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FROM THE ADRIATIC TO NORTH AFRICA: SEVEN YEARS OF MOVEMENT PATTERNS OF AN AUDOUIN'S GULL

Od Jadrana do sjeverne Afrike: sedam godina kretanja sredozemnog galeba

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ABSTRACT

GPS–GSM transmitters provide an opportunity to investigate bird movements at spatial and temporal resolutions that cannot be achieved through ringing. This is particularly valuable for understanding movements of threatened seabirds such as Audouin's Gull *Larus audouinii*, whose migration and wintering areas are often poorly known and long-term tracking of an individual bird is still infrequent. We present a seven-year GPS tracking dataset (2017–2024) from an adult female captured while breeding in the Lastovo Archipelago, Croatia. We investigated annual movements, spatial use during the extended breeding and wintering periods, migration routes, stopover use, and interannual consistency. The individual showed considerable prospecting and flexibility in breeding site selection, moving between colonies while maintaining high fidelity to the broader area. During the extended breeding period, movements were generally restricted within 30 km of the colony, whereas wintering ranges were considerably larger and concentrated along the Libyan coast, particularly around Gulf of Sirt. Migration was rapid and relatively direct, with few stopover sites and a median duration of 4.75 days in both directions. Despite annual variation in migration duration and route, coastal areas of Italy, Malta, and Tunisia were

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repeatedly used. These results reveal a combination of itinerant breeding behaviour, regional fidelity, wintering-range consistency, and flexible migration in this species.

Keywords: *Larus audouinii*, GPS-GSM transmitter, migration, breeding, wintering, Italy, Croatia

INTRODUCTION

The development and increasing affordability of miniature tagging devices has created opportunities to collect detailed information on bird movements, with fine-scale trajectories recorded over thousands of kilometres (Guilford *et al.* 2011). Previously, information was mostly provided by ring recoveries, which offered limited insight into broad movement patterns and area use (Bridge *et al.* 2012, Fiedler 2009). Today, various GPS and satellite tracking devices provide accurate, near real-time locations almost anywhere in the world and, through online data platforms, allow efficient management, mapping and visualisation of movement data (Bridge *et al.* 2012, Soriano-Redondo *et al*. 2020). Some are solar powered, allowing the collection of movement data over long periods and thus providing long-term information on birds' movement decisions and flexibility (Fiedler 2009). These devices are an excellent tool for gathering information on long-lived birds to improve understanding of which areas they use, not only during breeding, but also during migration and the wintering period, which are often less accessible for study than breeding sites, and how these changes with age. Long-term studies are also helpful for assessing the threats they may be exposed to (Ponti *et al*. 2024), and this is especially important for endangered seabird species, which are often difficult to study because they breed in remote areas.

The Audouin's Gull *Larus audouinii* is a Mediterranean endemic seabird whose breeding distribution is largely restricted to colonies around the Mediterranean basin and the south-western Iberian Peninsula (Oliveira *et al*. 2025). Although the species has been the subject of numerous studies, knowledge of its movements has relied on ringing recoveries, with most information originating from breeding populations in Spain and Corsica. These studies indicate that western Mediterranean birds generally migrate towards the Atlantic coast of northwestern Africa, while some individuals remain close to their breeding colonies throughout the year (Oro & Martinez 1994, Recorbed *et al*. 2012). However, the migration and wintering ecology of central and eastern Mediterranean breeding populations remains poorly understood because most available information is based on ringing recoveries rather than continuous tracking. Although ring recoveries suggest that birds breeding in Croatia and Greece primarily follow a central Mediterranean flyway, passing through Italy and Malta before wintering along the North African coast of Libya, Tunisia and Egypt (Croatian Institute of Ornithology Archives, EGA - RAC/SPA Waterbird Census Team 2012,

Mullin *et al*. 2012, Oliveira *et al*. 2025), these movements have never been described using long-term GPS tracking for birds breeding in the Adriatic Sea. The Audouin's Gull is an endangered species in Croatia, with a declining breeding population (Jurinović 2013, Jurinović *et al.* 2024, Engelen & Ječmenica 2025). For conservation purposes, a better understanding of its spatial behaviour was needed, so the first tagging was conducted in 2017 (Jurinović *et al.* 2019), with additional tagging carried out during the LIFE Artina – Future for Seabirds project (Zec *et al.* 2023).

Although numerous tracking studies on seabirds were conducted in recent years, a limited number of devices were active during several-year periods. Thus, we present a unique seven-year GPS tracking dataset from a single adult female Audouin's Gull (2017–2024), documenting repeated annual movements between breeding and wintering grounds. Using this long-term dataset, we characterise breeding and wintering areas, migration timing and routes, and stopover use. We also quantify interannual fidelity to breeding and wintering areas and migratory routes to assess consistency and flexibility in movement behaviour. Such information is essential for identifying key breeding, stopover, and wintering areas that may require conservation attention.

