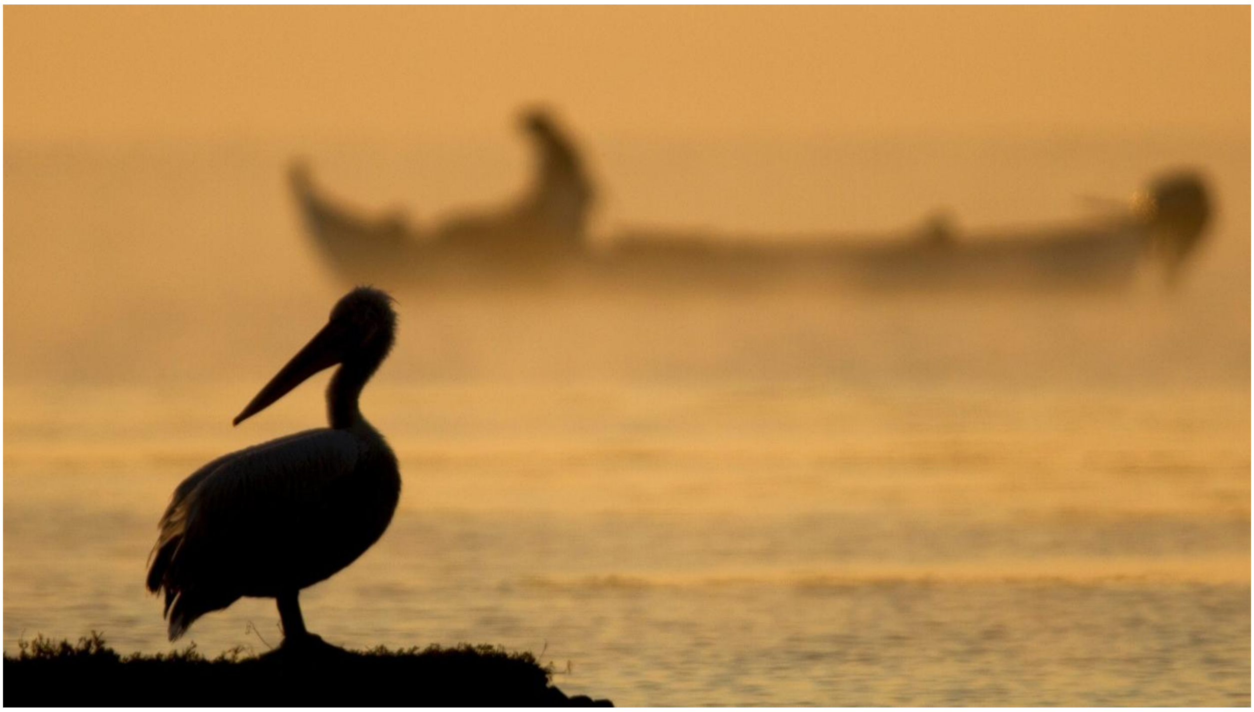
Dalmatian pelican monitoring with satellite telemetry
Technical report under actions A1 and D1



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1. Summary

This study used GPS tracking to examine the spatial ecology of Dalmatian pelicans (*Pelecanus crispus*) in southeastern Europe, across breeding colonies and staging areas in Greece, Bulgaria and Romania. Each bird's movement data was modeled with dynamic Brownian Bridge Movement Models to derive 95% home ranges (HR) and 50% core areas (CA), split into four seasons (breeding, post-breeding, pre-winter, winter). Analyses revealed that the northern group maintained significantly larger HRs and CAs than western pelicans, reflecting the broader and patchy wetland networks of Bulgaria, Romania, and adjacent countries. Seasonal patterns were less pronounced overall, though core-area size tended to increase during breeding. Linear models indicated a marginal interaction in post-breeding, suggesting that resource availability in northern wetlands becomes more dispersed once chicks fledge, temporarily reducing the difference in CA between north and west. Similarly, an interaction in the pre-winter period showed that northern birds reduced their CA ratio more than western birds, presumably due to wide-ranging dispersal or exploratory behavior. The mortality events (n=8) indicated diverse anthropogenic threats, including net entanglement and collisions with infrastructure. Two individuals died well outside their home ranges, implying heightened risk during long-distance travel, whereas others perished within intensively used sites, showing that hazards can also exist at the center of daily activities. Intersection of HRs with Special Protection Areas (SPAs) revealed that western pelicans' smaller home ranges were mostly contained within coastal SPAs (87–90% coverage), whereas the northern subpopulation, with extensive home ranges and high wetland use across multiple borders, had as little as 35–60% coverage. These results underscore the importance of a transboundary conservation strategy to ensure habitat connectivity and minimize mortality risks throughout the region's wetland networks. Overall, the findings highlight subpopulation-level differences in Dalmatian pelican spatial behavior, potential seasonal adjustments in foraging distribution, and possibly the need for enhanced protective measures, especially for the more wide-ranging northern birds.

2. Introduction

Understanding how animals utilize their environment—in particular, how they distribute their activities within a spatially defined "home range"—has long been central to ecological and conservation research. The view that individuals occupy finite geographical areas and allocate their time unequally across them supports much of modern wildlife management (Manly et al. 2007). Within these home ranges, animals often devote the majority of their activities to one or more "core areas," where foraging and resting are especially intense (Hodder et al. 1998). For large waterbirds such as pelicans, examining how and why they concentrate their behaviors in certain places can reveal how broader landscape features, resource variability, social factors, and seasonal changes shape their movement strategies (Kie et al. 2010). Despite its importance, there are still uncertainties regarding primary drivers of home-range size and structure. Resource availability, patch quality, predation risk, and social organization, can shape a species' spatial ecology, and it is not always clear which factor has the greatest impact at any given time (Cumming and Cornélis 2012). In colonial waterbirds that lack strict territorial behaviors, large flocks may roost communally and move together between wetlands, making home-range boundaries harder to define than in solitary, territorial birds.

Among pelican species worldwide, quantitative home-range studies have been relatively scarce. Most published work has focused on two New World species, the Brown pelican (*Pelecanus occidentalis*) and the American White pelican (*Pelecanus erythrorhynchos*), each of which exhibits distinctive migratory routes, habitat use, and social behaviors (King et al. 2013, King et al. 2016, Lamb 2016). Regarding the Dalmatian pelican's ranging behaviour, one recent study has so far investigated the annual home range of the species in northern Greece (Georgopoulou et al. 2023). In southeastern Europe, Dalmatian pelicans use various wetlands of differing sizes and resource qualities. In Romania, many individuals originating from Danube Delta breeding colonies travel over large distances along the Danube River and adjacent lakes in the Danube Plain especially during pre-winter and winter periods, where previously GPS tracked individuals revealed large congregations of up to several hundred individuals in some locations (Bugariu and Fântână 2008). Some birds, considered short-distance migrants, have been observed regularly moving among multiple waterbodies in search of foraging sites or roosting areas (Efrat et al. 2019). An open question is whether such mobility fosters a larger home range or whether the species, despite frequent travels, confines its principal foraging and resting to more limited "core" zones. Clarifying these spatial patterns is vital for making informed management decisions, since many of these wetlands are subject to anthropogenic stressors and some, though not all, lie within protected areas (Catsadorakis and Portolou 2018).

In this study, we used GPS tracking data from individuals tagged under the framework of the "Pelican Way of LIFE" Project, to quantify the size of Dalmatian pelican home ranges and core areas across colonies in Greece, Bulgaria and Romania. We aim to reveal whether important seasonal shifts occur in the spatial ecology of the species across seasons and populations and further explore if threats operate inside and outside their primary usage zones.

