defined as long rests (>12 h) during migration at suitable foraging sites (Van der Winden *et al*., 2012; Rappole, 2013). Migration distance was calculated as the sum of the distance from the starting point coordinate to the endpoint coordinate as recorded using the Geographic Information System (ArcGIS, 10.3).

To explore the home range size of the juvenile Chinese egrets in their breeding and wintering sites, kernel density estimation (KDE) was used with accumulated data based on location information by time. In particular, we investigated the home range sizes of two juvenile Chinese egrets in the post-fledging and pre-migration stages in their breeding sites. In the KDE analysis, the density distribution of the home range is expressed as a curve, where 95% represents the general home range and 50% represents the core home range (Seaman *et al*., 1999; Walton *et al*., 2001).

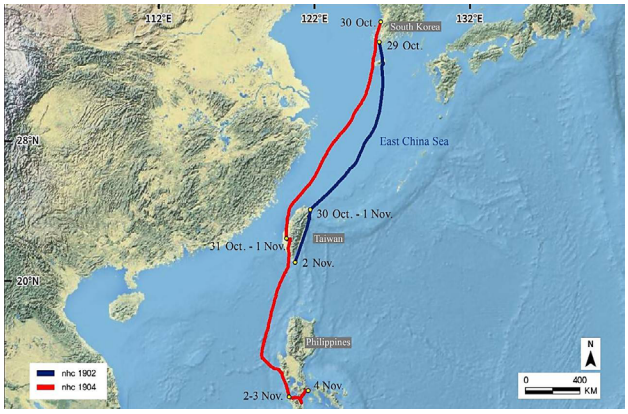


Fig. 1. Autumn migration routes of two juvenile Chinese egrets tracked with GPS telemetry from S. Korea in 2019.

## RESULTS

*Migration movements*

The migration routes to the two juvenile Chinese egrets (identified as nhc1902 and nhc1904) bred in Yeonggwang Chilsan Archipelago in 2019 were as follows (Fig. 1). nhc1902 departed from Heanam, South Korea, on October 29, 2019, flew approximately 1,402 km across the East China Sea and arrived in Yilan, Taiwan on October 30, 2019 (Fig. 1, Table I). nhc1902 remained in the rivers and agricultural lands of Yilan until November 1, 2019, and then moved approximately 406 km to Pingtung, Taiwan on November 2, 2019; thereafter, no further signal was received. The total recorded migration distance of nhc1902 was approximately 1,808 km.

nhc1904 commenced its migration from Gochang, South Korea, on October 30, 2019. It flew approximately 1,769 km across the East China Sea and arrived in Tainan, Taiwan, on October 31, 2019. After a short period in the river and the Tsengwen Reservoir, nhc1904 moved south again on November 1, 2019, and lived in the coastal area of the northern part of Mindoro Island in the Philippines from November 2 to 3, 2019 (Fig. 1). Finally, on November 4,

2019, nhc1904 moved to the wintering site in Pagbilao Bay in the Philippines and wintered there. The total migration distance of nhc1904 was approximately 3,321 km (Table I).

*Home ranges*

The home ranges in the post-fledging and pre-migration stages of the two juvenile Chinese egrets is shown in Figure 2. The home range of nhc1902 was observed in the nearby Yeonggwang Baeksu tidal flat after its release from the breeding site. It moved south to the Haenam tidal flat area and lived there before the autumn migration (Fig. 2A, B), showing a home range of 90.46 km$^2$ (KDE 95%) and 26.29 km$^2$ (KDE 50%) during the post-fledging stage and 34.40 km$^2$ (KDE 95%) and 8.84 km$^2$ (KDE 50%) during the pre-migration stage (Table II). Nhc1904 was also released from the Chilsan Archipelago and initially had a home range in the Yeonggwang Baeksu tidal flat. Subsequently, nhc1904 moved to the tidal flat in the Gochang area, and its home range was recorded prior to the autumn migration (Fig. 2C, D). The home range of nhc1904 was 45 km$^2$ (KDE 95%) and 5.56 km$^2$ (KDE 50%) during the post-fledging stage, and 43.98 km$^2$ (KDE 95%) and 5.92 km$^2$ (KDE 50%) during the pre-migration stage (Table II). After the autumn migration, nhc1904 lived in the wintering site in Pagbilao Bay, the Philippines. The home range of nhc1904 within the wintering site was 15.14 km$^2$ (KDE 95%) and 3.39 km$^2$ (KDE 50%) (Fig. 3; Table II).