METHODS

An adult female was captured using walk-in nest trap during the incubation period on 2 May 2017 at a breeding colony in the Lastovo Archipelago Nature Park (42°44′57.0″N, 16°52′36.0″E), together with four individuals. The sex was determined by analysing a blood sample using molecular methods (Fridolfsson & Ellegren 1995). The individual was fitted with a 21 g solar-powered satellite transmitter (model Saker L, Ecotone Telemetry), attached using a chest harness. The transmitter represented 3.79% of the bird's body mass at the time of tagging, which was acceptable considering that previous studies on Audouin's Gull have successfully used devices weighing up to 5% of body mass without detectable negative effects (Bécares *et al*. 2015). The device stopped transmitting data on 14 June 2024 without any indication of bird mortality (no prolonged data transmission from a single location) and with confirmed survival by Liuzzi C., who saw the bird in a healthy state, still carrying the transmitter on her back, on 25 May 2026.

The bird's tracking data were checked for duplicated timestamps and obvious location errors regarding coordinates misplacement. The duration, distance, and speed were calculated between each pair of consecutive points. Based on daily movements, measured as the daily distance travelled from the breeding colony, each track was segmented as movement associated with the breeding area, migration, or movement within the wintering grounds (Supplementary Fig. S1). Movement associated with the breeding area was characterized by

short-distance movements from the breeding colony within the Adriatic and Ionian Sea until the bird permanently left for the wintering grounds, which was defined as southward migration (Supplementary Fig. S1). Because the bird arrived before the actual breeding period (earliest in January) and stayed longer than breeding requires (until November), this period for the purpose of this study was named "extended breeding" period to cover all movement associated with breeding colony (Cramp & Simmons 2006). Migration ended when the bird reached its wintering area, defined as an area where the bird remained until it started returning to the breeding grounds, marking the start of northward migration (Supplementary Fig. S1). For migration, we identified stopover sites based on daily movements. For each day, we calculated the distance from the breeding colony. Days during which the distance changed by less than 10 km relative to the previous day were considered stationary. We used different distances as thresholds (2, 5, 10, 15 and 20 km) and selected 10 km as a highest threshold that provided the clearest distinction between stationary and moving periods. Sequences of consecutive stationary days were grouped using rleid() from the data.table package (Dowle & Srinivasan 2023), and each group was summarised by its start and end date, duration (days), and mean distance from the colony (km).

To quantify interannual variation in migration routes at specific geographic locations, predefined landmark transects (Dias *et al.* 2013) were created in QGIS and imported as vector line features (Supplementary Fig. S2). The landmarks were based on the individual's migration routes and the landscape being crossed (Supplementary Fig. S2). Migration trajectories were intersected with the landmark transects to identify the geographic positions where the bird crossed each landmark. The number of annual crossings per landmark was recorded to indicate how consistently each landmark was encountered across migration years. Additionally, we analysed the overall interannual consistency of migration routes separately for southward and northward migrations. Because migration duration and the number of GPS fixes varied among years, trajectories were standardized according to relative migration progress. For each migration, GPS locations of the trajectories were assigned a relative position along the route ranging from 0 (migration began) to 1 (migration was completed). Each track was then linearly interpolated to 100 equally spaced positions along this standardised migration axis. A mean migration trajectory was calculated by averaging the x and y coordinates at each standardised position. For each migration, route deviation was calculated as the Euclidean distance, using projected coordinates in WGS84/UTM Zone 33n (EPSG: 32633), between each interpolated GPS position and the corresponding position on the mean trajectory. Mean and maximum deviations were calculated for each annual migration to assess interannual route fidelity.

Area use during the extended breeding and wintering periods was estimated using kernel density estimation (KDE). During the extended breeding period, long-distance trips characterized as prospecting, extending more than 100 km from the colony, were excluded because they were not considered representative of local breeding movements. KDEs were calculated using the hr_kde function in the amt package (Singer *et al.* 2019). A scaled reference bandwidth was estimated using hr_kde_ref_scaled, with all observations treated as a single component (num.of.parts = 1). The resulting bandwidth was applied equally in the x and y dimensions. We estimated 50% and 95% utilization distribution isopleths, representing core-use areas and overall areas of use, respectively, during the extended breeding and wintering periods. Occurrence distribution areas were calculated from the resulting isopleths and expressed in km^2. All analyses and graphical representations were carried out in R software 4.2.1 and QGIS 3.16.11.

RESULTS

From 2017 to 2024, the tagging device on this individual provided approximately 2600 tracking days, completing seven annual migration cycles between breeding sites along the Adriatic coast of Croatia and Italy, and wintering sites along the North African coast (Libya and Tunisia) (Fig. 1). Migration movements were short and rapid, whereas the extended breeding, together with wintering periods lasted longer, with greater movement distances (Table 1). The bird attempted to breed on several breeding colonies throughout the years with breeding success unknown or failed. Additionally, the bird made frequent prospecting movements to other breeding colonies or suitable islands.

Table 1. Descriptive statistics of movement metrics for the four annual movement phases from 2017 to 2024 (northward migration, extended breeding (Jan – Nov), southward migration, and wintering). Values are presented as the median with the range (min – max) in parentheses. The extended breeding period excludes 2017 and 2024 because these tracking periods did not cover the complete period.

