Testing a simple and non-intrusive method for monitoring the breeding season of barn swallows in an urban area in Kaohsiung, Taiwan

測試以一種簡單且非侵入性的方式監測台灣高雄市區的家燕繁殖

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ABSTRACT

Monitoring of biodiversity with citizen scientists is increasing worldwide, including Taiwan. We present a simple and non-intrusive method for monitoring urban swallows that is ideal for nationwide student or citizen science monitoring projects. In 2019, we continuously monitored the breeding phenology and success of 57 barn swallow (*Hirundo rustica*) nests in an urban district in Kaohsiung City, southern Taiwan. We used minimal equipment (mirror on stick, flashlight, pen, and paper) to survey the eggs, nestlings, and fledglings inside the nests during the entire breeding season. Among the 46 active nests, 21 and 25 nests were associated with one or two breeding attempts, respectively. The two peaks of egg-laying occurred in April and from early to mid-May until early June. The mean clutch size for the first and second breeding attempt was 4.1 eggs and 3.8 eggs, respectively, and the mean fledgling number was 1.8 and 1.3 fledglings, respectively. The overall fledgling success rate was 40.8%. The number of nestlings correlated positively with the number of fledglings ($r^2 = 0.46$). The main result of this pilot study is that it is possible to conduct long-term monitoring of urban swallow populations with little training and minimal equipment and only a moderate investment of time and effort as long as the nests are accessible. We suggest that the implementation of a nationwide monitoring network of urban swallows would have several benefits, such as useful data on breeding phenology and breeding success, but also to entice more people to become citizen scientists and to educate people about the ecosystem services of birds.

摘要

包括台灣在內，公民科學家對生物多樣性的監測在世界各地不斷增加。我們提出了一種簡單且非侵入性的方式監測城市的燕子生態，非常適合全國學生或公民科學計畫。 在 2019 年，我們持續監測了台灣高雄市區 57 個家燕（*Hirundo rustica*）巢穴的繁殖物候和成功情況。在整個繁殖季節，我們使用最少的設備（黏在長棍上的鏡子、手電筒、筆和紙）來調查巢內的蛋、雛鳥和幼鳥。在 46 個活躍巢穴中，分別有 21 個和 25 個巢穴與一次或兩次繁殖嘗試相關。兩個產蛋高峰期分別發生在 4 月和 5 月上旬至 6 月上旬。第 1 次和第 2 次繁殖嘗試的平均窩卵分別為 4.1 枚蛋和 3.8 枚蛋，平均幼鳥數量分別為 1.8 隻和 1.3 隻。整體幼鳥離巢成功率為 40.8%。雛鳥數量與幼鳥數量呈正相關（$r^2 = 0.46$）。這項前導研究的主要結果顯示，但凡燕巢可接近，研究人員只需極少的訓練和最少的設備；並且投入適度的時間和精力，就可以對城市裡的燕子族群進行長期監測。根據上述結論，

我們建議實施全國性城市燕子監測網絡。其益處有許多，例如產生有關繁殖物候和繁殖成功的有用數據，並且還可以吸引更多人成為公民科學家，並教育人們有關鳥類生態系統服務的知識。

key words: citizen science, monitoring, urban biodiversity, breeding phenology, breeding success.

INTRODUCTION

The phenology of breeding seasons is an important aspect of the study of bird behavior and reproduction (Lovette and Fitzpatrick 2016). Due to rapid man-made changes to the biosphere, changes in breeding distribution and phenology as well as changes in population numbers can now be used as indicators of the biological effects of climate change, land-use change, chemical or light pollution, and other important changes due to human activity (e.g., Both *et al.* 2009; Barbet-Massin *et al.* 2012; Cooper *et al.* 2014; García-Pérez *et al.* 2014; Walther 2016; Dominoni *et al*. 2020; Wang *et al.* 2021).

To be able to monitor important avian population changes in Taiwan, the Taiwan Breeding Bird Survey (BBS) was initiated in 2009 and has already revealed important distribution and population changes (Ko *et al.* 2016; Ko *et al.* 2017; TESRI 2021; Lin *et al.* 2023). The BBS is a perfect example of the emergence of citizen science in Taiwan, which ideally engages interested citizens in the entire scientific process, such as the rationale for the study, generating questions or hypotheses, developing the methods, collecting and analyzing the data, and publishing and disseminating the results (ECSA 2015; Heigl *et al.* 2019). However, many citizen science projects are more limited in scope, and often the citizen scientists mostly collect data although in a scientifically rigorous way. Besides the BBS, other typical examples from Taiwan are recording migratory bird populations (TESRI 2019), bird poisoning events (Hong *et al.* 2018), avian influenza cases (Wu *et al.* 2023), or roadkills (Hsu *et al.* 2018; Chyn *et al.* 2019).

