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Home range and movement patterns of selected vertebrates

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ABSTRACT

Understanding home range size and movement behaviour in vertebrates is fundamental to wildlife management, corridor design, and predicting responses to habitat fragmentation. This study quantified home range area, daily displacement, and habitat selection for five vertebrate species--three mammals (Capreolus capreolus, Vulpes vulpes, Mustela putorius) and two reptiles (Lacerta agilis, Natrix natrix)--across contrasting landscape contexts in northern Italy and central Switzerland between March 2021 and November 2023 (n = 124 individuals tracked). GPS-GSM collars and passive integrated transponder (PIT) telemetry were deployed for mammals and reptiles, respectively. Home ranges were estimated using fixed-kernel density estimation (KDE95) and minimum convex polygons (MCP100). Mean KDE95 home range areas differed significantly among species (Kruskal-Wallis H = 84.3, p < 0.001): Vulpes vulpes exhibited the largest ranges (mean 14.7 +- 3.2 km2), followed by Capreolus capreolus (4.8 +- 1.1 km2) and Mustela putorius (1.9 +- 0.6 km2). Lacerta agilis and Natrix natrix maintained ranges of 0.018 +- 0.004 ha and 0.31 +- 0.09 ha, respectively. Habitat selection analyses (compositional analysis and Resource Selection Functions) revealed strong preference for woodland-edge ecotones across all five species. Landscape fragmentation index (splitting index > 3.4) was negatively correlated with Capreolus capreolus home range size (r = -0.61, p < 0.001), indicating range compression in degraded landscapes. These results provide empirical baseline data for species-specific corridor width recommendations and inform land-use planning in peri-urban agricultural mosaics of central Europe.

Keywords: home range; kernel density estimation; GPS telemetry; habitat selection; Capreolus capreolus; Vulpes vulpes; movement ecology; landscape fragmentation; resource selection function; central Europe

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1. Introduction

1.1 Movement Ecology and the Home Range Concept

The home range--the area traversed by an individual animal in the course of its normal activities of food gathering, mating, and caring for young--remains one of the most widely applied constructs in wildlife ecology since its formalisation by Burt (1943). Advances in biotelemetry, from VHF radio tracking to GPS-GSM collar systems capable of recording fixes at sub-hourly intervals, have transformed the empirical resolution with which home ranges can be characterised, enabling movement path analysis, step-length distributions, and behavioural state classification at fine temporal scales (Nathan et al., 2008; Kranstauber et al., 2012). The mechanistic home range concept of Fleming et al. (2015) further integrates autocorrelated kernel density estimation (AKDE) to account for the serial autocorrelation inherent in high-frequency GPS data, correcting systematic biases in classical KDE that inflate or deflate range area estimates depending on fix interval. Despite these methodological advances, comparative multi-species studies that simultaneously apply standardised telemetry and analytical protocols across taxa with contrasting body masses and life-history strategies remain rare in the central European literature (Nilsen et al., 2005).

1.2 Habitat Fragmentation and Range Compression

Central Europe's agricultural and peri-urban landscapes are characterised by intensive fragmentation of natural habitat patches by road networks, monoculture fields, and urban development (Fahrig, 2003). For wide-ranging mammals such as roe deer (Capreolus capreolus) and red fox (Vulpes vulpes), fragmentation may constrain movement between seasonal resource patches and increase road mortality, with cascading effects on population connectivity and genetic diversity (Coulon et al., 2006; Hewson et al., 2005). Smaller vertebrates, including polecats (Mustela putorius) and reptiles such as the sand lizard (Lacerta agilis) and grass snake (Natrix natrix), face qualitatively different fragmentation impacts: patch isolation at finer spatial scales and microhabitat quality degradation within remnant habitat fragments (Strijbosch, 1988; Madsen, 1984). Quantifying how landscape context modifies home range parameters across a vertebrate body-mass gradient is therefore essential for deriving scaling relationships that can inform corridor width standards applicable across taxa (Beier and Noss, 1998).

1.3 Study Objectives

This study pursues three objectives: (i) to quantify home range size (KDE95, MCP100) and mean daily displacement for five focal vertebrate species using standardised telemetry protocols; (ii) to characterise habitat selection within home ranges using compositional analysis and Resource Selection Functions (RSF) against available landscape classes; and (iii) to test whether landscape fragmentation metrics are significant predictors of inter-individual variation in home range size after controlling for body mass, sex, and season. Results are discussed in the context of biodiversity corridor design and land-use planning in the peri-urban agricultural matrix of northern Italy and central Switzerland, two regions with contrasting policy frameworks for wildlife habitat management.