Tablica 1. *Deskriptivna statistika parametara kretanja za četiri godišnje faze kretanja u razdoblju od 2017. do 2024. godine (migracija prema sjeveru, produljeno razdoblje gniježđenja (siječanj – studeni), migracija prema jugu i zimovanje). Vrijednosti su prikazane kao medijan s rasponom (minimum – maksimum) u zagradi. Razdoblje produljenog gniježđenja ne uključuje 2017. i 2024. godinu jer ta razdoblja praćenja nisu obuhvaćala cjelokupno razdoblje.*

	Northward migration	Extended breeding	Southward migration	Wintering
Start	21 Feb (30 Dec – 11 Mar)	26 Feb (4 Jan – 16 Mar)	12 Nov (3 Nov – 22 Nov)	16 Nov (9 Nov – 28 Nov)
End	25 Feb (3 Jan – 15 Mar)	11 Nov (2 Nov – 21 Nov)	15 Nov (8 Nov – 27 Nov)	20 Feb (29 Dec – 10 Mar)
Track duration (days)	4.75 (1.92–14.75)	250.76 (161.75–299.75)	4.75 (1.75–8.92)	88.75 (39.75–114.75)
Total distance (km)	1249.7 (1085.16–1818.18)	9759.63 (5739.73–14267.16)	1340.66 (1090.09–1558.63)	7594.94 (3549.76–10648.51)
Maximum distance from colony (km)	965.23 (950.55–1293.58)	246.96 (199.3–287.34)	987.07 (954.43–1208.1)	1155.83 (1062.68–1399.91)

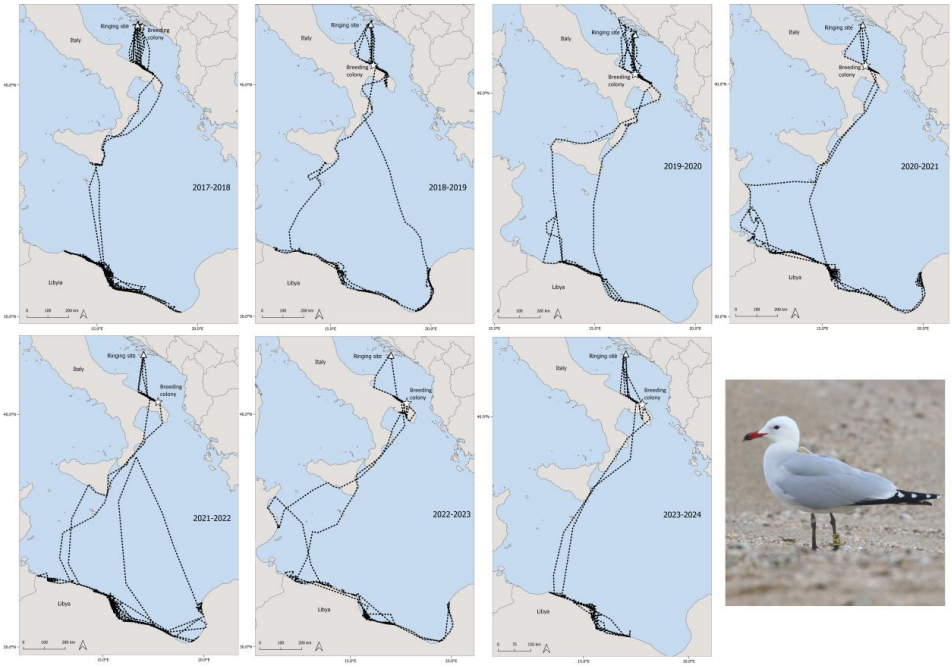


Figure 1. Annual movements of Audouin's Gull from 2017 to 2024, showing movement trajectories during the extended breeding (Jan – Nov), migration, and wintering periods. In the downright corner is the photo of the tracked female, with color ring CN, taken on January 12th, 2024 on the coast of Torre Canne (Brindisi province) by Cristiano Liuzzi.

Slika 1. *Godišnje kretanje sredozemnog galeba u razdoblju od 2017. do 2024. godine, koje prikazuje putanje kretanja tijekom produljenog razdoblja gniježđenja (siječanj – studeni), selidbe i zimovanja. U donjem desnom kutu nalazi se fotografija praćene ženke s prstenom u boji oznake CN, snimljena 12. siječnja 2024. na lokaciji Torre Canne (pokrajina Brindisi) čiji je autor Cristiano Liuzzi.*

Extended breeding area

The bird was captured while incubating eggs on the Lastovo Archipelago, Croatia, but soon afterwards breeding failed and she moved to the Italian coast, where she remained at or near the breeding colony on Eremita Rock, just south of Bari. Although this individual failed, the other four tagged individuals seemed to breed normally on Lastovo Archipelago. From 2018 to 2020 she attempted to breed on Eremita Rock, while in 2021 and 2022 she bred on the newly established colony of Giorgio Treviso Island, inside Brindisi harbour (Liuzzi *et al.* 2023), and in 2023 and 2024 she bred on La Chiesa Island, also in Brindisi harbour (Fig. 2). During the breeding months (April–July), the bird frequently visited other known breeding colonies and suitable islands, with occasional visits occurring

earlier in the season (Feb–Mar) and after the breeding period (Sep–Oct) (Supplementary Table S1).

