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RESEARCH PAPER

Phenological changes in arrival and breeding in common swifts (*Apus apus*) in central Israel

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Abstract. This study examines phenological shifts in arrival dates of common swifts (*Apus apus*) in Givatayim, central Israel, from 2015 to 2023. Utilizing data from closed-circuit television (CCTV) camera footage in urban nest boxes, we observed a significant advancement of 16 days in the species' arrival from 2015 to 2023. Our methodological framework involved monitoring dates of the swifts first (FAD), second, and median arrival dates, followed by statistical analyses to reveal temporal trends. We discovered a strong relationship between FAD and subsequent breeding milestones, such as egg laying, hatching, and fledging period, clarifying the potential impact of early arrivals on common swift reproductive timing. Phenology showed no relationship with temperature in early spring. Our results confirm the results of previous studies on other species, i.e. that common swifts are arriving earlier at their breeding grounds in central Israel.

Key words: phenology, ambient temperature, urban biodiversity, first arrival

Introduction

The common swift (*Apus apus*) is one of several migratory avifauna that are presently confronting challenges characterised by profound human impacts on global ecosystems (Laurance 2019). Renowned for their remarkable aerial prowess and pivotal role in regulating insect populations within urban locales (Nocera et al. 2012), these birds face formidable threats to their survival and reproductive success owing to rapid urbanization and climatic shifts, both characteristic of contemporary times (Zatoński 2016). Urbanization, marked by the expansion of human-built habitats, emerges as a primary driver reshaping biodiversity and ecosystem dynamics (He & Silliman 2019, Turvey & Crees 2019). For urban-adapted species such as the common swift, modern construction practices favouring materials such as glass, steel, and marble leave little room for nesting cavities, disproportionately affecting local avian populations and exacerbating urban population declines in the species (McDonald 2008, McDonald et al. 2008).

Amidst a recent surge in urban renovation projects rendering traditional nesting sites scarce (e.g. in England – Newell 2019; in Poland – Zatoński 2016), nest-boxes have emerged as a vital refuge for cavity-nesting species in central Israel (A. Hahn, unpublished data). This scarcity of traditional, urban nesting sites is compounded by the impacts of climate change, and especially increased ambient temperatures, which have demonstrably altered various biological phenomena (e.g. predator-prey mismatches – Damien & Tougeron 2019; species distribution – Márquez et al. 2011; invasive species – Finch et al. 2021; disease

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dynamics – Metcalf et al. 2017), including avian migration patterns (Horev et al. 2010, Zduniak et al. 2010). Recent investigations have documented notable shifts in the migration timing of the common swift and other avian species, suggesting plausible impacts of climate change on their lifecycle (e.g. northward expansion – Brommer 2004; reduction in body mass – Yom-Tov 2001; decline in breeding success – Rajchard et al. 2006, but see Gordo 2007). Recognizing this plight, the Friends of the Swifts (FoTS), a non-profit, non-governmental organization, has spearheaded efforts to install alternative nesting sites, specifically in the form of nest boxes fitted with cameras (Hahn & Yosef 2020, 2021). These nest boxes, whose primary objective is to provide nesting habitat for the common swift, also facilitate the placing of displaced nestlings that accidentally fall out of their nests into active nests with nestlings of similar age (Hahn & Yosef 2020), allowing insights into unusual behaviours (Hahn & Yosef 2021).

The International Union for Conservation of Nature (IUCN) currently classifies the common swift as of Least Concern (BirdLife International 2021). However, a concerning 10-year decreasing trend of 21% observed across Europe (Pan European Common Bird Monitoring Scheme 2020 – https://pecbms.info/report-on-the-paneuropean-common-bird-monitoring-scheme-june-2020/) has prompted its classification as Endangered on numerous national Red Lists (Eaton et al. 2009, Crowe et al. 2010, Stanbury et al. 2017, British Trust for Ornithology – BTO 2018). This disparity between the IUCN classification and national assessments underscores the need for focused research on urban populations of the species and their response to environmental fluxes (Grimm et al. 2008, Fraissinet et al. 2023).