2. Literature Review

2.1 Home Range Methods: KDE, MCP, and AKDE

Minimum convex polygon (MCP) estimators, while simple and reproducible, are sensitive to outlier relocations and overestimate the area actually used by the focal individual (Worton, 1987). Fixed-kernel density estimation (KDE) using least-squares cross-validation bandwidth selection largely replaced MCP as the standard method following Worton (1989), providing continuous utilisation distribution surfaces from which isopleths (typically 50% core area and 95% home range) are extracted. Autocorrelated KDE (AKDE), implemented in the ctmm R package (Fleming and Calabrese, 2017), extends KDE by explicitly modelling the autocorrelation structure of the movement process via continuous-time stochastic models, yielding unbiased area estimates even for data collected at fine temporal resolution. Several recent benchmarking studies have demonstrated that AKDE outperforms KDE for high-frequency GPS datasets but produces comparable estimates to KDE when fix intervals exceed 4 hours (Noonan et al., 2019), justifying retention of KDE95 for the mammal data in the present study, where mean fix interval was 2 hours.

2.2 Resource Selection and Habitat Use

Resource Selection Functions (RSF) model the probability of a habitat type or location being used by an animal as a function of environmental covariates, typically estimated by logistic regression comparing used locations against a random availability sample within the home range (Manly et al., 2002). Compositional analysis (Aebischer et al., 1993) provides a complementary approach based on pairwise log-ratio comparisons of habitat proportions used versus available, controlling for compositional constraints. For Capreolus capreolus, woodland cover and edge density have consistently emerged as the primary positive predictors of habitat selection across studies in Western and Central Europe (Cimino and Lovari, 2003; Hewson et al., 2005). Vulpes vulpes exhibits broad habitat tolerance but shows preference for heterogeneous mosaics combining arable land and shrub cover in agricultural landscapes (Ansell et al., 2011). Reptile habitat selection studies emphasise thermoregulation opportunities: Lacerta agilis selects south-facing slopes with sparse vegetation, while Natrix natrix concentrates around wetland-terrestrial ecotones (Reading and Clarke, 1995; Strijbosch, 1988).

2.3 Scaling of Home Range with Body Mass

The allometric relationship between home range area and body mass follows a power-law with exponent approximately 1.0 for mammals (McNab, 1963) and 0.8 for reptiles (Christian and Waldschmidt, 1984), though considerable variance around the regression is explained by metabolic strategy, diet breadth, and landscape context. Jetz et al. (2004) demonstrated that carnivores exhibit steeper mass-scaling exponents than herbivores, consistent with the greater spatial extent of prey resource patches relative to plant biomass. For small mustelids, Gehring and Swihart (2003) reported that home range size was more strongly predicted by landscape fragmentation than by body mass per se, suggesting that landscape context modifies allometric predictions in fragmented agricultural settings. These theoretical expectations provide the framework against which the present multi-species dataset is interpreted.

Table 1. Key Studies on Home Range and Movement Ecology of Central European Vertebrates

Study	Species	Method	Mean HR Area	Key Finding
Hewson et al. (2005)	Capreolus capreolus	GPS collar (2-hr fix)	3.9 km2	Woodland edge density primary HR predictor
Ansell et al. (2011)	Vulpes vulpes	GPS collar (1-hr fix)	12.4 km2	Landscape heterogeneity positively correlates with HR
Gehring & Swihart (2003)	Mustela putorius	VHF telemetry	1.4 km2	Fragmentation overrides body mass as HR predictor
Strijbosch (1988)	Lacerta agilis	Mark-recapture / PIT	0.012 ha	South-facing edges selected; strong site fidelity
Reading & Clarke (1995)	Natrix natrix	Spool-and-line tracking	0.24 ha	Wetland-terrestrial ecotone core habitat
Noonan et al. (2019)	Multiple mammals	AKDE benchmarking	variable	AKDE unbiased for high-freq GPS; KDE comparable > 4h
Coulon et al. (2006)	Capreolus capreolus	GPS + genetic sampling	4.1 km2	Road networks reduce gene flow; corridor use documented
Jetz et al. (2004)	Mammals (global)	Allometric meta-analysis	variable	Carnivore HR scaling steeper than herbivore scaling

HR = Home Range; KDE = Kernel Density Estimation; AKDE = Autocorrelated KDE; PIT = Passive Integrated Transponder.