Excluding prospecting trips to more distant breeding colonies on the Lastovo Archipelago and colonies in the Ionian Sea between Malva, Sant' Andrea and Campo Islands (Fig. 2), the area used was largely restricted to the southern Adriatic coast of Italy, extending from Eremita Rock to Giorgio Treviso Island (approximately 74 km apart), with predominantly west–east movements. The distribution of GPS points in relation to the breeding colonies showed that most GPS points were recorded within 30 km of the colonies (Supplementary Fig. S2). Locations within 15 km consistently represented the largest distance category each year (Supplementary Fig. S3).

The extended breeding area, represented by the 95% KDE utilisation estimate, varied among years, with a median of 751.26 km² and a range from 213.72 km² to 1,832.56 km² (Supplementary Table S2). The corresponding 50% KDE core areas were smaller, with a median of 137.98 km² and a range from 21.98 km² to 321.14 km².

Pairwise Jaccard similarity coefficients for the 95% KDE utilization estimates ranged from 0.12 to 0.86, with a median of 0.42, while those for the 50% KDE estimates ranged from 0.06 to 0.66, with a median of 0.40 (Supplementary Fig. S4). For the 95% KDE, the highest overlap was observed between 2023 and 2024 (Jaccard = 0.86), followed by 2019 and 2020 (Jaccard = 0.70), 2018 and 2019 (Jaccard = 0.67), and 2019 and 2022 (Jaccard = 0.61). The lowest overlap occurred between all years (except 2020) and 2017 (Jaccard = 0.12–0.28) (Supplementary Fig. S4). Similar patterns were observed for the 50% KDE, with the highest overlap between 2018 and 2020 (Jaccard = 0.66), followed by 2023 and 2024 (Jaccard = 0.63), 2018 and 2022 (Jaccard = 0.61), and 2020 and 2022 (Jaccard = 0.60). The lowest overlap was also between all years and 2017 (Jaccard = 0.06–0.17) (Supplementary Fig. S4).

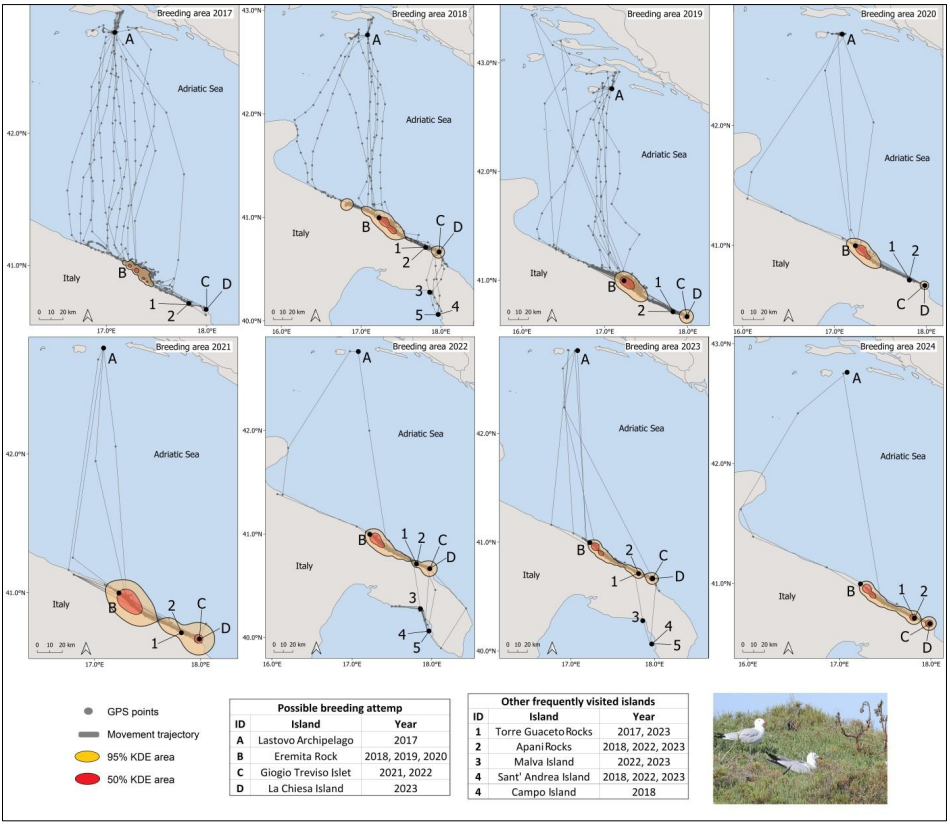


Figure 2. Annual movement of Audouin's Gull during the extended breeding period (Jan – Nov) from 2017 until 2024 with 95% and 50% KDE estimated areas. In the bottom right corner is a photo of the studied female while incubating eggs on Giorgio Treviso Island in 2021 taken by Cristiano Liuzzi.