3. Methods

3.1. Data collection

This study focuses on data from tagged birds originating from three major populations of Dalmatian pelican in southeastern Europe: the western Greek colonies, including Amvrakikos gulf and Messolonghi wetlands project sites, and the most northern colonies in Bulgaria (Belene Island Complex as a breeding colony and Atanasovsko Lake as a staging area) and Romania (Razim-Sinoe Complex and Tasaul-Corbu breeding colonies). A total of 24 individual pelicans were captured between 2021 and 2024 using leg-hold traps or as fledglings nearby breeding colonies. Individuals trapped in Greece were trapped as fledged juveniles on their colonies (n=3), whereas the rest three were trapped during the winter period. In Bulgaria three individuals were trapped as fledged juveniles around the colony whereas eight were trapped during the pre-winter and wintering period in Burgas wetland, while in Romania 2 individuals have been trapped during the winter period and 5 as fledged juveniles nearby their original colony. Each bird was fitted with a GPS-GSM patagial tag (OT-P33 and OT-P31; Ornitela Ltd.), in Greece (n=6), Bulgaria (n=11) and Romania (n=7). The transmitter duty schedule was set to record GPS fixes at intervals of 10–30 minutes, depending on battery capacity and solar recharge. In total, 11 birds were tagged as juveniles, nine as immatures and four as adults (Table 1).

3.2. Data Filtering & Cleaning

Raw data were imported into R (v.4.2.0) for processing. Prior to analyses, the data were inspected and visualized to check for outliers using the R package “move” (Kranstauber et al. 2018). Specifically, any duplicate timestamps were removed, and the raw GPS data were filtered to remove erroneous points such as implausible locations (e.g., >1000 km from known range, GPS spoofing etc.) and unrealistic speeds (>50 m/s) and gps bursts. Timestamps were standardized to UTC. To investigate the temporal variation in the spatial utilisation patterns of the species, the annual cycle of DPs was segmented into four stages after Georgopoulou et al. (2023): the breeding stage, which encompasses courtship, pair bonding, and egg laying for most of the population from 15th December to 20th April; the post-breeding stage that includes brooding and chick rearing for breeders and dispersal for non-breeders, occurring from 21st April to 31st July; the pre-winter phase covering the dispersal period for all birds, from 1st August to 10th October; and the wintering period from 11th October to 14th December. These dates were shifted one month later for the most northern Romanian population.

3.3. Data analysis

Following data filtering and seasonal splitting we assessed space use for all individuals. The utilisation distribution (UD), often represented by a density function that indicates the likelihood of locating an animal's position in a given area or its spatial use relative to its home range (Anderson 1982), was estimated using the dynamic Brownian Bridge Movement Model (dBBMM) (Horne et al. 2007, Kranstauber et al. 2012). The approach calculated the UD for each pelican individually, using an analysis of its movement patterns and behaviors (e.g. movement, resting). The model uses a conditional random walk (Brownian bridge) to estimate the bird’s path and specifically calculates its UD by factoring in the order of locations, the distances, and the time intervals between consecutive locations (Horne et al. 2007). The method assumes continuous movement, and the unpredictability in the bird's movement trajectory represented as the variance of Brownian motion (σ^2m) and the probable positional error. The σ^2m indicates the variation from linear motion in the trajectory of each pelican. The dBBMM can estimate a fluctuating σ^2m, which helps in recognizing shifts in a pelican’s movement pattern. Each bird’s track data for a given season were input into the dBBMM. For individuals tracked at 10 or 15-minute intervals, a window size of 41 locations and a margin of 15 locations were used, whereas for those tracked at 30-minute intervals we used a window size of 31 locations along with a margin of 11 locations. In both cases the location error was set to 20m. The choice of window and margin aimed to encompass the daily activity of the Dalmatian pelican, as for diurnal soaring birds one should successfully identify both daily and across-day changes in the σ^2m within each individual’s trajectory. The dBBMMs were generated using the library “move” in the R package v. 4.0.6 (Kranstauber et al. 2018). The resulting utilization distribution (UD) raster defined a probability surface indicating the likelihood of presence across space. For each UD, we extracted two isopleths: a 95% boundary, which we refer to as the home range (HR), and a 50% boundary, referred to as the core area (CA). Additionally, we calculated a CA-to-HR ratio by dividing the 50% isopleth area by the 95% isopleth area for each season and each bird to assess the relative concentration of core usage within the larger home range.

Mortality data, i.e. coordinates, date, and cause of death, were integrated by overlaying each mortality point onto the relevant individual's UD surface. At the mortality coordinate, we extracted the UD value to classify whether the bird had died outside the 95% home range (0.0), within the 50% core area (<0.5), or within the 95% home range (>0.5). Protected-area coverage, focused on Special Protection Areas (SPAs) designated under Natura 2000, was assessed by intersecting each bird's 95% HR polygon with SPA shapefiles retrieved from the European Environment Agency. For each subpopulation (western Greece vs. northern Bulgaria/Romania) and each season, we derived the total HR area (UD_total) and the HR area that fell within SPAs (UD_PA). We then computed the percentage coverage as (UD_PA / UD_total) × 100. Furthermore, we recorded the number of distinct SPAs visited by each bird to explore the use of multiple protected sites across seasons.

Table 1. Tracking data of 24 Dalmatian pelicans monitored by GPS/GSM telemetry under the framework of "Pelican Way of LIFE" Project in south-east Europe. The 95% Utilization Distribution (Home Range) and 50% Utilization Distribution (Core Area) are given in km^2.

Country	Region	Bird's name	Age when tagged	Sex	Date tag deployed	Current date or date of death	Status	Breeding		Post-breeding		Pre-winter		Wintering	
								95% UD	50% UD	95% UD	50% UD	95% UD	50% UD	95% UD	50% UD
Greece	Messolonghi	Maistros	Immature	M	29/03/2021	22/03/2025	Alive	170.98	2.26	29	0.74	29.06	1.26	29.5	1.3
Bulgaria	Burgas	Maria	Immature	F	22/02/2021	10/12/2021	Dead	30.71	0.93	186.86	0.99	121.42	1.15	94.35	1.38
Greece	Amvrakikos	Anna	Adult	F	09/04/2021	13/01/2023	Dead	51.01	0.31	20.43	0.54	8.69	0.35	35.56	0.47
Bulgaria	Burgas	Albena	Immature	F	07/03/2023	22/03/2025	Alive	997.59	31.75	154.84	1.23	112.9	1.31	1703.26	26.83
Bulgaria	Burgas	Desi	Immature	F	19/02/2023	16/09/2023	Dead	135.62	2.08	655.56	1.36	NA		NA	
Bulgaria	Burgas	Hristina	Adult	F	05/03/2023	22/03/2025	Alive	883.52	36.05	106.24	6.18	63.5	2.76	1503.94	6.59
Bulgaria	Ruse	Kali	Juvenile	F	24/06/2022	30/10/2022	Dead	NA		136.46	0.17	195	1.63	53.07	0.63
Bulgaria	Burgas	Nasi	Adult	F	18/02/2023	22/03/2025	Alive	1248.89	44.74	53.97	1.87	267.62	4.57	268.43	12.99
Greece	Messolonghi	Kleisova	Juvenile		07/04/2023	22/03/2025	Alive	33.31	0.48	9.74	0.07	34.62	0.82	97.91	1.65
Greece	Messolonghi	Liloukos	Immature	M	22/02/2024	22/03/2025	Alive	6.33	0.32	2.84	0.06	7	0.28	19.38	0.89
Greece	Messolonghi	Askos	Juvenile		28/03/2024	22/03/2025	Alive	12.64	0.04	28.16	0.21	12.07	0.21	48.19	0.69
Greece	Messolonghi	Triada	Juvenile		07/04/2023	19/07/2023	Unknown	NA		6.2	0.05	NA		NA	
Bulgaria	Burgas	Nikolaya	Immature		06/12/2023	19/10/2024	Dead	646.19	24.6	63.72	2.81	115.08	4.01	NA	
Bulgaria	Burgas	Plamena	Adult		04/12/2023	16/02/2024	Dead	320.18	25.53	NA		NA		21.86	1.97
Bulgaria	Ruse, Silistra	Kalimok1	Juvenile		30/06/2024	22/03/2025	Alive	1604.94	118.45	245.56	1.53	461.14	1.65	520.53	8.13
Bulgaria	Burgas	Stela	Immature		23/11/2023	22/01/2024	Dead	97.74	6.72	NA		NA		35.8	3.03
Bulgaria	Ruse, Silistra	Kalimok2	Juvenile		30/06/2024	28/03/2025	Alive	366.16	12.61	599.34	1.4	1343.61	20.14	316.32	14.61
Romania	Danube Delta	R13	Juvenile		30/05/2024	31/12/2024	Alive	NA		259.48	0.08	263.55	0.84	144.57	0.08
Romania	Danube Delta	R12	Immature		12/12/2023	23/12/2024	Alive	353.06	0.56	52.9	1.06	231.73	1.47	139.82	0.4
Romania	Danube Delta	R14	Juvenile		30/05/2024	21/03/2025	Alive	200.29	3.08	175.46	1.31	721.68	11.79	172.05	0.47
Romania	Danube Delta	R15	Juvenile		30/05/2024	21/03/2025	Alive	709.01	1.53	1439.35	2.52	750.13	9.34	667.48	6.49
Romania	Danube Delta	R22	Juvenile		30/05/2024	21/03/2025	Alive	221.1	1.65	195.37	1.02	189.31	4.69	159.05	1.63
Romania	Constanta	R23	Juvenile		21/06/2024	27/09/2024	Dead	NA		73.48	0.67	5.19	0.11	NA	
Romania	Danube Delta	R11	Immature		22/11/2023	22/03/2025	Alive	312.36	0.21	48	1.08	239.41	3.78	109.33	0.2