The common swift, a migratory species, arrives in Israel in early spring, where it nests for a brief period of just over three months, after which they return to sub-Saharan Africa with their offspring (Åkesson et al. 2012), earning them the nickname 'the 100-day bird' in Israel (Tigges 2003). Notably, evidence suggests a decline in Israel akin to trends observed in European countries (Miroz et al. 2017).

Here, we record the return of the first breeding swifts to nest boxes at the residence of the lead author in Givatayim, central Israel. We then examine common swift arrival patterns in Givatayim over nine years, hypothesising that any earlier spring arrival will correlate with escalating temperatures.

Material and Methods

Study area

Givatayim (32°04′17′′ N, 34°48′36′′ E), literally "two hills" in Hebrew, is so called because it was established in 1922, east of Tel Aviv, as a city built on two hills (85 m a.s.l.). Owing to the urban expansion of central Tel Aviv-Jaffa encompassing all its suburban cities and towns, including Givatayim, it now forms part of the Greater Tel Aviv metropolis known as Gush Dan. The municipal area of Givatayim is 3.21 km^2 and its population has grown from ca. 9,800 residents in 1948 to 61,924 in 2022, i.e. a density of 19,000 ind./km^2 (Israel Central Bureau of Statistics, retrieved 1 July 2024, https://www.gov.il/en/search?queryD&btnSearchPageSearch=&OfficeId=). It is the second most densely populated city in Israel and renovation plans will make it the densest of all cities (Nisani 2022 – https://en.globes.co.il/en/article-new-plan-calls-for-expanding-givatayims-population-by-66-1001425029). Of the original habitats, natural areas at present represent ca. 1.4% of the city (Kapaliuk & Wolfson 2016).

The FoTS has undertaken an international initiative to support urban common swift populations by retrofitting 35 nest boxes on public buildings in Givatayim. These nest boxes, constructed of 16 mm birch plywood measuring 110 × 30 × 18 cm (L × B × H), feature six equal-sized cells (31 × 28 × 16 cm each), with entrance holes drilled into either the sides or the bottom of the front side (Fig. 1).

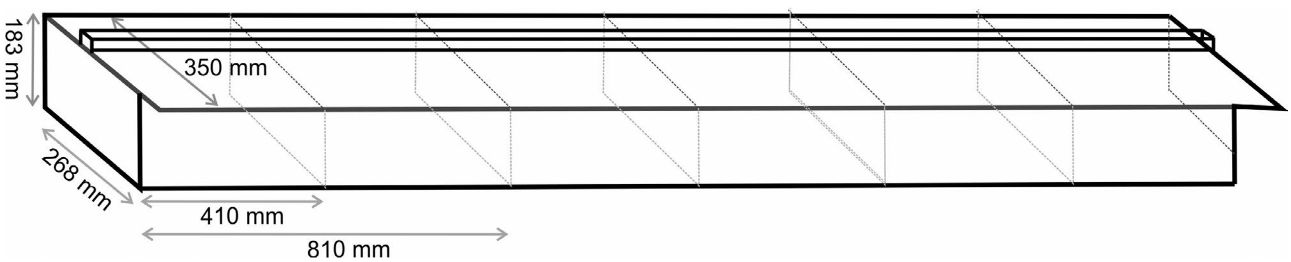

Fig. 1. Illustration of the six cells in each nest box complex, retrofitted in central Israel by Friends of the Swifts.

Additionally, since 2019, CCTV cameras have been strategically placed in eight occupied nests to monitor the breeding ecology of swifts (Hahn & Yosef 2020, 2021, 2022). These cameras have been used to help document the first arrival day (FAD) and second arrival day (SAD). Before the installation of cameras, A. Hahn had to watch the nest boxes from his window, a distance of ca. 6 m, to establish the arrival dates of breeding pairs.