After living in Taipei City for three years, the first author (BAW) realized that urban swallows (Hirundinidae) are very easy to monitor because (1) they are not scared by the presence of people (with some nests less than a meter away from where people are), (2) most of their nests are very accessible, and (3) they are found almost across the entire island of Taiwan except the high mountains. Since urban swallows are so easy to monitor and so ubiquitous, they should be an ideal study species for student or citizen science monitoring projects. Before embarking on a citizen science project, however, one needs to field test whether monitoring urban swallows is indeed feasible with a reasonable amount of time and manpower and without disturbing or harming the birds. Therefore, we here present a simple and non-intrusive monitoring method which (1) we field tested to demonstrate its feasibility and (2) could be the starting point for many citizen science projects to monitor the breeding phenology of swallow species, which are widespread and common in Taiwan but also in other countries (for citizen science projects that monitored British, Chinese and Malaysian swallows, see Kettel *et al.* 2021, Jiang *et al.* 2019, and Mansor *et al.* 2021).

On the main island of Taiwan (from hereupon called Taiwan), five species of swallows (Gray-throated Martin *Riparia chinensis*, Barn *Swallow Hirundo rustica*, Pacific Swallow *Hirundo tahitica*, Striated Swallow *Cecropis striolata*, and Asian House-Martin *Delichon dasypus*) have been recorded as regular breeders (Ding *et al*. 2023). They usually breed in cities, villages, cliffs, sand banks, tunnels, and under bridges (Severinghaus *et al.* 2017).

In our urban study area in Kaohsiung, we recorded only the barn swallow and the striated swallow as breeders. The barn swallow is found throughout Taiwan from 0-2300 m a.s.l., and its usual breeding season lasts from April to August (Severinghaus *et al.* 2017). The striated swallow is found throughout Taiwan in the plains to the mid-elevation mountains, and its usual breeding season lasts from April to July (Severinghaus *et al.* 2017).

While Severinghaus *et al.* (2017) notes that the barn swallow's open bowl-shaped nests are built on a vertical wall under the eaves of buildings and on beams and light fixtures, the preferred location in Taiwanese cities is often inside the porches or colonnades of city houses (called verandahs by Wang and Hung 2019 and Wang *et al.* 2021). Many Taiwanese city houses (especially older ones built in the decades after World War II) have a space in front of the entrance door which is open to the street and also usually open to the neighboring houses, but is covered either by a roof or by a ceiling from the story above it (Fig. 1). This space protects the house entrance from heat, offers an open but shaded place for people to sit or walk, and also protects people and belongings from rain. The distance from the entrance door to the front of the roof or ceiling is usually several meters, and the roof or ceiling covers the entire width of the building. If many of these porches are seamlessly connected, people can use them to walk along the street protected from sunshine and rain; in that case, these spaces could also be called colonnades.

These spaces offer the swallows a very well-protected site for breeding because they combine vertical walls for the nest's attachment (usually at 2-4 m height), protection from heat and rain, and an open pathway for flying from the nest into the street (Fig. 1). Given their location, there are also almost no predators (but see Wang and Hung (2019) for a recent and novel predator as well as our Discussion below).

For the striated swallow, Severinghaus *et al.* (2017) notes that nests are usually built in hallways, colonnades, porches, and under the beams of houses, schools, or other man-made structures. However, the nest is not open, but a closed tunnel in the shape of a long-necked jug (Fig. 2). Because it is impossible to see the inside without special equipment, we did not monitor the breeding season of the striated swallow.

In contrast, the open nests of urban barn swallows (Figures 1 and 2) are extremely easy to observe even without any equipment or with just binoculars. Barn swallow nests can be extremely close together in suitable locations and include nests constructed by the birds themselves or nesting opportunities provided by people (Fig. 2). Residents provide such nesting opportunities because "barn swallows have traditionally been well-loved by local residents" (Severinghaus *et al.* 2017, see also Pagani-Núñez *et al.* 2016; Jiang *et al.* 2019; Wang and Hung 2019).

The main purpose of this study is to conduct a pilot study which demonstrates that the documentation of the breeding phenology and breeding success of the barn swallow in Taiwanese cities, towns, and villages is possible with little training and minimal equipment and only a moderate investment of time and effort. This study may then serve as a blueprint for a nationwide citizen science monitoring effort.