For home-range and core-area measures, we implemented linear mixed-effects models (LMMs) in R using lme4 package to investigate differences across subpopulations and seasons. We used these models because individual birds were observed repeatedly over multiple seasons thus colony and season were fixed effects whereas individual bird was included as a random intercept. The primary response variables were 95% HR area, 50% CA area, and the CA/HR ratio. Model assumptions were checked using residual plots, normal Q-Q plots, and tests for homoscedasticity. To examine differences in protected-area coverage, we used non-parametric Kruskal-Wallis test.

4. Results

Individuals tagged in western Greece used almost the same areas across season, areas that are located along western Greece coastline. No bird showed any long-distance dispersal. Main sites used included Amvrakikos Gulf, Messolonghi lagoons and Acheloos Delta, Voulkaria Lake, Lysimachia Lake and Kalamas Delta. Additionally, during the breeding season birds seem to systematically use Strofylia wetlands for foraging (Fig. A1-A4). On the other hand, northern birds - especially those from Bulgaria showed much higher mobility, regularly moving along coastal sites in the Black Sea, with main CAs located in Burgas and several wetlands in Danube delta. Birds also consistently used stretches along the Danube River. Furthermore, during post-breeding and pre-wintering periods birds used wetlands in Turkey near the Marmara Sea. During the winter two birds wintered in wetlands in Northern Greece. Birds tagged in Romania were also highly mobile and, similarly to the Bulgarian ones, use Burgas, several lakes in the Danube plain and the entire length of the Danube River between Romania and Bulgaria even reaching wetlands in the border with Serbia. Furthermore, they frequently moved across the border to Ukraine, up to Dniester National Park, and occasionally to Biloberezhia Sviatoslava National Park (Fig. A5-A8).

Overall, the home ranges of the 24 Dalmatian pelicans showed clear differences in the population-level. The northern pelicans (Bulgaria, Romania) showed consistently larger 95% HR values compared to the western pelicans (Greece). Seasonally, there were few robust differences in mean home-range extent, although results suggested that some pelicans used larger core areas during the breeding period. Specifically, linear model outputs showed a significant main effect of subpopulation ($p=0.02$), indicating that northern pelicans had a substantially larger home range on average (β = 475.6 km2 difference; Fig.1). None of the seasonal main effects (post-breeding, pre-winter, or winter) approached significance ($p>0.85$), nor did any interactions. Thus, the primary driver of 95% HR differences was the origin of a bird. A second linear model examining CA confirmed that the northern colonies had a significantly larger average core area ($p=0.008$), with an estimate of around 20 km higher than western birds (Fig.1). However, these differences in CA size between north and west might be slightly reduced in the post-breeding phase ($p=0.05$). Finally, a model considering the CA ratio (the proportion of the entire home range occupied by the core area) was also run to assess how pelicans concentrate their activities within their overall range. Results showed that although the country-level main effect was not statistically significant ($p=0.25$), there was a notable interaction between the northern subpopulation and the pre-winter season ($p=0.02$), implying that northern birds decreased their ratio relative to the west group in that period (Fig.2). Non-parametric (Kruskal-Wallis) tests indicated that core-area size was larger in breeding than in other seasons albeit marginally significant (p=0.05) showing that, as expected, pelicans might intensify local site use around breeding colonies. Additionally, adult pelicans tended to exhibit higher CA or CA/HR ratios than juveniles or immatures, though the sample size for robust age-group comparisons was somewhat limited (Fig.2).

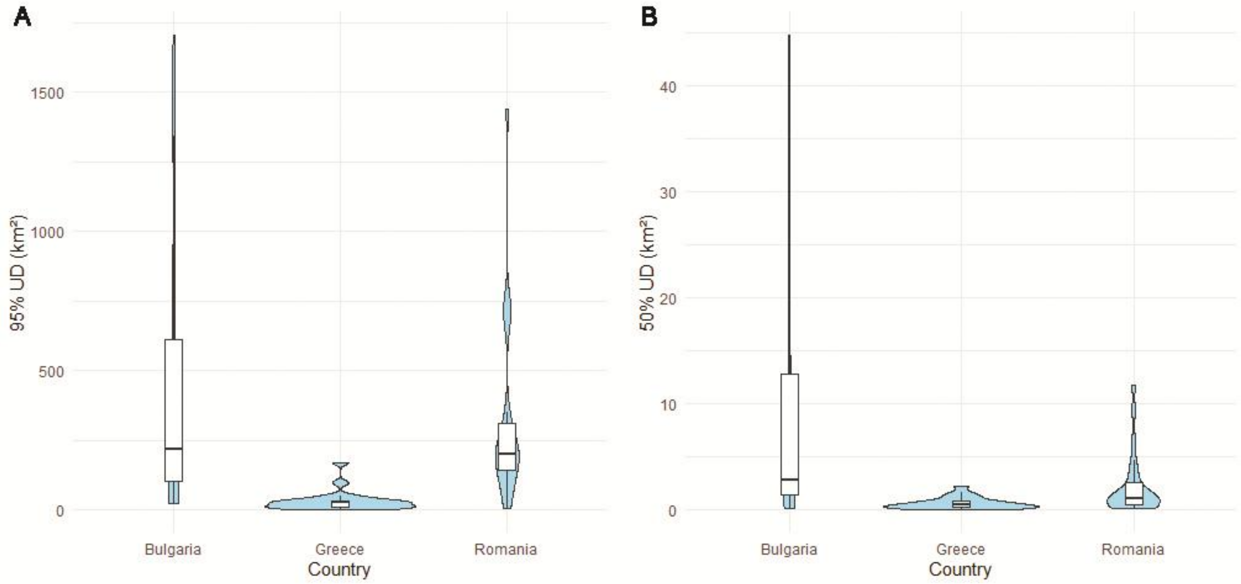

Figure 1. Violin plots with boxplots depicting A) the mean 95% UD (Home Range) and B) 50% UD (Core Area) sizes of birds tagged in each country.