Maximum monthly air temperature data from January to April 2015 to 2024 were obtained from the website of the Israel Meteorological Service (https://ims.gov.il/en/data_gov).

Statistical analysis

To accurately determine FAD and SAD, we employed a standardized observational protocol that included daily monitoring of nest boxes from early spring until the arrival of the first individuals. Observations were conducted by a team of researchers led by A. Hahn, supplemented by data from the CCTV cameras installed in selected nest boxes. All observations were recorded and verified in real time to ensure the highest accuracy of arrival dates. When the first individual occupying an empty nest box was observed, it was considered as FAD. When the second individual of a pair was observed in the box, whether using the cameras or simple observations, it was considered as SAD.

All basic statistical analyses, including Spearman correlations and linear regression model slopes, were conducted following the guidelines outlined by Zar (1999) and implemented using R software (R Core Team 2024). Locally weighted scatterplot smoothing (LOWESS) was employed to depict phenological trends. LOWESS is a non-parametric regression technique which facilitates the creation of a smooth line for a scatter plot to discern the underlying trend in the data. This method operates by fitting multiple regressions in localized subsets of the data, allowing it to adapt to various data structures without assuming a predefined global model form.

In the period between 2005 and 2015, where direct observational data were unavailable, the trend in FAD was estimated using the LOESS (locally estimated scatterplot smoothing) method implemented in the *ggplot2* package in R (Wickham 2016). LOESS is a non-parametric regression technique that fits a smooth curve to data points by performing localized regressions, which is particularly useful not only for modelling non-linear relationships in time series data (Cleveland & Devlin 1988) but also when faced with the absence of continuous data (Fan & Gijbels 1996, Loader 1999). The application of LOESS smoothing is widely recognized in ecological and environmental studies for estimating missing data and capturing underlying trends (Hastie & Tibshirani 1990, Loader 1999).