MATERIALS AND METHODS

The study was conducted within a fully urbanized district of Kaohsiung, which is located in southern Taiwan as the second largest city that features the busiest harbor in Taiwan (Republic of China). The climate is categorized as tropical savanna climate with monthly mean temperatures ranging from 20 to 29°C and high relative humidity ranging from 71 to 81%. The warmer season lasts from April to November and the cooler season from December to March. Annual rainfall is around 1885 mm and falls mainly from June to August. For Gushan District, the Annual Climatological Data Report for 2018 by Taiwan's Central Weather Bureau gives the annual mean temperature as 25.4°C and the annual precipitation as 2576 mm. The highest temperature is in July (29.3°C) and the lowest temperature in February (19.2°C). The highest precipitation is in August (1299 mm) which accounts for almost half of the entire annual precipitation.

We carried out our 18 surveys from 7 April to 17 August 2019 in the local area called Hamasing which is at the southern end of Gushan District of Kaohsiung. This district is adjacent to the harbor and National Sun Yat-sen University (Table 1, Fig. 3). Hamasing was created when land was reclaimed by the Japanese colonial government in the 19th century when it was the site of the local government.

For each of the 18 surveys, we walked along all the streets within this district from 7:00-9:00 hours. This district has many houses with roofed colonnades where swallows chose to build their nests. Once a nest was spotted, its location was noted on a map. In order to look inside the nests with minimal disturbance to the breeding parents, we attached a mirror to a 1.8 m long metal stick which enabled us to count the eggs and nestlings in each nest (Fig. 4). Even without this mirror, citizen scientists could observe the later stages of the breeding cycle when the nestlings are so large that they are clearly visible inside the nest using binoculars (and often without binoculars). With the mirror, we looked inside each nest to record the number of eggs, nestlings, and fledglings present (Fig. 4). Sometimes, a flashlight was needed to better illuminate the nest. Wang and Hung (2019) and Wang *et al.* (2021) used a similar method, but replaced the mirror with a smartphone camera.

For the purpose of this study, nestlings were defined as any live juvenile birds present in the nest, no matter what their developmental status was such as hatchling or nestling, as long as they could not actively fly (Figures 1 and 5, left panel; see Brown and Brown (1999), Turner (2006), and Fernaz *et al.* (2012) for detailed descriptions). Consequently, fledglings were defined as having reached the developmental stage "when the feathers and wing muscles are sufficiently developed for flight" (Wikipedia 2023). Thus, a nestling became a fledgling when it became clearly capable of flying about on its own (Fig. 5, right panel). These fledglings were actively flying out of and back into the nest, especially at night to rest.

If adults were present in the nest, we waited until they left the nest before checking the nest. We often observed that adults would return quickly to the nest after our observations, and we never observed that a nest was abandoned due to our very short disturbance (usually less than ten seconds, rarely longer than one minute). Likewise, no nest abandonments were observed during a similar multi-year study conducted in Taipei (2013-2018 breeding seasons, unpublished data of first author).

The Mann-Whitney U test was used when we investigated differences between the first and the second breeding attempt (which was the binary variable in this case). For linear relationships, we used both the non-parametric Spearman rank test and the parametric simple linear regression. Any P-value < 0.05 was considered statistically significant.

RESULTS

Breeding phenology

During the 2019 breeding season,

we monitored 57 barn swallow nests, of which 46 nests (80.7%) were actively used. The date of 21 April was when at least five nests had at least one nestling. Overall, we clearly observed two peaks of egg-laying: most eggs were laid for the first clutch in April, and fewer eggs were laid for the second clutch from early to mid-May until early June (Fig. 6). We call these two periods "first breeding attempt" and "second breeding attempt." While most breeding pairs closely followed this phenology, there were of course a few pairs which began laying eggs earlier or later than these two periods. Although the incubation is given at 14-15 days in Severinghaus *et al.* (2017), we observed the peaks for nestling numbers at 30 days after the peak for egg numbers (namely, 7 April and 31 May for eggs and 7 May and 30 June for nestlings).

Breeding success

Among the 46 active nests, 21 nests (45.7%) were associated with two breeding attempts and the remaining 25 nests with only one breeding attempt. Among these 25 nests, ten and 15 nests were associated with only the first and only the second breeding attempt, respectively. Thus, there were only 31 active nests during the first breeding attempt but 36 active nests during the second breeding attempt.

Not all nests actively used by barn swallows produced eggs (or they produced eggs, but the eggs disappeared before we could record them; see Discussion). During the first breeding attempt, 31 out of the 46 nests contained freshly laid eggs (67.4%). The mean clutch size was 4.1 ± 0.9 (± 1 std. dev., range 2-5; Fig. 7). Of the total of 126 eggs laid, 57 produced fledglings that successfully left the nest (45.2%). Out of the 31 nests with eggs, 13 nests produced no fledglings at all (41.9%). The mean fledgling number across the 31 nests was 1.8 ± 1.6 (range 0-4).