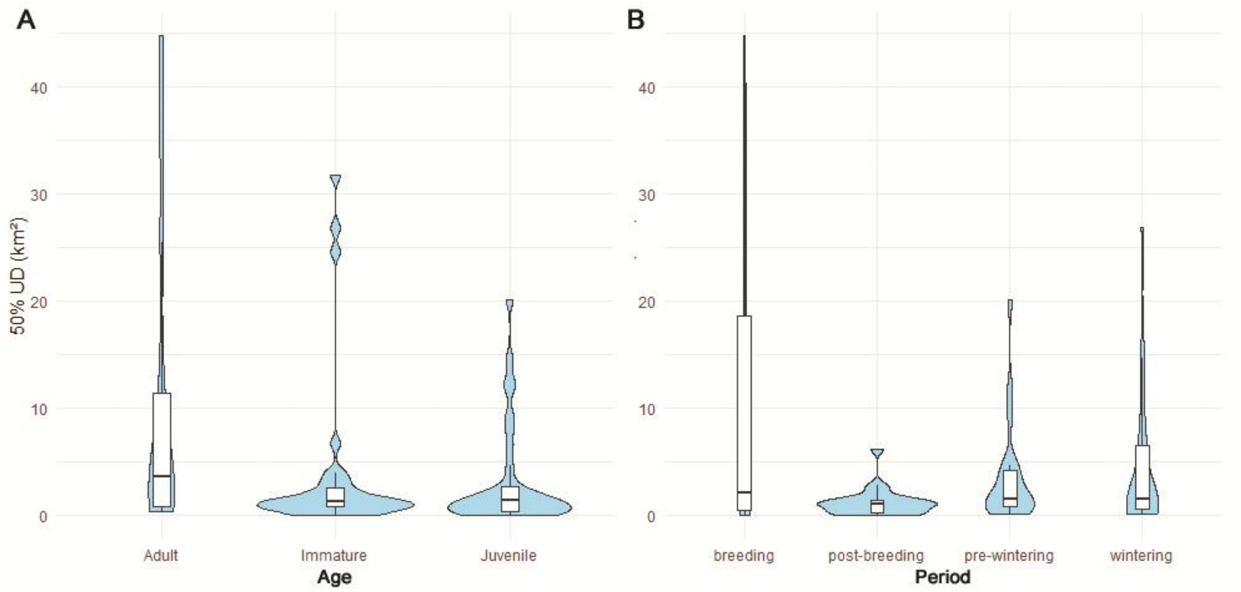

Figure 2. Violin plots with boxplots depicting the mean 50% UD (Core Area) per A) age class and B) different season, across all birds tagged.

During the course of the tracking, eight mortality events were documented. Causes included entanglement in fishing nets (n=3), collisions with power lines (n=1) and barges (n=1), shooting (n=1), whereas in two cases causes were unknown. Two birds, Desi and Plamena, died at sites with usage probability with values of zero, implying they were outside their home range at the time of death. Anna, Maria, Kali, and Stela died within their 95% HR, while R23 died within its CA (Table 2).

The intersection of each 95% HR polygon with the Natura 2000 SPAs revealed strong population-level contrasts in coverage (Table 3). For pelicans in western Greece, over 85% of their HR fell within SPAs in all four seasons (87–90% coverage). On the other hand, northern pelican HR protected area coverage ranged from ~35% in post-breeding to ~60% in breeding and winter. Number of SPA sites visited also differed markedly, with northern birds often recorded using 50–60 distinct SPAs across multiple countries, whereas western pelicans typically used fewer (5–9) sites.

Table 2. Mortality incidents of tagged Dalmatian pelicans along with cause of death and the UD value of the site the bird was found.

Bird_id	Age	Date	Cause _of_death	Place of death	UD
Anna	Adult	13/01/2023	Unknown	Kalamas, Greece	95%
Maria	Immature	10/12/2021	Collision with power lines	Sitaria, Greece	95%
Kali	Juvenile	30/10/2022	Collision with with a barge	Ruse, Bulgaria	95%
Desi	Immature	16/09/2023	Shot	Odessa, Ukraine	0
Stela	Immature	22/01/2024	Entanglement in a poaching fishing net	Mandra, Burgas, Bulgaria	95%
Plamena	Adult	16/02/2024	Entanglement in a fishing net	Golovita Lake, Romania	0
Nikolaya	Immature	19/10/2024	Entanglement in a fishing net	Kut-Lumba Gulf, Ukraine	0
R23	Juvenile	27/09/2024	Unknown	Mandra, Burgas, Bulgaria	50%

Table 3. Population level UDs, per season and subpopulation, along with percentage of the UD within SPA sites and number of them used.

Population	Season	UD_area_total	UD_area_PA	% within_SPA	Number of SPA sites used
west	Breeding	22161	19311	87.1	9
west	Post-breeding	7306	6494	88.9	7
west	Pre-wintering	7763	6785	87.4	5
west	Wintering	15768	14165	89.8	5
north	Breeding	474291	288043	60.7	52
north	Post-breeding	388781	139530	35.9	60
north	Pre-wintering	355268	166841	47.0	50
north	Wintering	458691	254088	55.4	63

5. Discussion

Our findings clearly show that individuals originating from Bulgaria and Romania exhibit consistently larger HR and CA values than their conspecifics in western Greece. Previous studies on pelican species have also documented variability in home-range size across different colonies (King et al. 2013, King et al. 2016, Georgopoulou et al. 2023). These distinct spatial behaviours suggest that resource distribution, wetland size, and the number of available foraging sites shape how far and how intensively pelicans travel (Schoener 1983, Legagneux et al. 2009, Bounas et al. 2023, Georgopoulou et al. 2023). Northern individuals appear to track multiple resource-rich wetlands often covering substantial distances along the Black Sea coast and Danube River (Bugariu and Fântână 2008) whereas western pelicans exploit a more restricted set of coastal lagoons in the Ionian region. For short-distance migrants like Dalmatian pelicans, environmental conditions (fish availability, water levels) can differ enough between western and northern sites to lead to contrasting movement strategies (Efrat et al. 2019). The fewer and stable lagoon systems in western Greece may reduce the need for long-range dispersals, hence smaller HRs, while the larger, patchy mosaic of wetlands in the north likely fosters high mobility and broader ranges.

Although overall seasonal main effects were limited, CA size tended to be larger in the breeding period suggesting that pelicans intensify local site use. For waterbird species that are not strictly territorial, an enlarged CA in breeding might reflect the need to exploit a consistent, high-quality feeding area near the nesting colony (Nelson 2006). Interestingly, we observed a marginal interaction in the post-breeding phase for CA differences between the north and west populations, implying that northern birds partially reduce their typical CA advantage. This could mean that resource availability in certain northern wetlands becomes more dispersed once chicks fledge, driving northern individuals to roam more widely (Georgopoulou et al. 2023). By contrast, the western birds may encounter fewer shifts, keeping their CA somewhat stable even after breeding.

Similarly, the CA ratio (CA to total HR proportion) showed no clear subpopulation effect but revealed a significant interaction in the pre-winter period, indicating that northern pelicans decreased the fraction of their range used more intensively. One plausible explanation is that pre-winter period includes partial migration or exploratory movements, with pelicans dispersing to multiple wetlands and often performing long cross-border movements. As a result, they allocate less time or feeding activity to any single high-intensity zone, thus lowering their CA ratio. Meanwhile, western pelicans apparently retain more localized usage patterns in the Ionian wetlands, sustaining a relatively stable CA ratio. These seasonal shifts in CA are consistent with a general pattern among large colonial waterbirds of adjusting foraging strategies in response to short-term resource or weather fluctuations (Efrat et al. 2019).