Slika 2. *Godišnje kretanje sredozemnog galeba tijekom perioda produljenog gniježđenja (siječanj – studeni), u razdoblju od 2017. do 2024. godine, uz prikaz 95% i 50% KDE procijenjenog područja. U donjem desnom kutu nalazi se fotografija proučavane ženke tijekom inkubacije na otoku Giorgio Treviso 2021. godine, koju je snimio Cristiano Liuzzi.*

Wintering area

The birds overwintered predominantly along the Libyan coast, from Zuwara to Benghazi, with fewer records from Kerkennah Island, Tunisia (Fig. 3). Wintering areas were relatively large, with a median 95% KDE utilization estimated area of 89,844.13 km² (28,273.26–137,367.61 km²), whereas 50% areas were considerably smaller, with a median 50% KDE utilisation area of 20,285.11 km² (5,698.43–25,770.35 km²). The broad wintering areas generally included the central Libyan coast between Tripoli and Sirt, while the 50% KDE utilisation areas

showed greater interannual variation in both location and size (Fig. 3, Supplementary Table S2). Pairwise Jaccard similarity was higher for the 95% KDE (median = 0.44, range = 0.21–0.75) than for the 50% KDE (median = 0.20, range = 0.02–0.55) (Supplementary Fig. S5). For the 95% KDE, the greatest overlap was observed between winters 2021/2022 and 2022/2023 (Jaccard = 0.75), followed by 2018/2019 and 2022/2023 (Jaccard = 0.73), 2018/2019 and 2021/2022 (Jaccard = 0.67), and 2020/2021 and 2021/2022 (Jaccard = 0.61). The lowest overlap occurred between all winters (except 2019/2020) and 2023/2024 (Jaccard = 0.21–0.32) (Supplementary Fig. S5). There was low overlap for the 50% KDE utilisation areas, with the highest overlap occurring between 2017/2018 and 2021/2022 (Jaccard = 0.55), followed by 2020/2021 and 2021/2022 (Jaccard = 0.43) and 2017/2018 and 2022/2023 (Jaccard = 0.42). Other winters showed low overlap, with Jaccard similarity index lower than 0.29.

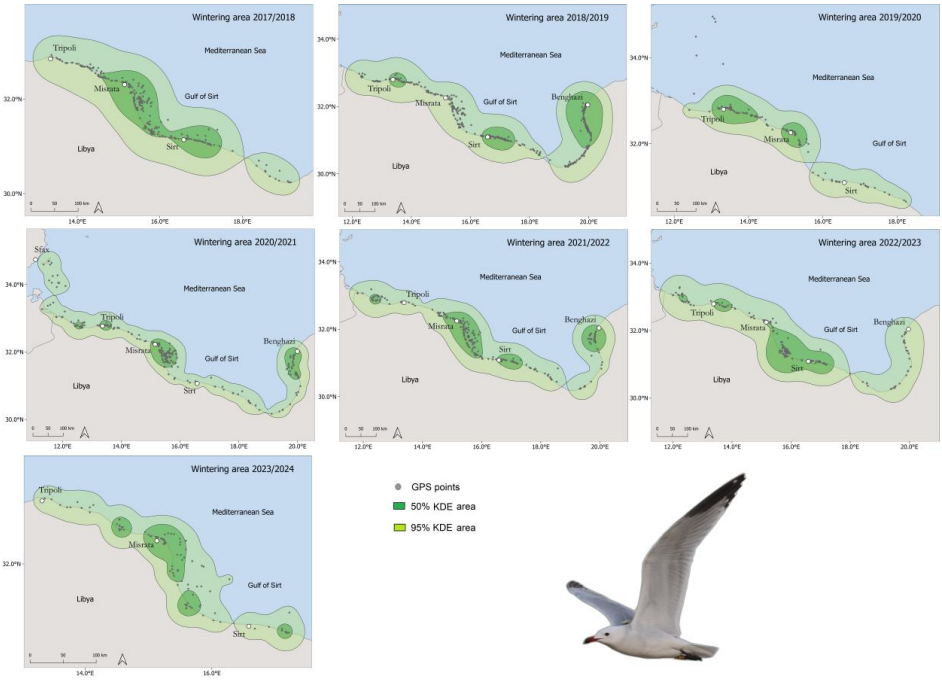


Figure 3. Annual movement of Audouin's Gull during the wintering period from 2017 to 2024. with 95% and 50% KDE estimated areas.

Slika 3. *Godišnje kretanje sredozemnog galeba tijekom razdoblja zimovanja od 2017. do 2024. godine, s prikazom 95% i 50% KDE procijenjenog područja.*

Migration

The bird migrated quickly and directly, with a median of 4.75 travel days for both departure and return migration (Table 1). For both directions, the shortest migration lasted two days. In 2019, the bird completed the southward migration over a total distance of 1,085.15 km at an average speed of approximately 542.58 km/day. Similarly, in 2023, it completed the northward migration over 957.44 km at an average speed of approximately 478.72 km/day. The longest southward migration occurred in 2019 and lasted 9 days, during which the bird travelled 1558.63 km at an average speed of approximately 173.18 km/day. The longest northward migration occurred in 2023, lasting 15 days and covering 1818.18 km at an average speed of approximately 121.21 km/day. The second-longest northward migration occurred in 2018, lasting 12 days and covering 1,624.09 km, corresponding to an average speed of approximately 135.34 km/day.