During the second breeding attempt, 32 out of the 46 nests had new eggs in them (69.6%). The mean clutch size was 3.8 ± 1.0 (range 1-5; Fig. 8). Of the total of 134 eggs laid, 49 produced fledglings that successfully left the nest (36.6%). Out of the 36 nests with eggs, 20 nests produced no fledglings at all (55.6%). The mean fledgling number across the 36 nests was 1.3 ± 1.4 (range 0-4).

The differences between the clutch sizes and the fledgling number per nest were not statistically significant between the first and the second breeding attempt (Mann-Whitney U test, $P > 0.05$).

In total, 260 eggs resulted in 106 successful fledglings (40.8%). The mean clutch size across both breeding attempts was 3.9 ± 1.0 (range 1-5). Of the 67 nests, 33 produced no fledglings at all (49.3%). The mean nestling number across the 67 nests was 2.5 ± 1.6 (range 0-5), and the mean fledgling number was 1.5 ± 1.5 (range 0-4).

Across both breeding attempts, the number of eggs (or clutch size), nestlings and fledglings were all positively and significantly correlated with each other, whether tested with the non-parametric Spearman rank test (all $P < 0.03$) or the parametric simple linear regression (clutch size vs. nestlings, std. coeff. = 0.43, $F = 14.3$, $r^2 = 0.18$, $P = 0.0003$; clutch size vs. fledglings, std. coeff. = 0.30, $F = 6.1$, $r^2 = 0.09$, $P = 0.02$; nestlings vs. fledglings, std. coeff. = 0.09, $F = 54.7$, $r^2 = 0.46$, $P < 0.0001$).

DISCUSSION

The results of our pilot study clearly demonstrate that the documentation of the breeding phenology and breeding success of the barn swallow in Taiwanese cities, towns, and villages is possible with little training and minimal equipment and only a moderate investment of time and effort. Our study thus generated some basic natural history data about an urban swallow population in southern Taiwan. To our knowledge, this is the first study of the breeding phenology of the barn swallow in Kaohsiung which is at the southern tip of Taiwan. Over the breeding season, we observed a decreasing number of eggs and nestlings (Fig. 6), a decrease in clutch size (especially fewer clutches of five eggs, Figures 7 and 8), a decrease in overall fledgling success (from 45.2% to 36.6%) and the number of successful fledglings per nest (1.8 to 1.3), and an increase in the proportion of completely failed nests (from 41.9% to 55.6%). However, these trends are not very strong and not statistically significant. Such declining rates of breeding success for successive breeding attempts are known in many bird populations (e.g., Wang *et al.* 2021).

However, high ambient temperature may also play a role. Because of the southern location and the additional urban heat effect, the swallows in Kaohsiung should experience some of the highest temperature levels of any urban swallows in Taiwan. It has been well established that high ambient temperatures can cause physiological stress and hyperthermia in nestlings, which lead to various detrimental effects including death (Mertens 1977a; Mertens 1977b; Murphy 1985; Salaberria *et al.* 2014; Catry *et al.* 2015; Rodríguez and Barba 2016; Imlay *et al.* 2019). For example, in experimentally heated nests, heated nestlings were lighter on their 15th day after hatching than control nestlings, but only when outside temperatures were also relatively high (Rodríguez and Barba 2016). Consequently, Rodríguez and Barba (2016) argued that ambient temperatures > 34°C begin to cause negative effects on nestling physiology. This upper-temperature threshold was supported by other studies; e.g., nestling survival declined when internal nestbox temperatures exceeded 35°C (Ardia 2013), and various indicators of nestling growth and survival were reduced by temperatures > 32°C (Geraert *et al.*

1996; Quinteiro-Filho *et al.* 2010; Cunningham *et al.* 2013). Even adult wild birds lost body weight when maximum air temperatures exceeded 35.5 °C (Du Plessis *et al.* 2012). Interestingly, a study of two Chinese populations showed that nestling survival decreased with increasing temperatures at the tropical site, but not at the temperate site (Tian *et al.* 2022), which supports the detrimental effect of very high temperatures on barn swallow nestlings. The possibly detrimental role of high temperatures on nestling growth and survival should also be investigated in Taiwan, possibly even by citizen scientists (see our four suggestions below).

The normal clutch size for barn swallows in our study was 3-5 eggs with a mean of 3.9 ± 1.0, which is very similar to the mean of 4.4 ± 1.1 and 4.1 ± 1.1 reported by Wang *et al.* (2021) for the first and second breeding attempt, although their clutch size decreased to 2.8 ± 1.7 during the third breeding attempt. The clutch sizes for a southern and a northern Chinese population were 4.33 ± 0.87 eggs and 4.62 ± 0.80 eggs, respectively (Tian *et al.* 2022). The clutch sizes for the first and second breeding attempt were 4.8 ± 0.9 eggs and 4.3 ± 0.5 eggs in a South Korean study, respectively (Choi and Kwak 2019).