Eight mortality incidents were documented, highlighting diverse anthropogenic threats: net entanglements, collisions with infrastructure, and direct killing. Net entanglements can indicate a increased threat especially in pre-winter and winter periods when food supplies are lower, and birds locally make use of nets to retrieve already caught fish. Notably, two birds (Desi and Plamena) died outside their home ranges, suggesting that the birds were traveling beyond the areas the frequently used for feeding and roosting, thus possibly on dispersal flights or exploratory movements. In other large waterbirds, similar collisions or entanglements have been reported when birds transit between foraging sites (Haig et al. 1998, Lamb 2016). If future data confirm a disproportionate risk of colonies in a specific threat (e.g., consistent power line crossing), targeted mitigation measures (such as line retrofitting or fishermen outreach to reduce net bycatch) could enhance survival.

The Natura 2000 overlay revealed a pronounced discrepancy in SPA coverage between west (~87–90%) and north (~35–60%) populations. While western pelicans with their restricted HR, frequently remain within protected coastal wetlands, their northern counterparts traverse multiple countries (Bulgaria, Romania, Turkey, Ukraine, Serbia), often venturing into partially unprotected zones.

Similar shortfalls in coverage have been observed in other cross-border waterbird populations (Haig et al. 1998). Considering that pelicans move into non-EU countries with areas outside the Natura 2000 network such discrepancy is expected. However, it should be noted that the majority of wetlands used by pelicans are designated Ramsar sites, that have the potential to significantly boost waterbird population trends (Kleijn et al. 2014, Gaget et al. 2020). Still, a transboundary conservation approach is vital. Ensuring connectivity among wetlands, minimizing collision and poaching risks, and safeguarding roosting and foraging hotspots—particularly during more mobile phases—are essential to support the species' long-term stability. The number of SPA sites each bird visited further underscores the wide geographic range of northern pelicans, who rely on dozens of distinct wetlands, pointing out the species' flexible yet regionally fragmented resource use.

Overall, our results align with the broader knowledge that large colonial waterbirds, including pelicans, require extensive networks of wetlands (Haig et al. 1998). Our evidence for wide-ranging northern movements, often crossing multiple administrative borders, emphasizes that management strategies must look beyond single sites to address an entire corridor or set of roost/foraging sites. The documented mortalities underscore how anthropogenic pressures can threaten pelicans even in intensively used protected core areas, reinforcing the need for risk assessments and targeted mitigation in high-usage corridors. Overall, this study provides a preliminary look on how Dalmatian pelicans in southeastern Europe can form two (at least) ecologically distinct subpopulations, each facing different conservation challenges.