During the southward migration, the individual used one stopover site in Italy, on the coast near the city of Crotone in 2018, where it stayed for three days at a mean distance of 211.32 km from the Eremita Rock colony (Fig. 4). During the northward migration, it used two different stopover sites. One was also in Italy in 2018, on the coast near the town of Pozzallo, where it stayed for five days at a mean distance of 697.99 km from the colony. Another stopover site was used in Tunisia, on the coast near the town of Chebba in 2023, where the bird stayed for three days at a mean distance of 851.58 km from the La Chiesa Island colony (Fig. 4).

Across seven southward migration trips, the individual deviated on average 135.40 ± 35.71 km from its mean migration path, while during northward migration it showed even less consistency, deviating on average 165.59 ± 88.72 km (Supplementary Table S3). The southward migration was more straightforward, following the south-east coast of Italy, along the east coast of Sicily, then passing near Malta to Libya (Fig. 3). The northward migration was more widespread, with one route crossing the open Ionian Sea and another following the west coast of Sicily (Fig. 4). During both southward and northward migration, landmarks T1, T2 and T5 were used over multiple years. During southward migration, one additional landmark was used (T4), while during northward migration three other landmarks were used (T3, T4 and T6). Extensive inland crossings are regularly observed in Apulia in both directions, on a width of 23.66 to 93.09 km, whereas they occurred only once in Calabria (2020, northward, 86.76 km) and Sicily (2023, northward, 78.82 km).

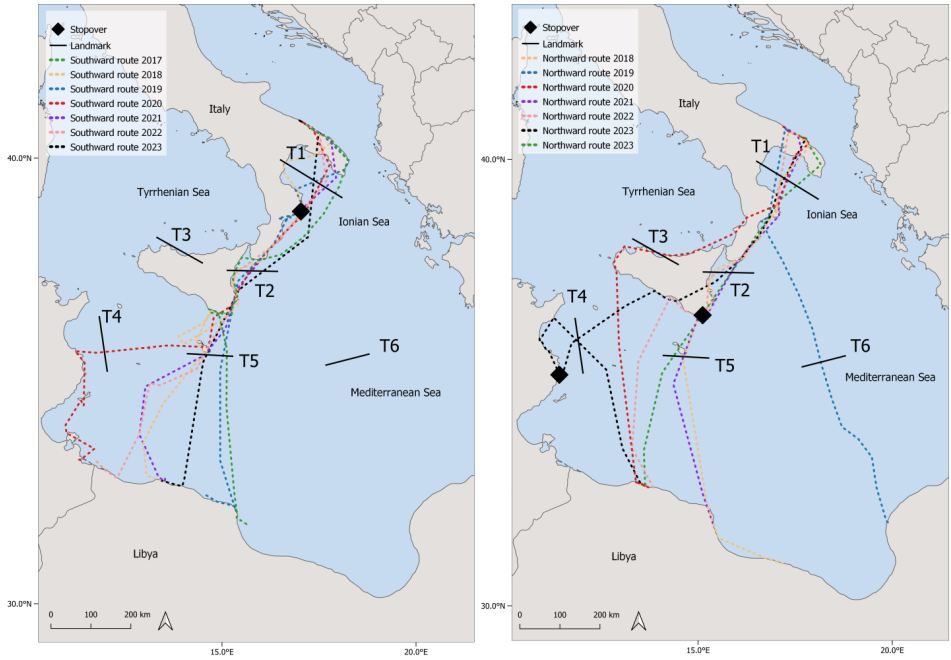


Figure 4. Comparison of annual migration routes of Audouin's Gull during southward (left) and northward (right) migration between 2017 and 2024. Consistency of migration route was compared with crossing six landmarks: T1 – Gulf of Taranto, T2 – Italian coast of the Ionian Sea, T3 – Sicilian coast of the Tyrrhenian Sea, T4 – Tunisia, T5 – Malta, T6 – open south-eastern Mediterranean Sea.

Slika 4. *Usporedba godišnjih migracijskih puteva sredozemnog galeba tijekom selidbe prema jugu (lijevo) i prema sjeveru (desno) u razdoblju od 2017. do 2024. godine. Dosljednost migracijskog puta uspoređena je na temelju prolaska kroz šest orijentira: T1 – Tarentski zaljev, T2 – talijanska obala Jonskog mora, T3 – sicilijska obala Tirenskog mora, T4 – Tunis, T5 – Malta, T6 – otvoreno more jugoistočnog Sredozemlja.*

DISCUSSION

This study presents the annual movements of a female Audouin's Gull that was captured in 2017 while attempting to breed on Lastovo, Croatia. The bird was fitted with a GPS-GSM transmitter that provided data for seven years, yielding valuable information on movement patterns and spatial use during breeding and wintering, as well as on the migration route and its consistency. The bird showed a highly variable movement pattern and distinct spatial boundaries between breeding areas on the Adriatic coasts of Italy and Croatia and wintering areas on the Mediterranean coasts of Libya and Tunisia, with a short migration and only a few stopover sites. Patterns reported here may not represent the Adriatic breeding population as a whole and results should be interpreted as individual-level behaviour observations.