**Table I.- Information of Autumn migration movements by Chinese egrets bred in Chilsan Archipelago, South Korea.**

| Individual ID | Age | Sex | Departure sites | Stopover sites | Arrival sites | Migration distance (km) |
|---|---|---|---|---|---|---|
| nhc1902 | Juvenile | Male | Heanam, South Korea | Yilan, Taiwan | Pingtung, Taiwan | 1,808 |
| nhc1904 | Juvenile | Female | Gochang, South Korea | Tainan, Taiwan<br>North Mindoro, Philippines | Pagbilao Bay, Philippines | 3,321 |

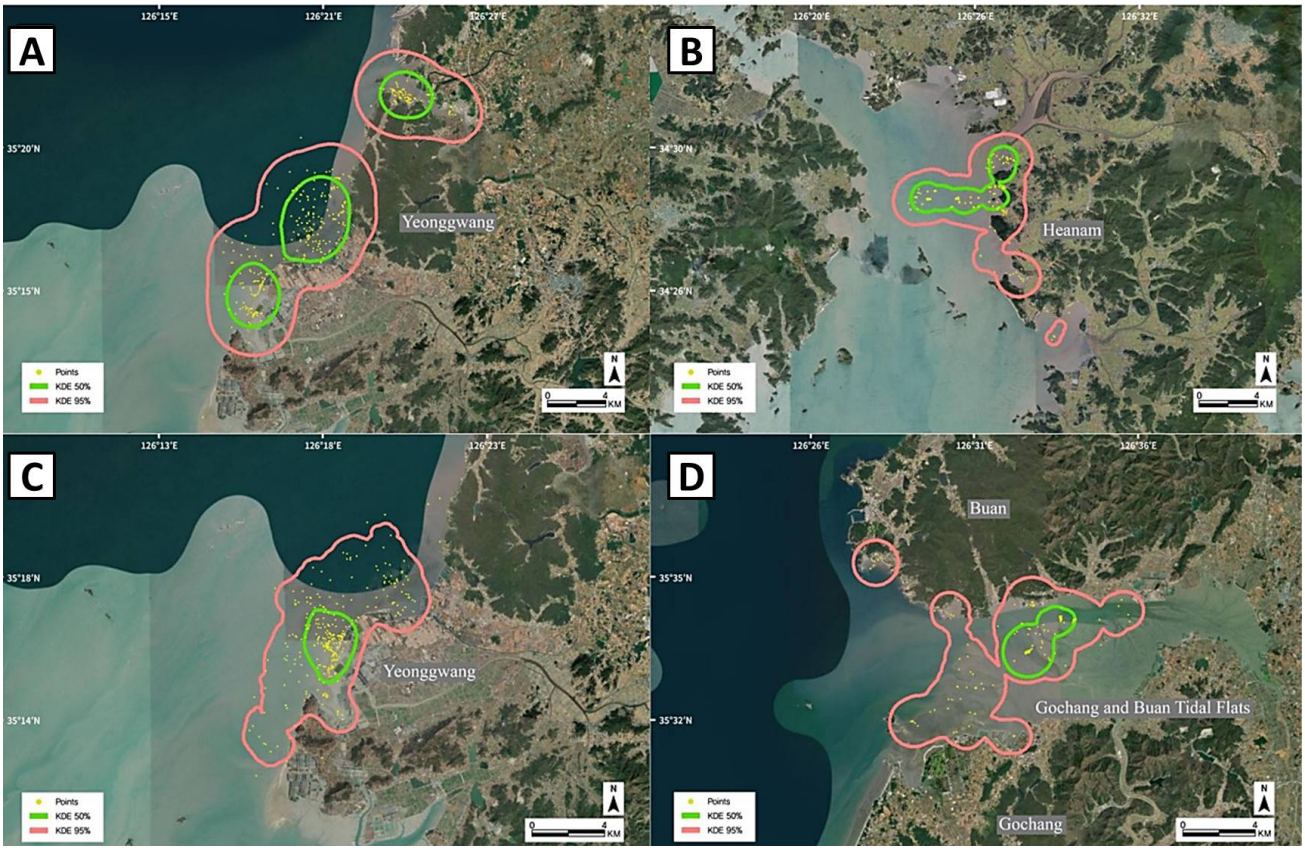


Fig. 2. Home ranges of two juvenile Chinese egrets at breeding sites in South Korea: A, nhc1902 (post-fledging stage); B, nhc1902 (pre-migration stage); C, nhc1904 (post-fledging stage); D, nhc1904 (pre-migration stage).

**Table II.- Home range sizes (km²) estimated using KDE (95%, 50%) methods for Chinese egrets at breeding sites and wintering sites.**

| Individual ID | Breeding sites | | | | Wintering sites | |
|---|---|---|---|---|---|---|
| | Post-fledging stage | | Pre-migration stage | | Post-migration stage | |
| | KDE 95% | KDE 50% | KDE 95% | KDE 50% | KDE 95% | KDE 50% |
| nhc1902 | 90.46 | 26.29 | 34.70 | 8.84 | - | - |
| nhc1904 | 45.00 | 5.56 | 43.98 | 5.92 | 15.14 | 3.39 |

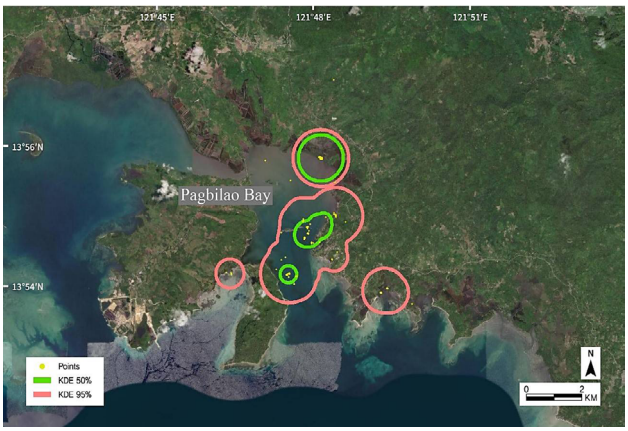


Fig. 3. Home range of one juvenile Chinese egrets (nhc1904) during the post-migration stage at wintering sites in Philippines.

## DISCUSSION

This study revealed the wintering sites and autumn migration routes of two juvenile Chinese egrets bred in the Chilsan Archipelago in 2019 and examined their habitat use pattern through the home range analysis. Both nhc1902 and nhc1904 flew across the East China Sea to move from the breeding site to the wintering site (Fig. 1). As part of the East Asian–Australasian flyway, this migration route is important