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APPENDIX

Fig A1. Map of UD for the western subpopulation during the breeding period

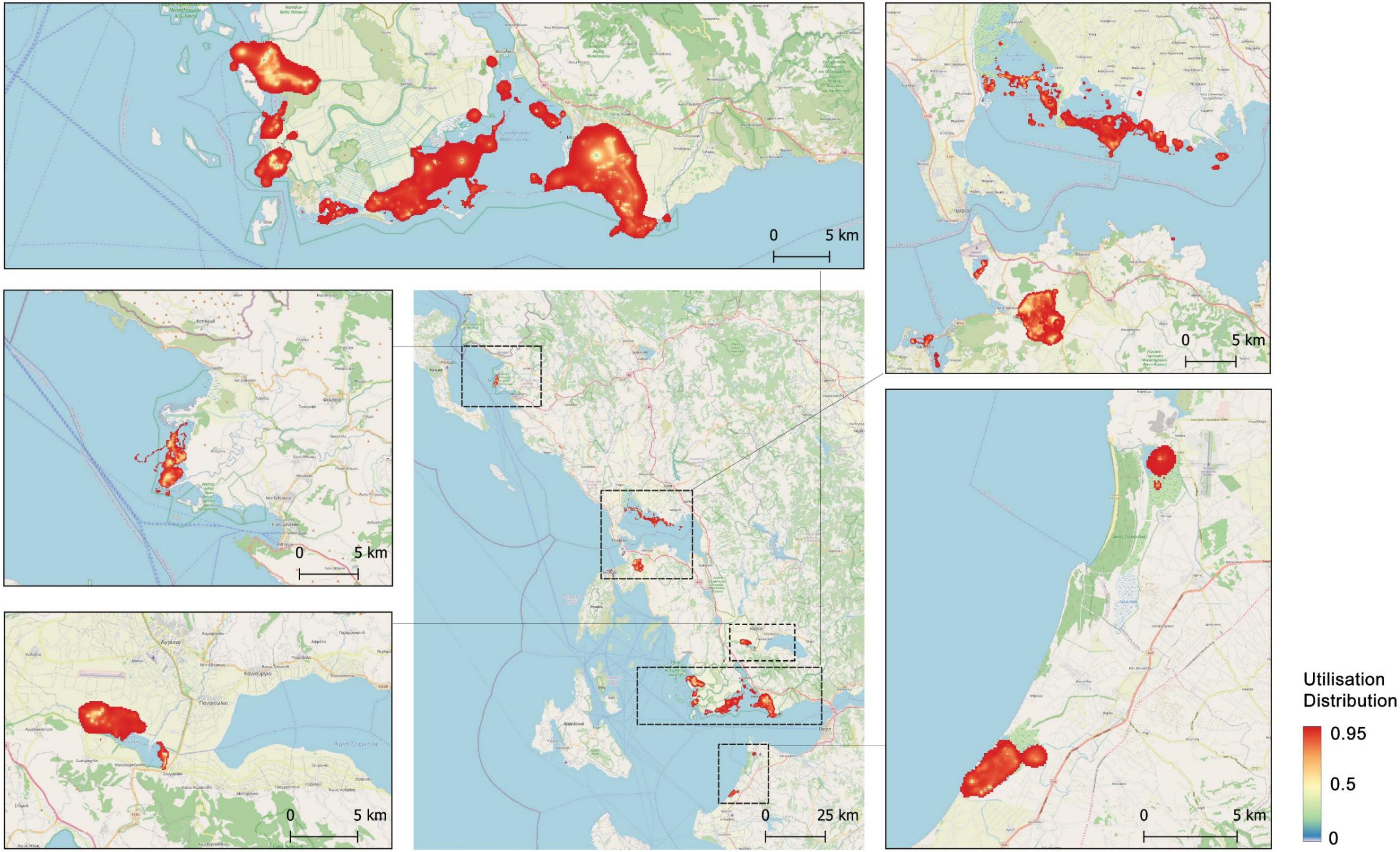

Fig A2. Map of UD for the western subpopulation during the post-breeding period

Fig A3. Map of UD for the western subpopulation during the pre-wintering period

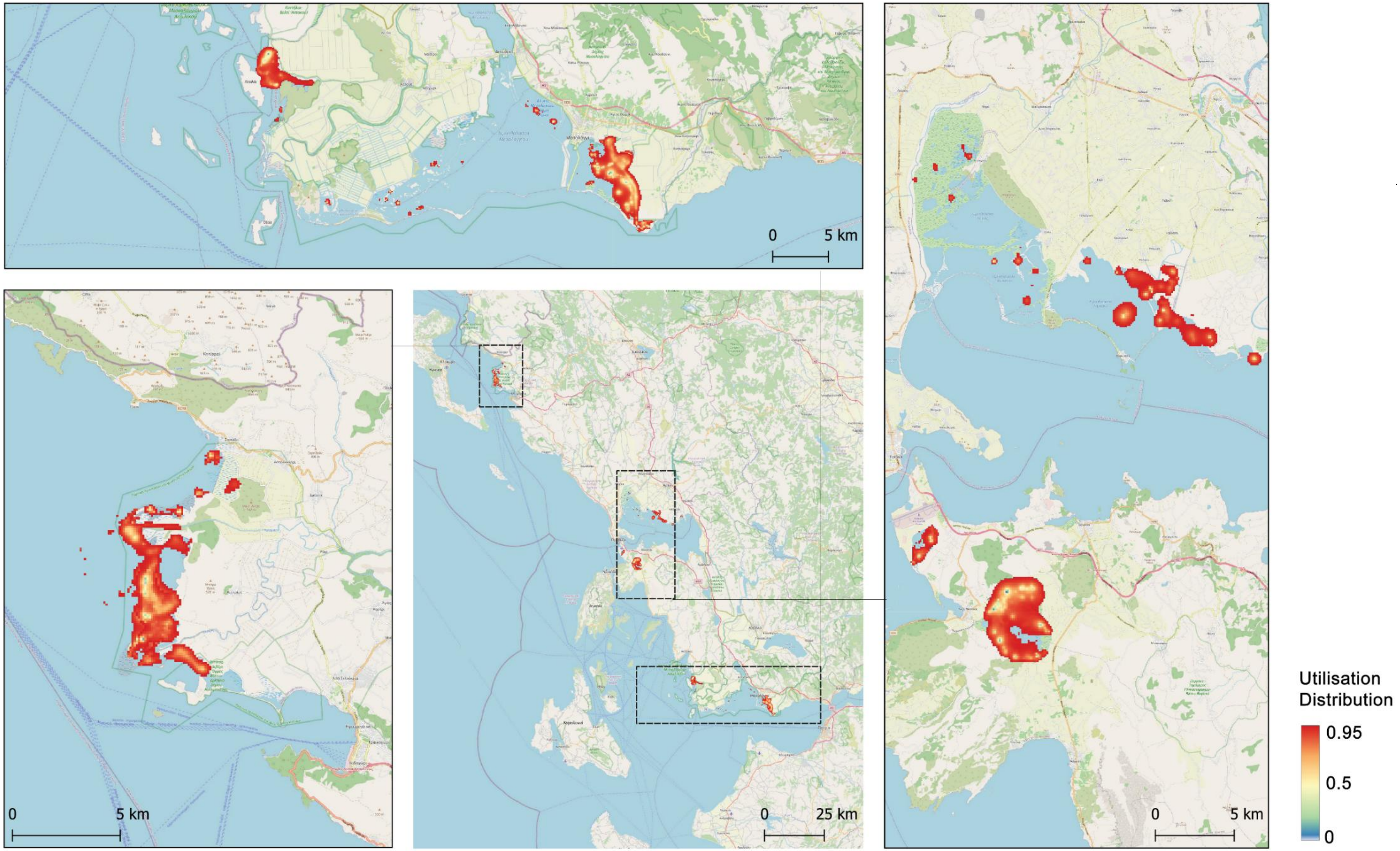

Fig A4. Map of UD for the western subpopulation during the wintering period

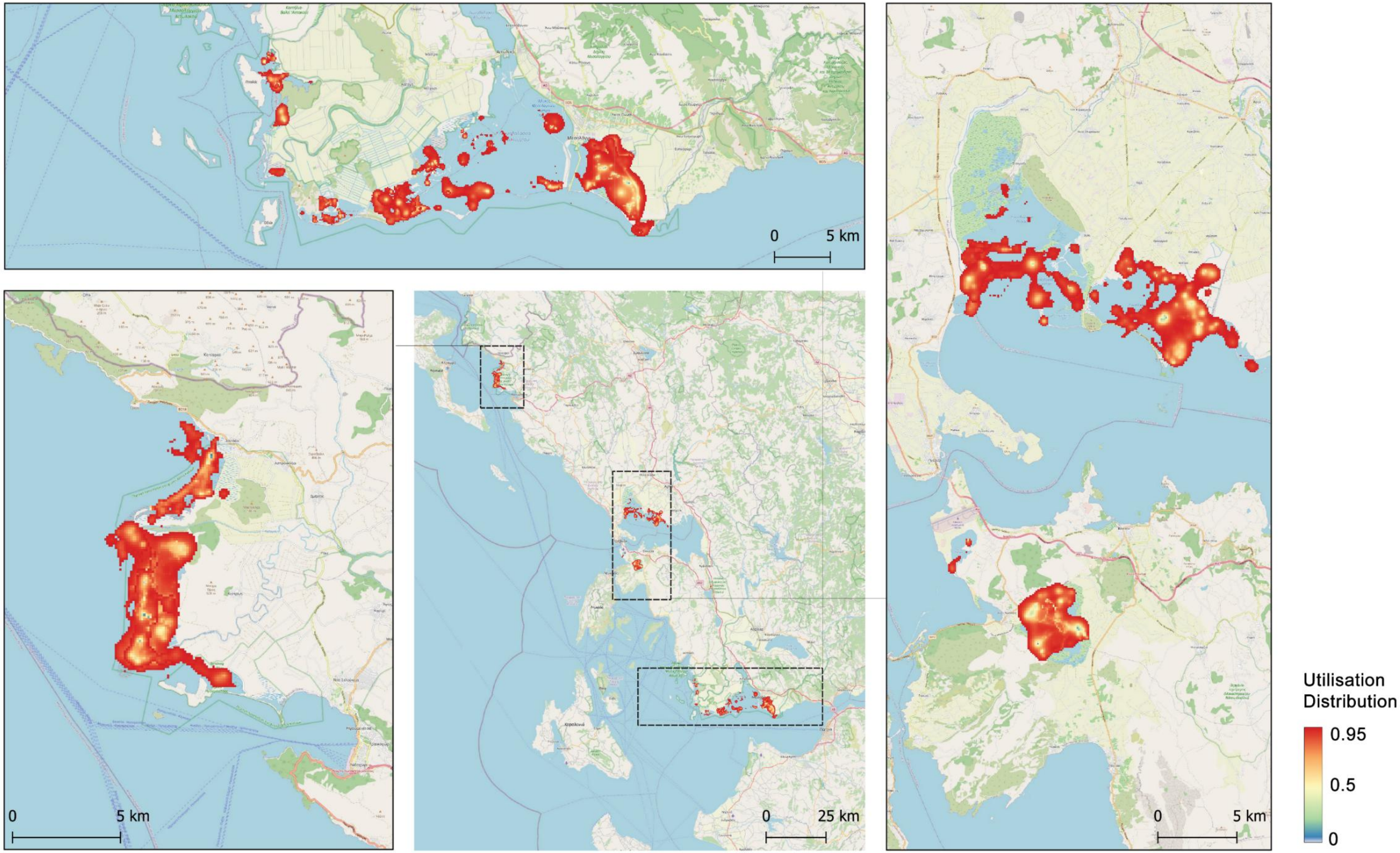