The few clutches smaller than three eggs in our study seem to be anomalies. The two clutches of two eggs each during the first breeding attempt (Fig. 7) were likely abandoned or predated because the eggs had disappeared after only 1-2 weeks. During the second breeding attempt (Fig. 8), one nest contained one egg from 17 July until the end of the surveys; we assume that this egg was abandoned. Furthermore, there were two clutches of two eggs each which disappeared after only one week, but one clutch of two eggs actually produced two fledglings.

Clutch size predicted the number of

nestlings and fledglings, although with much unexplained variation (82% and 91%, respectively). Thus, clutch size was not a good predictor of the number of nestlings or fledglings. However, the linear relationship between the number of nestlings and fledglings explained 46% of the variation, so clearly the number of hatched young was a somewhat decent predictor of the number of successfully fledged young.

The mean number of nestlings and fledglings in our study was 2.5 ± 1.6 and 1.5 ± 1.5, respectively. These numbers are substantially lower than the respective means of 3.0 ± 1.8 and 3.0 ± 1.9 for nestlings and 2.7 ± 1.7 and 2.2 ± 1.8 for fledglings reported by Wang *et al*. (2021) for their first and second breeding attempts (their numbers further decreased for the third breeding attempt). Again, this difference may be due to the higher temperatures at our study site.

Severinghaus *et al.* (2017) provides some natural history information on Taiwanese barn swallows. First, they state that the barn swallow commonly has two clutches per year, one in April and a second one in July. While our first clutch was also in April, the second clutch was from early to mid-May until early June, much earlier than stated in Severinghaus *et al.* (2017). Again, this difference might be due to the higher temperatures in southern Taiwan. Wang *et al.* (2021) even reported up to three clutches in Taipei in northern Taiwan where temperatures are lower than in Kaohsiung. In southern China, the breeding season of barn swallows lasted from February to July in one study (Tian *et al.* 2022) and from April to July in another study, with up to three breeding attempts per season (Pagani-Núñez *et al.* 2016). In northern China, it lasted from May to August (Tian *et al.* 2022). Severinghaus *et al.* (2017) further wrote that “incubation takes 14-15 days” and “nestlings fledge at about 20 days, but remain near the parents post-fledging.”

We also observed such lengths of time in most cases.

This study should mainly be seen as a pilot study or a proof-of-concept study. Therefore, the main result is that it is possible to conduct long-term monitoring of urban swallow populations with little training and minimal equipment (mirror on stick, flashlight, pen, and paper) and only a moderate investment of time and effort as long as the nests are accessible, as was in our case. Indeed, the second author (HY) had no prior experience in ornithological fieldwork but was trained by the first author within a short period of time. After that, he conducted the field work completely independently from the first author. In essence, the second author was a "citizen scientist" in the true sense of the word; a regular citizen who became interested enough to spend the time and effort in order to be able to record something interesting about the natural world.

With this pilot study as well as the experiences gained by the first author during his multi-year study conducted in Taipei (unpublished data), we were able to demonstrate that the documentation of the breeding phenology and breeding success of barn swallows and possibly other swallow species is easily possible by citizen scientists. Therefore, we suggest that the implementation of a nationwide monitoring network of urban swallows would have the following benefits.

1. The Taiwan BBS monitors population changes, but it generates no data on breeding phenology and breeding success. Monitoring bird populations such as swallows would augment the BBS with data on breeding phenology and breeding success, which can then be linked to variables related to weather, climate change, urban environment, and so on. Thus, inferring causal changes for bird population changes may become stronger, such as the influence of artificial light (Dominoni *et al.* 2020; Wang *et al.*

2021), breeding date (Pagani-Núñez *et al.* 2016), climate change (Cooper *et al.* 2014; García-Pérez *et al.* 2014) or nest-site selection (Safran 2006) on breeding phenology and breeding success.

2. Since swallows are extremely easy to monitor, they should be an ideal study species for student or citizen science monitoring projects, even including children and high school students. To be able to monitor a bird species without much prior knowledge and with little equipment can entice more people to become enthusiastic citizen scientists, which then often leads to these people to become interested in birdwatching, conservation work, and environmental advocacy. Children and teenagers are especially interested in observing natural phenomena, and interactions with nature are important for their mental and physical development and well-being (Taylor *et al.* 2001; Louv 2009; Moss 2012; Zhang *et al.* 2014). Still, school children in Taiwan spend way too much time in the classroom and too little outside experiencing the real world as it is (CNA 2020).