for many migratory birds species (Bamford *et al*., 2008; Amano *et al*., 2010). As the signal from nhc1902 was lost in Pingtung, Taiwan, on November 2, 2019, we were unable to confirm whether this individual inhabited the wintering site after this date. However, nhc1904 data confirmed that the individual flew approximately 3,321 km in 5 days and wintered in Pagbilao Bay, the Philippines. Notably, nhc1904 rested for less than a day (<24 h) at stopover sites such as Tainan, Taiwan, and North Mindoro, the Philippines, before continuing to move to the wintering site. This differs from what is known for other Ardeidae species, which generally rest sufficiently at stopover sites before continuing their migration (Kim *et al*., 2015; Ledwoń and Betleja, 2015). A juvenile Grey Herons *Ardea cinerea*, which was bred in Korea and released, flew across the Yellow Sea and then rested at a stopover site (Qingdao, China) for 39 days before moving to its wintering site (Kim *et al*., 2015). However, the purple heron *Ardea purpurea*, which is similar in size to the grey heron, spent a very short time at its stopover site before moving to its wintering site (Van der Winden *et al*., 2012). Given these results, although the rest duration of migratory birds at the stopover site may be related to the size or mass of the species (Van der Winden *et al*., 2010), it may also depend on the species' preferred habitat environment. Moreover, juveniles are generally defeated in competition because they have a lower foraging efficiency and a higher predation rate than adults (Anders *et al*., 1997; Woodrey, 2000; Robinson, 2004). Therefore, the juvenile Chinese egrets may have migrated relatively quickly from the stopover site to the wintering site because of limited food supply and competition with adults and other species.