Fig A5. Map of UD for the northern subpopulation during the breeding period

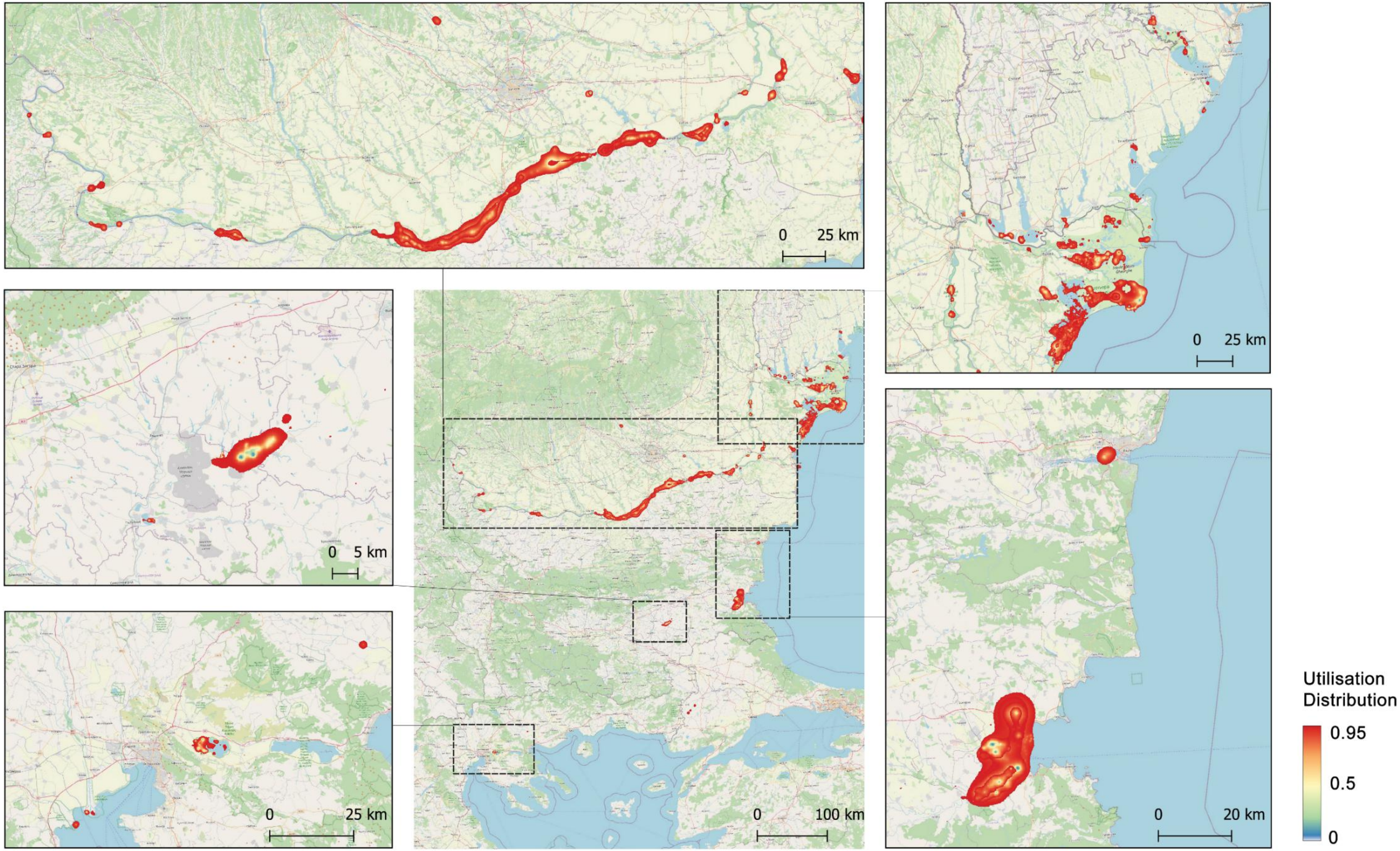

Fig A6. Map of UD for the northern subpopulation during the post-breeding period

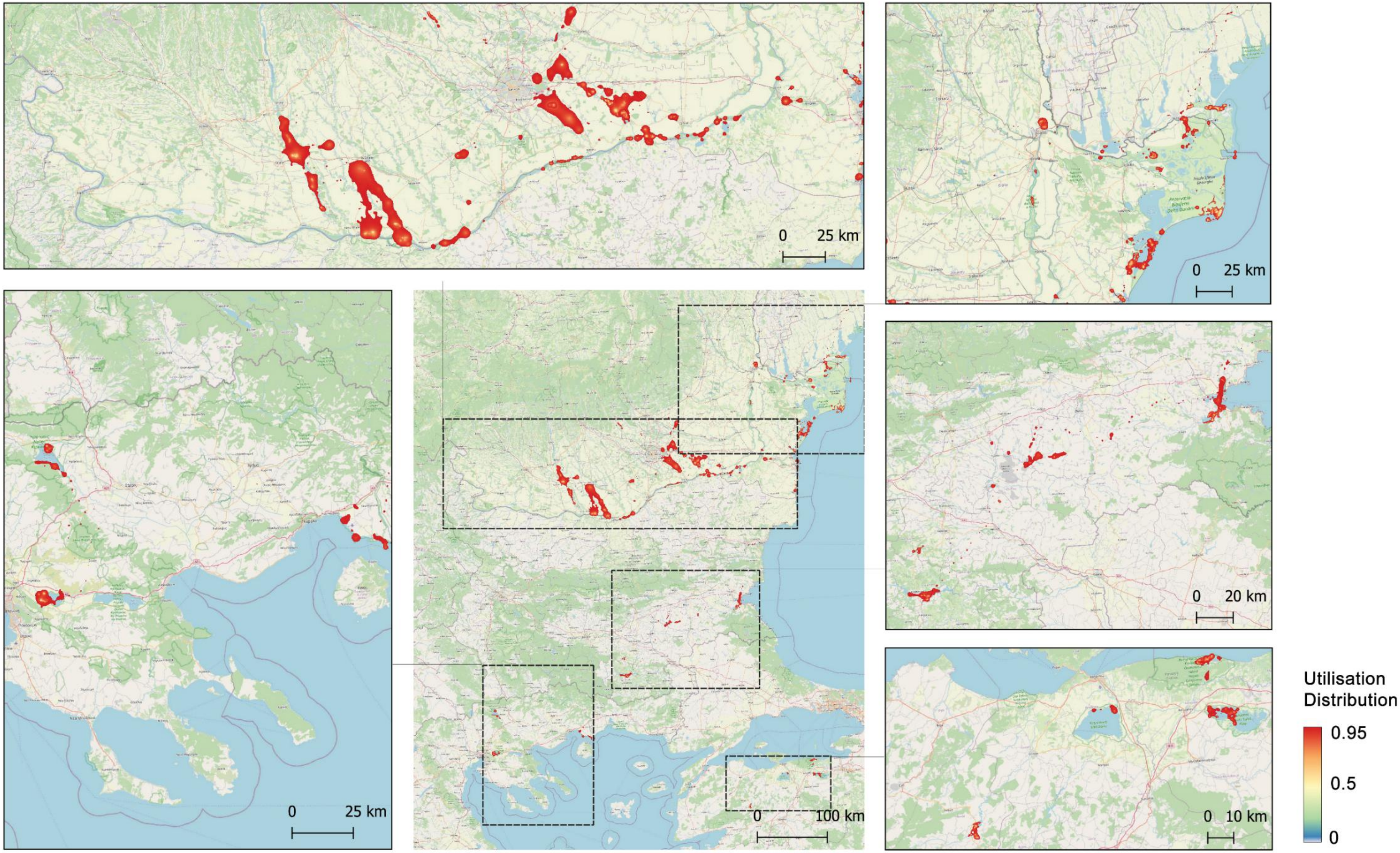

Fig A7. Map of UD for the northern subpopulation during the pre-wintering period

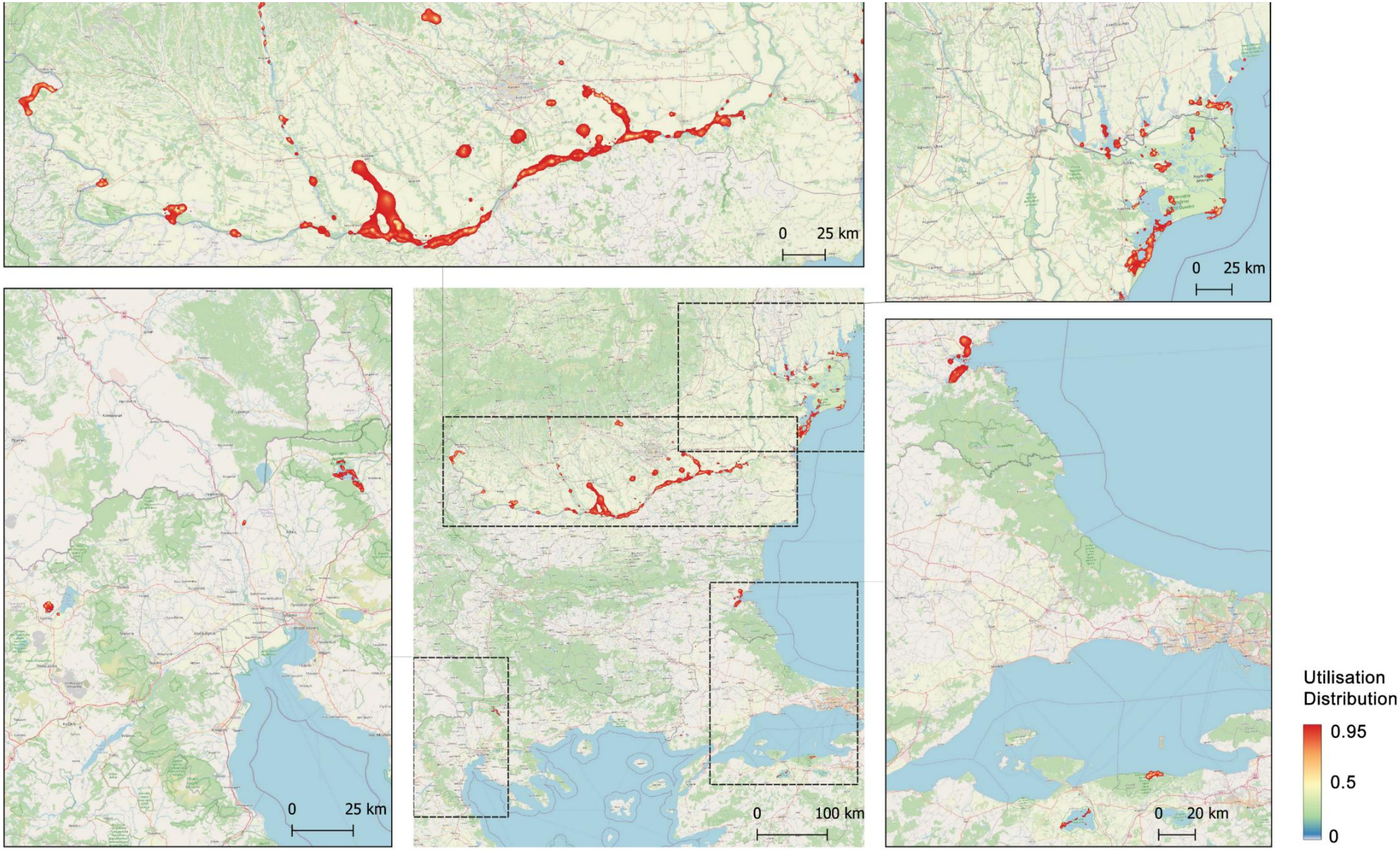

Fig A8. Map of UD for the northern subpopulation during the wintering period

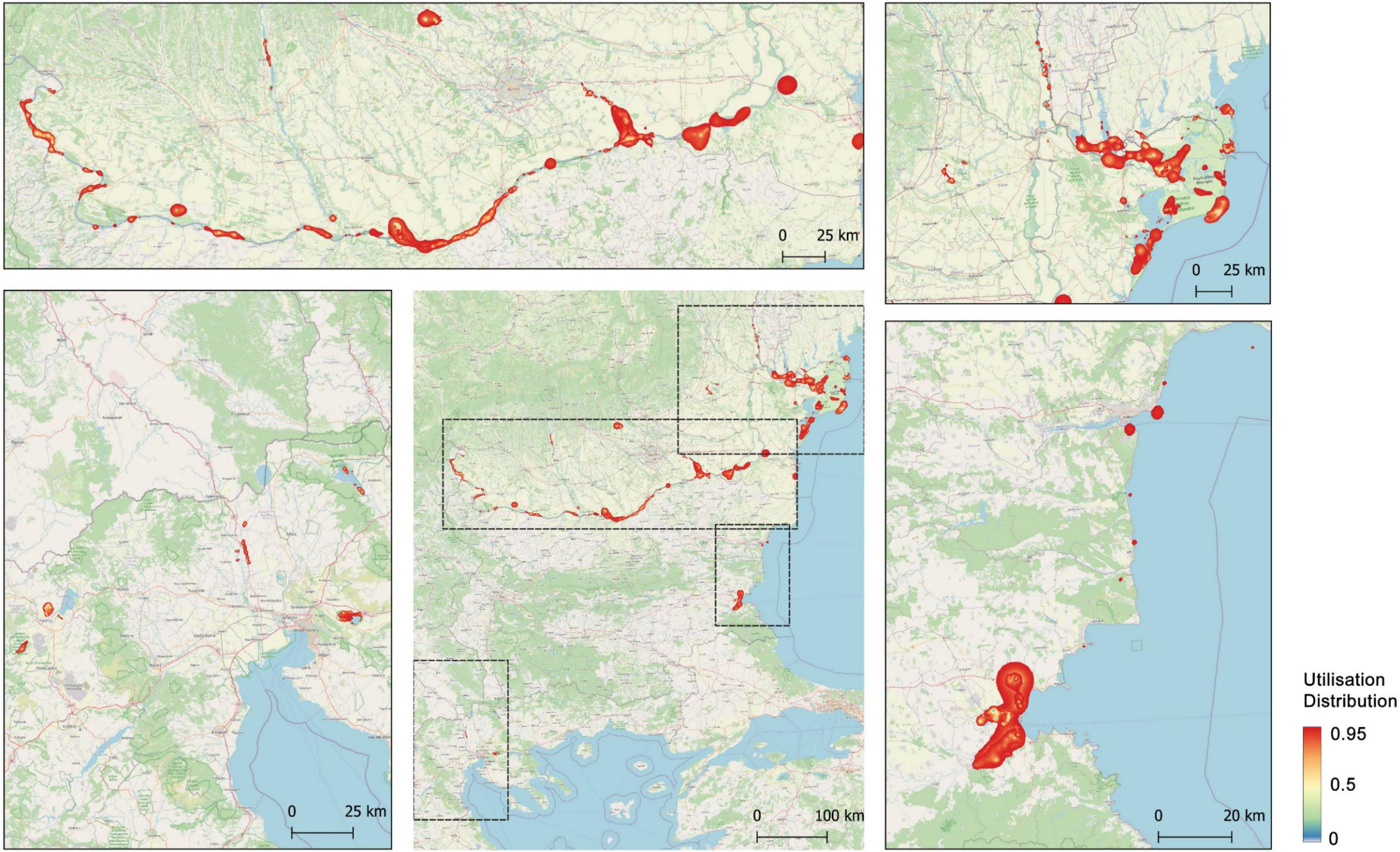

Photo A1: Tagging of an immature individual at Sinoie lake in Romania (photo: Sebastian Bugariu)

Photo A2: Re-sighting of an immature individual at lake Mostistea in Romania (photo: Ciprian Fântână)

Photo A3: Tagging of an adult individual in Burgas wetland in Bulgaria (photo: BSPB)

Photo A4: Tagging of adult individual in Burgas wetland in Bulgaria (photo: BSPB)

Photo A5: Tagging of an adult individual in Amvrakikos gulf in Greece (photo: V. Saravia-Mullin/ HOS)

Photo A6: Tagging of juvenile in Messolonghi wetland in Greece (photo: V. Saravia-Mullin/ HOS)