3. Swallows are insectivores which consume large amounts of insects, including noxious ones, such as flies, mosquitoes, and plant pests. Therefore, they could be used for educational purposes, such as illustrating the ecosystem services of birds (Whelan *et al.* 2015; Sekercioglu *et al.* 2016; Michel *et al.* 2020) and a healthy urban environment (Dearborn and Kark 2009; Goddard *et al.* 2009; Ahern *et al.* 2014). Many Taiwanese people have a positive attitude towards nesting swallows (see Introduction), and therefore swallows would make a great “mascot” or “messenger” for attracting people to learn about birds and perhaps also become citizen scientists who collect data about breeding behavior.

4. Of course, the purely observational approach used in this study is not useful if more detailed data need to

be gathered, e.g., blood samples or the changing weight of the nestlings, but the advantages are that it is very easy to learn and quick to conduct with minimal disturbance to the breeding birds, which is essential for citizen scientist studies. Nevertheless, one could imagine that the monitoring could be expanded to gather more scientific data. For example, we suggested several times above in the Discussion that temperature is an important factor influencing breeding phenology and success. However, we did not collect any data to support this supposition. Citizen scientists could perhaps quickly measure the ambient temperature every time they visit the nest, or, even better, continuous temperature monitors could be installed and maintained by the citizen scientists (Croston *et al.* 2018). Another factor which influences breeding success and even adult survival is parental visitation rates (Öberg *et al.* 2015) and nest predation (Wang and Hung 2019). Again, citizen scientists could record visitation rates for a period of time (e.g., 30 minutes) or could install and maintain data-loggers (Pierce and Pobprasert 2013; Öberg *et al.* 2015). In short, monitoring by citizen scientists of swallow nests allows many possibilities to collect interesting and valuable scientific data.

CONCLUSION

These benefits should also apply to many other countries which have easily observable urban swallow populations, e.g., China, Malaysia, and South Korea (Pagani-Núñez *et al.* 2016; Choi and Kwak 2019; Jiang *et al.* 2019; Mansor *et al.* 2021; Tian *et al.* 2022; Zhao *et al.* 2022; Kim *et al.* 2023). Notably, China has barn swallow populations in most cities (Zhao *et al.* 2021) as well as a burgeoning community of dedicated birdwatchers (Walther and White 2018), and successful citizen science projects have already been conducted, e.g., for the scaly-sided merganser (*Mergus squamatus*) (Zeng *et al.* 2018). Citizen science is now used worldwide to monitor biodiversity at various spatial and temporal scales (e.g., Dickinson *et al.* 2010; Hochachka *et al.* 2012; Sullivan *et al*. 2014; Chandler *et al*. 2017; Hong *et al.* 2018). We here add a simple and non-intrusive citizen science method for monitoring the breeding phenology and breeding success of urban swallows, which we hope will find widespread adaptation in many places and situations.

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Table 1. English and Chinese names of the streets in Gushan District, Kaohsiung, which we regularly monitored for barn swallow nests during our study.
表格 1. 我們在研究期間定期監測的家燕燕巢位於高雄市鼓山區街道的英文和中文名稱。

English street name	Chinese street name
Binhai 1st Road	濱海一路
Binhai 2nd Road	濱海二路
Chang-an Street	長安街
Gunan Street	鼓南街
Gu-po Street	鼓波街
Guyuan Street	鼓元街
Linhai 1st Road	臨海一路
Linhai 2nd Road	臨海二路
Lisyong Street	麗雄街
Yanping Street	延平街

Fig. 1. A typical porch (or colonnade) of a Taiwanese city house in Xinyi District, Taipei. The vertical walls inside these colonnades are preferred nesting places for swallows (white arrow). Insert: Four barn swallow nestlings a few days before they fledge (16 May 2013). Photos taken by the first author.

圖 1. 台北市信義區台灣城市住宅的典型門廊（或柱廊）。 這些柱廊內的垂直牆壁是燕子的首選築巢地（白色箭頭）。 插入：離巢前幾天的四隻家燕幼鳥（2013 年 5 月 16 日）。 照片由第一作者拍攝。

Fig. 2. Left: A closed-tunnel nest of the striated swallow attached to the corner of a colonnade's roof. Right: Two open bowl-shaped nests of the barn swallow attached to the vertical wall just below a colonnade's roof. Sometimes, people provide the swallows with a nesting platform or basket, such as the nest on the right. Photos taken by the first author in Gushan District, Kaohsiung (left panel, 12 August 2020) and Xinyi District, Taipei (right panel, 3 June 2013).