Extended breeding period

Audouin's Gulls are known to have itinerant behaviour with regard to breeding locations (Sacchi *et al*. 2025). Rather than returning to the same island each year, individuals may shift between different breeding sites, which can be located close to one another within the same area or, as observed in this study, as far as approximately 195 km apart (Sacchi *et al*. 2025). This individual attempted to breed on Lastovo in 2017, but from 2018 to 2020 it was breeding on Eremita Rock, while in 2021 this colony was completely abandoned by Audouin's Gulls (Liuzzi *et al*. 2023). Then, our bird attempted to breed in 2021 and 2022 on Giorgio Treviso Islet (74 km from Eremita Rock), and in 2023 and 2024 on La Chiesa Island, which is just 80 m from Giorgio Treviso Islet. As already observed by Sacchi *et al*. (2025), this movement is based on individual dispersal or coordinated shift of all adult individuals to another island. This pattern of relocation between colonies could be a response to breeding conditions, particularly colony size, as reported by Fernández-Chacón *et al.* (2013). This is, however, not entirely consistent with our bird. In 2017, Smokvica Island on Lastovo had 13 breeding pairs, but in 2018 colony moved to the nearby island (Jurinovic L. unpubl. data). In the same year, the bird moved to Eremita Rock, where there were on average eight pairs from 2016 to 2020, with a maximum of 13 pairs in 2017 (Liuzzi C. unpubl. data). In 2020, Eremita Rock had seven breeding pairs, while in 2021 the colony was abandoned by the beginning of May (Liuzzi *et al*. 2023). Giorgio Treviso Island had its first confirmed colony in 2020, with 222 breeding pairs, and our bird began breeding there in 2021, when the island had 168 breeding pairs (Liuzzi *et al*. 2023). Due to its itinerant behaviour, this individual shows fidelity to a well-defined spatial unit, a broader area of use rather than a single breeding colony, suggesting defined population boundaries, a behaviour also observed in other Audouin's Gull breeding populations (Sacchi *et al*. 2025).

The bird also visited Giorgio Treviso Island regularly before starting to breed there, which was related to social interaction and prospecting behaviour (Kralj *et al.* 2023). This bird prospected several other known breeding colonies and potentially suitable breeding locations each year, mostly during April, May, and June. It also repeatedly revisited locations where it had previously bred, especially the Lastovo colony, which was the only colony it returned to every year. Given the distance of approximately 195 km from Italian colonies, Lastovo appears to have been an important site for this individual. This might suggest that it was its natal colony or the colony where it bred for the first time, although the available data do not allow this conclusion. However, Audouin's Gulls show fidelity to their natal breeding colonies, as suggested by ring recoveries (Muntaner *et al*. 2005, Oro & Martinez 1994), and dispersal between neighbouring colonies and prospecting of potential breeding sites have been shown to be related to breeding

success (Oro *et al.* 2021). Therefore, the behaviour of this individual may represent a combination of prospecting and natal colony fidelity and again supports the suggestion of a broader area of use, as defined population boundaries (Sacchi *et al.* 2025).

Except for occasional prospecting trips, the area used during the extended breeding period was quite small (95% KDE median = 751.26 km², range 213.72–1,832.56 km², 50% KDE median = 137.98 km², range 21.98–321.14 km²), mostly within 30 km of the colony, indicating a restricted range during the extended breeding period. The flying range is similar to another study in which birds remained within 40 km of the colony (Manosa *et al*. 2004), although an even smaller foraging range of 10–12 km was recorded in Greece (Mullin *et al*. 2012). The spatial overlap between years suggests that changes in the breeding colony were associated not only with shifts in the breeding colonies but also with locations used for resting. The only clear difference in KDE overlap area was between 2017 and the other years, due to a failed breeding attempt at the Lastovo colony. The other years showed high or moderate overlap for the 95% KDE area, suggesting that the overall area was used to a similar extent every year, while overlap for the core area was higher in certain years, such as 2023–2024 (Jaccard = 0.63), which coincides with the period when breeding occurred at La Chiesa Island. However, for other high-overlap years no such pattern was observed, suggesting that the bird is using areas beyond the breeding colony itself, highlighting the importance of locations used for resting. Although this individual showed low fidelity to a single breeding colony, it showed high fidelity to the broader regional area (Sacchi *et al.* 2025), suggesting there is sufficient food around breeding colonies (Borrmann *et al*. 2019).

Wintering

This individual spent most winters on the coast of Libya, a known wintering area for Audouin's gull, especially for the central and eastern Mediterranean population (EGA - RAC/SPA Waterbird Census Team 2012, Mullin *et al*. 2012). According to the Atlas of wintering waterbirds of Libya, our bird used areas reported as some of the top locations, particularly in the Misratah area, where its core wintering range was located in most years, but also around Sirt and Benghazi (EGA - RAC/SPA Waterbird Census Team 2012). During winter, the bird used a much larger and more dispersed area than during the breeding period (95% KDE median = 89,844.13 km², range 28,273.26–137,367.61 km², 50% KDE median = 20,285.11 km², range 5,698.43–25,770.35 km²). Movement was predominantly restricted to the Libyan coast, with pelagic trips rarely undertaken.