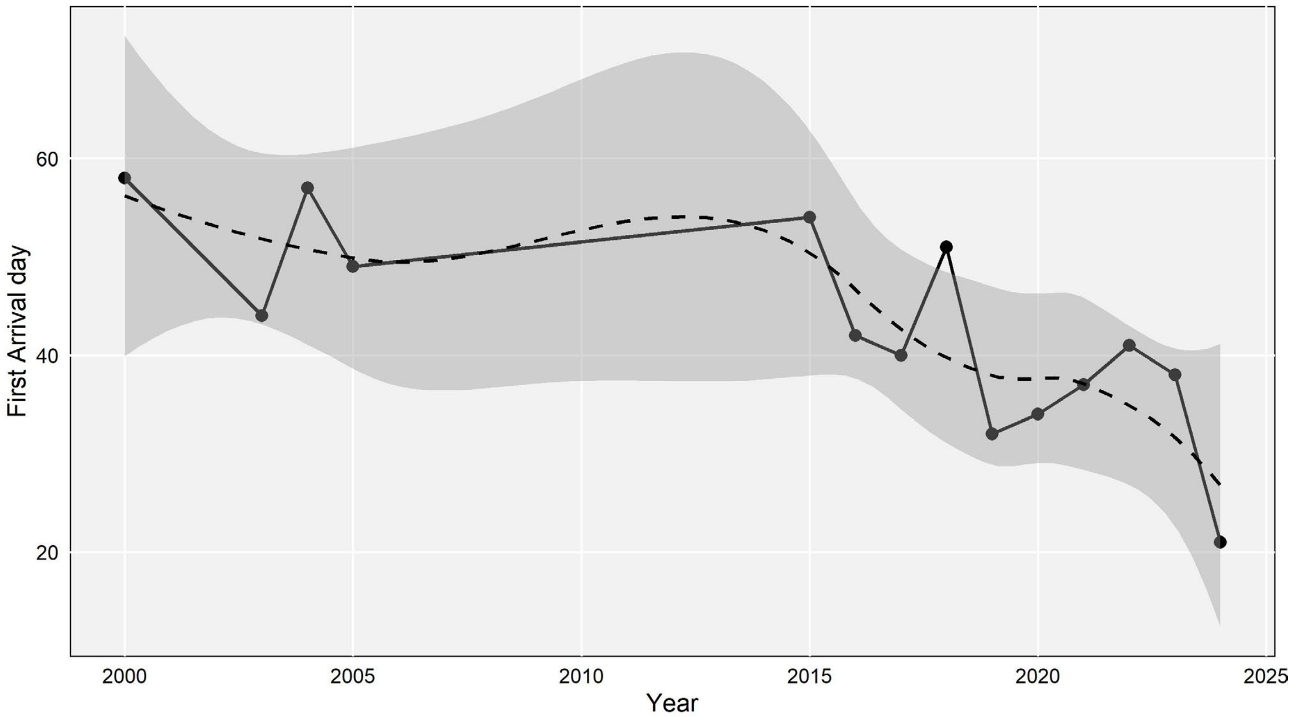

Fig. 2. First arrival dates (days after 31st December) of common swifts in Givatayim, Israel, from 2000 to 2023 (solid lines). The dashed line represents the LOWESS fit, and the grey areas show the standard error for this estimate.

Results

The entire documented population consisted of 40 breeding pairs. FAD was observed for 16 breeding pairs between 2000 and 2005, and for 39 pairs from 2015 to 2024, while SAD was observed for 36 pairs between 2020 and 2023. The remaining reproductive parameters, such as first egg-laying day (FELD), hatching day and fledging period, were determined for 29 broods between the years 2019 and 2023.

Over the study period, the FAD of common swifts in Givatayim displayed noteworthy variability from January 21 to February 27, with a median arrival date (MAD) of February 10 (n = 14 years). Similarly, SAD ranged between February 11 and March 28, with a MAD of February 21 (n = five years). MAD for swifts fluctuated between February 8 and March 5 across the study years (n = five years). A significant correlation was observed between SAD and FAD (r = 0.67, P = 0.03) and between SAD and MAD (r = 0.81, P = 0.01). However, there was no correlation between FAD and MAD (r = 0.03, P = 0.57).

Over the study duration, FAD exhibited a pronounced trend toward earlier arrival, confirmed by a significant negative slope of –0.928 ± 0.248 (t = –3.737, P = 0.002; Fig. 2), indicating a progressive advancement in swift arrivals across the years. In contrast, changes in SAD (slope 0.02 ± 0.185, t = 1.135, P = 0.339) and MAD (slope 0.03 ± 3.228, t = 1.007, P = 0.338) were not significant. The arrival times of the first and second individuals within a pair were not synchronized (r = 0.10, P = 0.889).

Between 2020 and 2023, FELD ranged from January 22 to May 13, with a median occurrence on April 5 (n = 29). This crucial breeding parameter exhibited a significant correlation with FAD (r = 0.57, P = 0.0001; Fig. 3a), indicating a linkage between the timing of swift arrival and the onset of egg-laying activity. Similarly, hatching day showed considerable variation, ranging from March 19 to June 7, with median occurrence on April 29 (n = 28). Hatching day was significantly associated with FAD (r = 0.699, P < 0.001; Fig. 3b). The fledging period, which extended from April 15 to July 10, with a median occurrence on June 2 (n = 28), was also found to be dependent on FAD (r = 0.533, P = 0.004; Fig. 3c).