圖 2. 左圖：赤腰燕在封閉隧道內的巢穴，附著在柱廊屋頂的一角。右圖：兩個開放的碗狀家燕燕巢附著在柱廊屋頂下方的垂直牆上。有時，人們會為燕子提供築巢的平台或籃子，例如右側的巢穴。第一作者在高雄市鼓山區（左圖，2020 年 8 月 12 日）和台北市信義區（右圖，2013 年 6 月 3 日）拍攝的照片。

Fig. 3. Map of the study area in Gushan District, Kaohsiung. Both sides of each street within the red line were monitored for barn swallow nests, including all the streets along the border. Map made by the second author.

圖 3. 高雄市鼓山區研究區域地圖。家燕巢穴的監測範圍為紅線內每條街道兩側（包括邊界沿線的所有街道）。地圖由第二作者製作。

Fig. 4. The first author holding a mirror attached to a long metal stick to peer inside one of the barn swallow nests found inside a city house's colonnade. Photo taken by the second author in Gushan District, Kaohsiung (12 August 2020).

圖 4. 第一作者拿著一面附在一根長金屬棒上的鏡子，觀察在城市房屋柱廊內發現的一個家燕燕巢的內部。 照片由第二作者 在高雄市鼓山區拍攝（2020 年 8 月 12 日）。

Fig. 5. Barn swallow nestlings (left panel, 8 May 2013) and fledglings (right panel, 17 May 2013) as defined for the purpose of this study (see Methods for details). Photos taken by the first author in Xinyi District, Taipei.

圖 5. 為本研究目的而定義的家燕雛鳥（左圖，2013 年 5 月 8 日）和幼鳥（右圖，2013 年 5 月 17 日）（詳見方法）。照片由第一作者在台北市信義區拍攝。

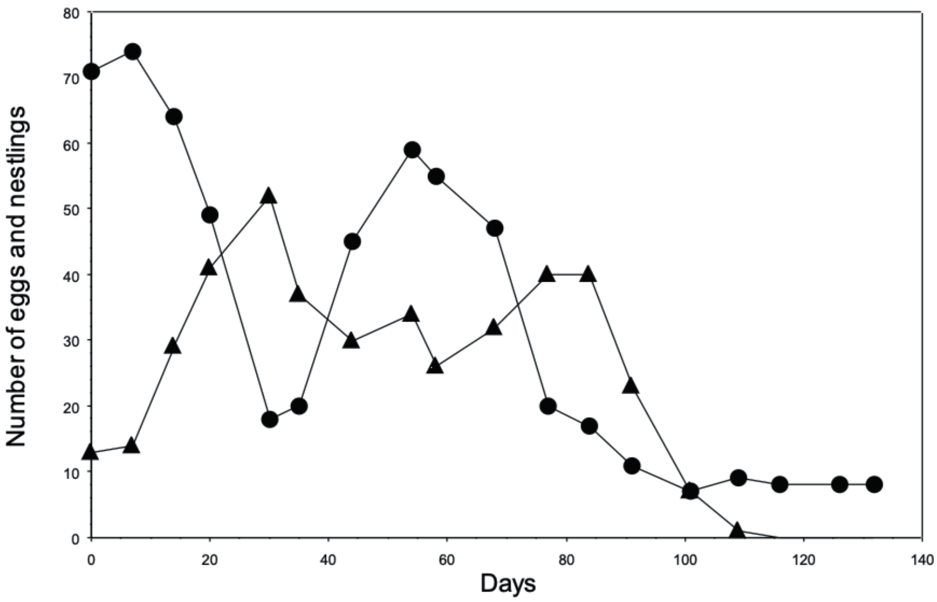

Fig. 6. The number of eggs (full circles) and nestlings (full triangles) observed in 46 active barn swallow nests from 7 April to 17 August 2019 in Gushan District of Kaohsiung (days 0-23 represent April, days 24-54 represent May, days 55-84 represent June, days 85-115 represent July, and days 116-132 represent August).

圖 6. 2019 年 4 月 7 日至 8 月 17 日高雄市鼓山區 46 個活躍燕巢觀察到的蛋（實心圓圈）和雛鳥（實心三角形）數量（第 0-23 天代表 4 月，第 24-54 天代表 5 月，天數 55-84 日代表 6 月，85-115 日代表 7 月，116-132 日代表 8 月）。