The habitat environment of breeding and non-breeding sites is essential for migratory birds (Morton and Stutchbury, 2005). Especially for juveniles, the ability to consume enough food in a habitat suitable for the pre-migration stage as well as the post-fledging stage is vital for long-distance migration (Chernetsov, 2006; Austin *et al*., 2017; Son *et al*., 2020). After their release from the Chilsan Archipelago, nhc1902 and nhc1904 showed a pre-migration stage home range within the Yeonggwang Baeksu tidal flat, approximately 6.5 km away, and a nearby paddy field and farmland. The core home range, KDE 50%, was observed in the tidal flat area (Fig. 2A, C). The Baeksu tidal flat is known to be a major feeding site for spoonbills and Chinese egrets bred and released from the Chilsan Archipelago (National Research Institute of Cultural Heritage, 2019; Son *et al*., 2020). Chinese egrets slowly walk along shallow wetland when feeding (Aboushiba *et al*., 2013), and the Baeksu tidal flat is a suitable feeding site for these birds. In the pre-migration stage, nhc1902 migrated from the Baeksu tidal flat to the Haenam area and showed a home range in the tidal flat and a nearby agricultural land. The core home range was observed in the tidal flat area (Fig. 2B). nhc1904 showed a home range as it moved to the tidal flat of Gochang (Fig. 2D). Various species, including birds, are known to inhabit this area (Fouda and Fishar, 2012; Oh and Rho, 2013), which encompasses a tidal flat of approximately

4,550 ha registered as the "Gochang and Buan Tidal Flats" Ramsar wetland site. In the wintering site, nhc1904 showed a home range near the tidal flat area of Pagbilao Bay (Fig. 3), which is a sparsely populated region. The coastal area consists of a tidal flat and mangrove colony (Gilbert and Janssen, 1998). The mangrove area provides a variety of environmental goods and services and is an important habitat with abundant food sources particularly suitable for egrets and other birds (Miranda and Collazo, 1997; Kushlan, 2000; Martínez, 2010).

Following typhoon damage (KAMMURI) in the Philippines on December 5, 2019, the GPS signal was cut off, and nhc1904 could no longer be tracked. However, this study represents the first observation that the autumn migration route and habitat home range of Chinese egrets were mainly in areas of tidal flat, agricultural land, and mangrove, as recorded using a GPS location tracking system. Thus, there is a need for coordinated efforts between South Korea and the Philippines to protect the habitats of Chinese egrets by limiting activities, such as construction and human interference, near the home range at the breeding and wintering sites identified in this study. Furthermore, there is a need to establish a management plan to preserve the habitat of Chinese egrets in the breeding sites, wintering sites, and stopover sites by identifying additional migration routes and habitats.

## CONCLUSIONS

In this study, it was found that the two juvenile Chinese egrets bred in South Korea crossed the East China Sea and migrated to Taiwan and the Philippines in autumn, and it was found that the habitat home range mainly appeared in the tidal flat area.

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*Statement of conflict of interest*

The authors have declared no conflict of interests.

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