Discussion

Over 14 years, from 2000 to 2023 for FAD and from 2015 to 2023 for other phenological and

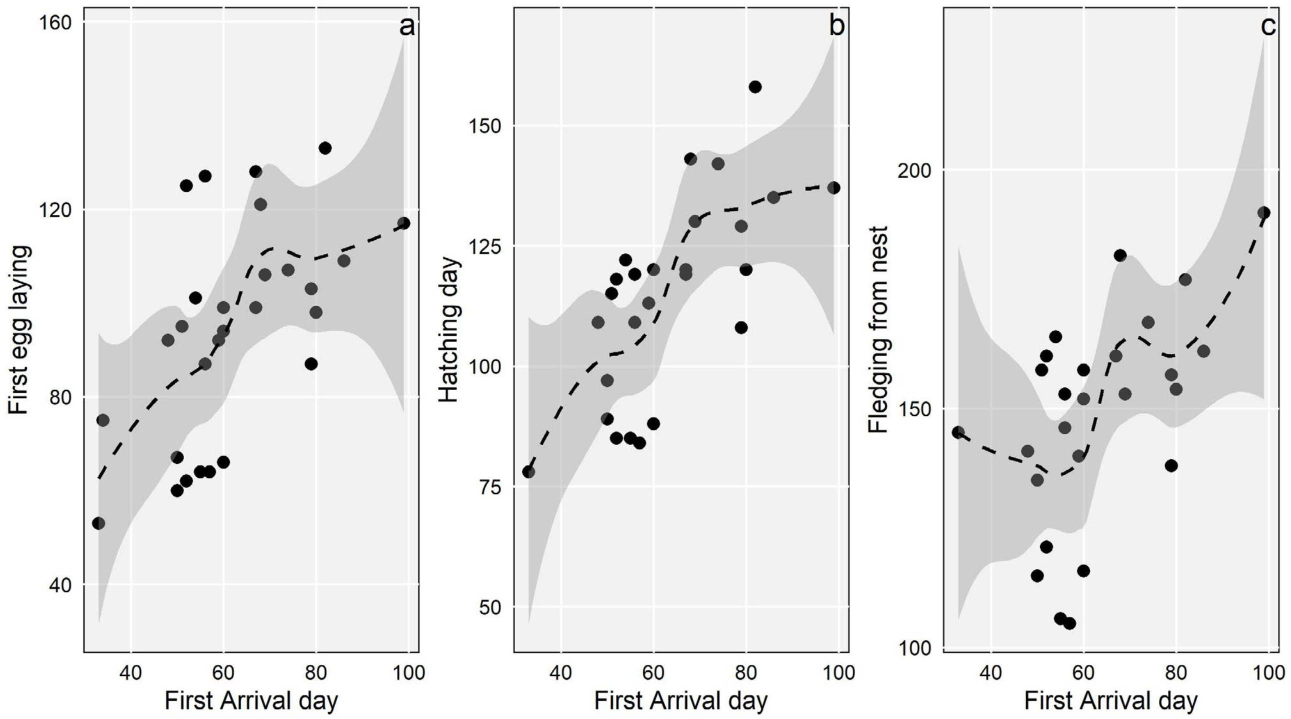

Fig. 3. Relationship between a) the first arrival day (FAD) and the first egg-laying day (FELD), b) FAD and hatching day, and c) FAD and fledging. The dashed line represents the LOWESS fit, and the grey areas show the standard error for this estimate. The average maximum temperature from January to April did not affect any of the phenological parameters we analysed (FAD, second arrival day (SAD) and Median). The slope of the regression function did not differ significantly from 0 (P > 0.05 in all cases). Similarly, reproductive parameters (FELD, hatching day and fledging from the nest) were not dependent on temperatures for these months (P > 0.05).

breeding parameters, we documented a significant advancement in the arrival dates of common swifts, with the first arriving 16 days earlier in 2023 compared to 2000. Our findings highlight the influence of arrival timing on the breeding dynamics of common swifts, as earlier arrivals correlate with advanced breeding activities. This trend has implications for the conservation and management of this species amid evolving environmental conditions. Hatching day was significantly associated with FAD, underscoring the impact of arrival timing on hatching activities. The FAD and SAD within a pair were not synchronized, and this asynchrony may imply that individual swifts respond differently to environmental cues or are influenced by other factors, such as intraspecific competition, individual condition, or environmental conditions on migration (Åkesson et al. 2012, 2020). Similar findings in other migratory species suggest that asynchrony within pairs could impact reproductive success and coordination (Both et al. 2004, Rajchard et al. 2006).