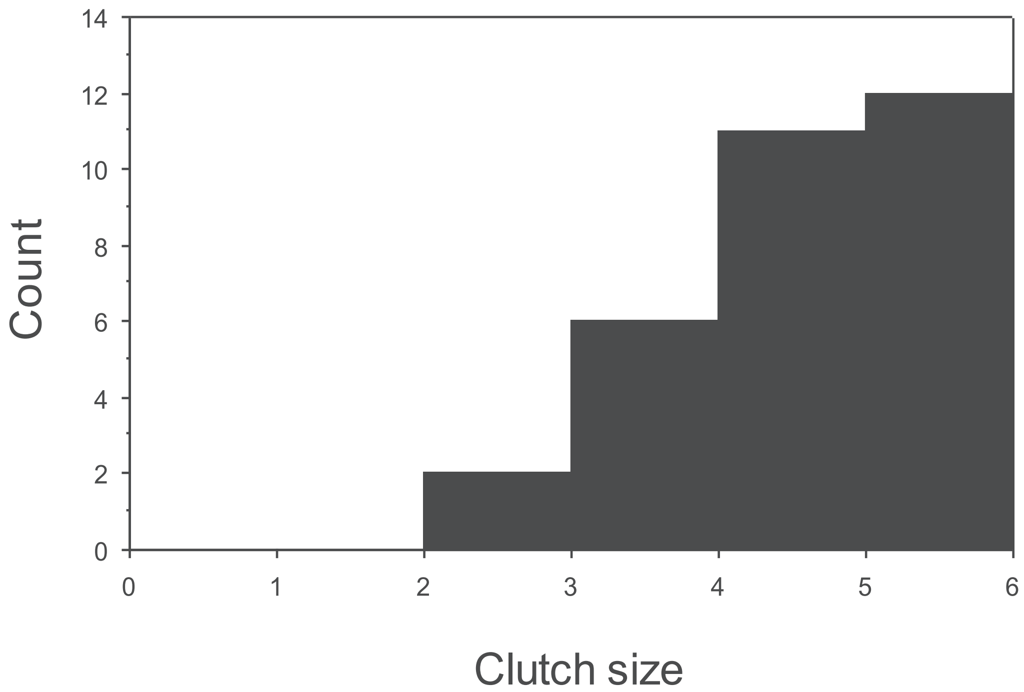

Fig. 7. Histogram of the clutch sizes of the 31 nests of the first breeding attempt.
圖 7. 第一次繁殖嘗試的 31 個燕巢窩卵數直方圖。

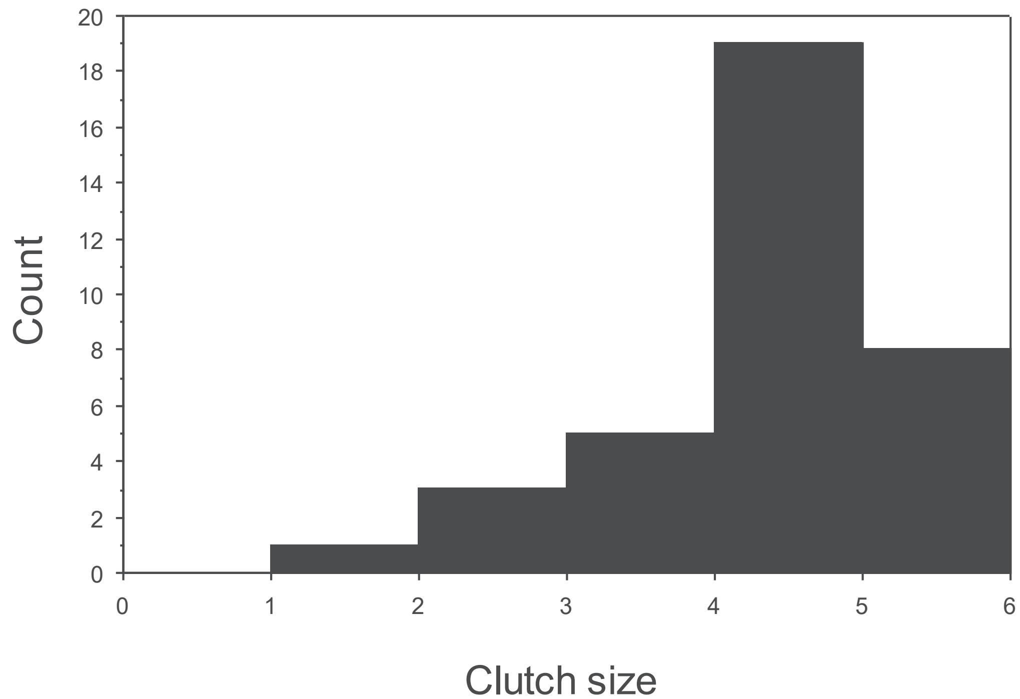

Fig. 8. Histogram of the clutch sizes of the 36 nests of the second breeding attempt.
圖 8. 第二次繁殖嘗試的 36 個燕巢窩卵數直方圖。