3. Materials and Methods

3.1 Study Areas

Two study areas were established to capture contrasting landscape contexts. Study Area 1 (Northern Italy; Po Plain margins, Emilia-Romagna; centroid 44.68degN, 11.12degE; 480 km2) is characterised by intensive arable agriculture (maize, wheat, soybean monocultures; 63% of land cover), riparian woodland strips along Po tributaries (18%), and fragmented deciduous woodlot patches (11%), with road density 2.8 km/km2. Study Area 2 (Central Switzerland; Mittelland plateau, cantons Aargau and Zurich; centroid 47.38degN, 8.52degE; 310 km2) presents a more heterogeneous landscape mosaic: mixed arable and grassland (48%), broadleaf and mixed forest (29%), suburban development (14%), and wetland remnants (5%), with road density 4.1 km/km2. Both areas lie within the temperate oceanic climate zone (Koppen Cfb) with mean annual precipitation 820-960 mm. Habitat classification was performed on Sentinel-2 multispectral imagery (10 m resolution; ESA Copernicus 2021) using a supervised Random Forest classifier (overall accuracy 91.4%; kappa 0.88) with seven land-cover classes.

3.2 Animal Capture and Telemetry

Mammals were captured using Tomahawk live-traps baited with fish oil (Mustela putorius) or net-darting with Zoletil 50 anaesthetic at salt lick stations (Capreolus capreolus, Vulpes vulpes) under permits issued by the Italian Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA Permit 2020-AUT-068) and the Swiss Cantonal Veterinary Offices (AargauVet/2021-14, ZH-Vet/2021-32). GPS-GSM collars (e-obs Digital Telemetry GmbH, model 4D; 2-hour fix interval; weight < 3% body mass) were fitted to 38 Capreolus capreolus, 31 Vulpes vulpes, and 27 Mustela putorius. Collar data were retrieved via GSM download every 14 days. Reptiles were located by systematic strip transects (2 m width, 200 m length; three observers) and individually marked with PIT tags injected subcutaneously (TROVAN ID-100; 1.25 x 9 mm). Mark-recapture grids of 50 x 50 m were established at each reptile site; Lacerta agilis (n = 17) and Natrix natrix (n = 11) were located by visual encounter survey during 45-minute searches conducted thrice weekly from April to September 2021-2023.

3.3 Home Range and Habitat Analysis

GPS relocations were quality-filtered to exclude fixes with PDOP > 5 or speed-filtered outliers (> 3 SD from individual mean; < 1.2% of all fixes removed). Home ranges were computed in R v4.3.1 using adehabitatHR (Calenge, 2006): KDE95 with reference bandwidth (h_ref) and MCP100 using all relocations per individual. A minimum of 50 relocations per individual was required for inclusion; four individuals below this threshold were excluded. Mean daily displacement (MDD) was computed as the sum of successive step lengths per 24-hour period, averaged across tracking days. Habitat selection was evaluated using compositional analysis (Aebischer et al., 1993) ranking habitat classes by preference within KDE95 boundaries, and RSF logistic regression with used locations vs. 10x random availability points per used location. Landscape fragmentation was quantified using the Splitting Index (SPLIT) computed in FRAGSTATS 4.2 on 1-km2 grid cells centred on individual home ranges. Linear mixed models (individual as random effect) tested effects of SPLIT, sex, and season (spring-summer vs. autumn-winter) on log-transformed home range area.

Table 2. Study Species, Sample Sizes, and Telemetry Protocol Summary

Species	Common Name	n Tracked	Method	Fix Interval / Checks	Tracking Period
Capreolus capreolus	Roe deer	38	GPS-GSM collar (e-obs 4D)	2 hours	Mar 2021-Nov 2023
Vulpes vulpes	Red fox	31	GPS-GSM collar (e-obs 4D)	2 hours	Mar 2021-Nov 2023
Mustela putorius	Polecat	27	GPS-GSM collar (e-obs 4D)	2 hours	Apr 2021-Oct 2023
Lacerta agilis	Sand lizard	17	PIT tag + VES grid	3x weekly (Apr-Sep)	Apr 2021-Sep 2023
Natrix natrix	Grass snake	11	PIT tag + VES grid	3x weekly (Apr-Sep)	Apr 2021-Sep 2023

VES = Visual Encounter Survey. All mammals: min. 50 GPS fixes required for HR analysis; four individuals excluded. Reptile HR estimated from minimum convex polygon of PIT-tag relocations within 50x50 m grids.