These results suggest that relying solely on the first recorded individual each year (i.e. FAD) to determine arrival patterns could be misleading as a single observation may be an anomaly and not accurately represent the entire population's migratory pattern (Gordo et al. 2007). Instead, using population measures such as MAD and SAD should provide a more reliable indicator, capturing actual migratory patterns and minimizing the impact of random or extreme observations (Sparks et al. 2001, Ptaszyk et al. 2003).

The fledging period, from April 15 to July 10 (median June 2), depended on FAD, highlighting how arrival timing affects fledging. These findings underscore the interplay between swift migration and breeding parameters, illuminating the profound influence of arrival timing on the reproductive cycle of common swifts.

The advancement in arrival timing suggests a potential mismatch between the swifts' migration schedule and the availability of suitable breeding resources, such as food and/or nesting sites (Damien & Tougeron 2019), i.e. earlier arrivals may challenge swifts in synchronizing breeding activities with optimal conditions, potentially impacting reproductive success (Rajchard et al. 2006).

Our analysis showed that temperature does not affect breeding biology or any of the phenological parameters we analysed, contradicting our hypothesis that rising temperatures would be the cause of earlier spring arrivals. This finding suggests a complex interaction between temperature and migratory behaviour (Gordo et al. 2007), possibly mediated by other environmental factors or internal physiological mechanisms (Berthold 2001). Alternatively, the decoupling of arrival and reproductive timing from local temperatures could result from the buffering effects of microclimates in urban habitats or other environmental variables, such as food availability and/or predator pressure (Tryjanowski et al. 2002, Dunn 2004, Gordo et al. 2007).

Earlier arrival may increase competition for limited nesting sites, especially in urban areas where modern construction limits suitable cavities. This competition could constrain breeding success and population resilience, necessitating conservation measures (Van Rooyen 2009, Reynolds et al. 2019). We suggest that efforts should focus on preserving and enhancing nesting habitat for common swifts in urban environments, including nest box programs (Schaub et al. 2016), habitat restoration (Finch et al. 2022), and urban planning policies that integrate wildlife-friendly features and prioritize green spaces (Braun et al. 1999, Zatoński 2016).

Monitoring swift populations is crucial for understanding the effects of arrival timing changes and for informing adaptive management strategies. By addressing challenges posed by early arrivals and ensuring suitable breeding resources, we could enhance the resilience of common swifts in urban settings. Earlier arrival times could indicate 1) multifactorial changes at wintering grounds (Evans et al. 2012), 2) changes in habitat and large-scale weather patterns along the migratory routes (Åkesson et al. 2012), or 3) shifts in resource availability (e.g. nest sites, aerial plankton) due to urbanization (Braun et al. 1999).

Acknowledging our study's limitations, including its focus on a specific species within an urban context, we emphasize the need for broader, multi-species, multi-year, and multi-regional studies to understand the impact of urbanization and climate change on migratory avifauna (Morelli et al. 2016, 2020). We advocate for expanded conservation initiatives, such as installing nest boxes in urban areas, to support common swift breeding success. Further research should also examine urban environments as potential refuges for migratory birds facing climate change and habitat loss.

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Author Contributions

A. Hahn, R. Yosef conceptualization, data curation; J.Z. Kosicki, R. Yosef analyses and quality control; R. Yosef, J.Z. Kosicki writing the first draft; R. Yosef, J.Z. Kosicki, A. Hahn writing the final draft.

Data Availability Statement

The data supporting this study's findings are available in the Mendeley Data, version 1: doi: 10.17632/wnnwmmf9bx.1.

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