Despite the relatively extensive wintering areas, the high overlap of the 95% KDEs between most years indicates consistency in the broader wintering range. In contrast, overlap between the 50% KDEs was generally lower, indicating that

the most intensively used areas within this broader range were more variable. Familiarity with the larger area provides the opportunity to switch between locations with better conditions in different years (Brown *et al*. 2021).

Migration

The bird migrated quickly and relatively directly, with a median migration duration of 4.75 days in both directions, which is fast compared with other gull species (Klaassen *et al*. 2012). However, there was variation in migration consistency, duration, distance travelled, and speed. Migration speed differed between years, with some migrations lasting two days, as during the autumn migration in 2019 when the bird flew approximately 540 km per day, while the longest northward migration in 2023 lasted 15 days and covered 121 km per day. Similar behaviour was observed in a Norwegian population of Lesser Black-backed Gulls *Larus fuscus*, which was explained by waiting for favourable wind conditions or the need to build up body reserves before returning to the breeding area (Bustnes *et al.* 2013). The longer migration also corresponds with the few stopover sites this individual used during spring migration, paired to relatively more frequent inland crossings. However, the general absence of prolonged stopovers indicates that the individual does not depend on specific locations during migration and is capable of feeding while migrating, a fly-and-forage behaviour (Dias *et al.* 2012, Klaassen *et al*. 2012). Another reason for fast migration, at least in autumn, is moulting, as this bird started migrating in November, which gives it enough time to finish moulting in the breeding area (Cramp & Simmons 2006). Some gulls start migrating but then have prolonged stopovers, which suggests that, in addition to food consumption, these sites are used for flight feather moult (Klaassen *et al*. 2012). Also, gulls are known to be gregarious during winter without having specific territories to defend, so there is no pressure to arrive first and early (Klaassen *et al*. 2012). However, start of a spring migration was prolonged, starting as early as the end of December and extended until mid-March, and the reason for this is unknown. The migration route could be more straightforward if the bird flew directly towards North Africa across open sea and backwards, but the individual repeatedly used coastal areas of Italy and Malta, and to a lesser extent Tunisia, indicating that this area may provide suitable opportunities for short resting and feeding stops (Klaassen *et al*. 2012). The use of coastal sites may be particularly important because they can provide predictable feeding and resting opportunities and opportunities for ridge soaring and low-energy flight, while also serving as navigational features (Brown *et al.* 2021, Klaassen *et al*. 2012). Overall, these differences show flexibility and an ability to adjust to environmental conditions and food availability, which is thought to be one of the traits of an opportunistic and flight-generalist gull species (Brown *et al.* 2021, Klaassen *et al*. 2012).

Tracking an individual bird over a seven-year period is rare occasion, especially for a long-lived and highly mobile species such as the Audouin's Gull. Such long-term tracking provides important insights into inter-annual variation in annual gull movements and behaviour, and into the consistency and flexibility of individual strategies. The individual survival for at least nine years after tagging shows that the chest harness did not affect the survival of this individual. Although these tracking data cannot be extrapolated to the entire population, they offer valuable insight into the movement behaviour of this species, particularly its broader area use during the breeding season and its connectivity with other breeding colonies. These movements provide evidence of connectivity among individuals and colonies and, more broadly, contribute to our understanding of the spatial boundaries of the population.

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Supplementary Information

The online version contains supplementary material available at https://hrcak.srce.hr/supplement/976.

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SAŽETAK

GPS–GSM odašiljači pružaju mogućnost istraživanja kretanja ptica na prostornoj i vremenskoj razini koja se ne može postići prstenovanjem. To je osobito vrijedno za razumijevanje kretanja ugroženih morskih ptica poput sredozemnog galeba *Larus audouinii*, čija su područja migracije i zimovališta često nedovoljno poznati, kao što je slučaj s jadranskom populacijom. Također, dugoročno praćenje pojedine ptice i dalje je rijetkost. U ovom radu prikazujemo sedmogodišnje podatke dobivene GPS praćenjem (2017–2024) odrasle ženke uhvaćene tijekom gniježđenja u Lastovskom otočju u Hrvatskoj. Istraživali smo godišnja kretanja, korištenje prostora tijekom produljenog razdoblja gniježđenja i zimovanja, migracijske rute, korištenje odmorišnih područja te dosljednost kretanja između godina. Jedinka je pokazala izraženo izviđanje i fleksibilnost pri odabiru mjesta gniježđenja, premještajući se između kolonija, uz istodobno visoku vjernost širem području. Tijekom produljenog razdoblja gniježđenja kretanje je uglavnom bilo ograničeno na područje unutar 30 km od kolonije, dok su područja korištena tijekom zimovanja bila znatno veća i koncentrirana uz obalu Libije, osobito u okolici Misrate. Migracija je bila brza i razmjerno izravna, s malim brojem odmorišta i medijanom trajanja od 4,75 dana u oba smjera. Unatoč međugodišnjim razlikama u trajanju i ruti migracije, obalna područja Italije, Malte i Tunisa ponavljano su korištena. Rezultati ukazuju na kombinaciju nomadskog ponašanja pri odabiru mjesta gniježđenja, regionalne vjernosti, dosljednosti korištenja područja zimovanja i fleksibilnosti migracije kod ove vrste.