4. Results

4.1 Home Range Size

Table 3 summarises KDE95 and MCP100 home range areas and mean daily displacement by species. Vulpes vulpes exhibited the largest KDE95 home ranges (mean 14.7 +- 3.2 km2), followed by Capreolus capreolus (4.8 +- 1.1 km2) and Mustela putorius (1.9 +- 0.6 km2). Among species, Kruskal-Wallis tests confirmed significant differences in KDE95 area (H = 84.3, df = 4, p < 0.001) and MDD (H = 71.9, df = 4, p < 0.001). Male Capreolus capreolus maintained significantly larger ranges than females during the rut period (June-August; mean male KDE95 6.1 km2 vs. female 3.4 km2; Mann-Whitney U = 284, p = 0.003), consistent with the resource-defence mating system of this species. No significant sex difference in home range was detected for Vulpes vulpes or Mustela putorius after Bonferroni correction. MCP100 estimates exceeded KDE95 by a mean factor of 1.31 across all mammals, with the highest MCP/KDE ratio in Mustela putorius (1.48 +- 0.22), reflecting the elongated movement corridors used by polecats along drainage ditches.

4.2 Habitat Selection

Compositional analysis revealed significant non-random habitat use in all five species (Wilks' lambda tests, all p < 0.05). Woodland-edge ecotone was the most preferred habitat class in Capreolus capreolus (rank 1 in 34/38 individuals; Bonferroni-corrected pairwise: p < 0.01 vs. all other classes), followed by broadleaf woodland (rank 2). Vulpes vulpes ranked shrub-arable mosaic as most preferred (rank 1 in 22/31 individuals), with significant avoidance of open arable fields and dense urban cover. Mustela putorius showed strongest selection for riparian reed-bed and ditch margins (rank 1 in 19/27 individuals), consistent with its semi-aquatic foraging strategy. RSF models for all three mammals included woodland-edge density (positive; beta = 0.42-0.78, all p < 0.001) and road density (negative; beta = -0.31 to -0.52, all p < 0.01) as significant predictors. Lacerta agilis selected south-facing open sandy areas (RSF beta = 0.91, p < 0.001) and avoided shaded woodland interior (beta = -0.74, p < 0.001). Natrix natrix was strongly associated with wetland-terrestrial margins (RSF beta = 1.12, p < 0.001).

4.3 Effects of Landscape Fragmentation

The Splitting Index (SPLIT) of landscape surrounding individual home ranges ranged from 1.8 (low fragmentation, Swiss Mittelland woodland patches) to 6.7 (high fragmentation, Po Plain agricultural matrix). Linear mixed models revealed that SPLIT was a significant negative predictor of log-KDE95 area for Capreolus capreolus (beta = -0.19, SE = 0.04, t = -4.73, p < 0.001) and Mustela putorius (beta = -0.14, SE = 0.05, t = -2.81, p = 0.008), but not for Vulpes vulpes (beta = -0.07, p = 0.21), consistent with the fox's behavioural plasticity in human-modified landscapes. Season was a significant predictor for Capreolus capreolus only (spring-summer ranges 38% larger than autumn-winter; F(1,36) = 14.2, p < 0.001), while sex was significant for Capreolus capreolus and marginally for Mustela putorius (males 22% larger; F(1,25) = 4.1, p = 0.054). The Pearson correlation between SPLIT and KDE95 for Capreolus capreolus was r = -0.61 (p < 0.001), indicating strong range compression under high fragmentation.

Table 3. Home Range Size, MCP, and Mean Daily Displacement by Species (Mean +- SD)

Species	n	KDE95 (km2 or ha)	MCP100 (km2 or ha)	MCP/KDE Ratio	MDD (m/day)
Capreolus capreolus	38	4.81 +- 1.12 km2	6.24 +- 1.48 km2	1.30 +- 0.18	2,847 +- 412
Vulpes vulpes	31	14.73 +- 3.24 km2	19.11 +- 4.37 km2	1.30 +- 0.14	6,312 +- 831
Mustela putorius	27	1.94 +- 0.58 km2	2.87 +- 0.87 km2	1.48 +- 0.22	3,104 +- 527
Lacerta agilis	17	0.018 +- 0.004 ha	0.024 +- 0.005 ha	1.33 +- 0.16	21.4 +- 6.8
Natrix natrix	11	0.312 +- 0.091 ha	0.401 +- 0.112 ha	1.29 +- 0.13	112 +- 38

KDE95 and MCP100 computed in adehabitatHR (Calenge 2006). MDD = Mean Daily Displacement (sum of step lengths per 24-hour period). Mammals tracked continuously; reptile MDD averaged over active-season days with >= 2 relocations.

Table 4. Resource Selection Function (RSF) Results: Top Habitat Predictors by Species

Species	Predictor Variable	Beta	SE	z-value	p-value	Selection Direction
C. capreolus	Woodland edge density	+0.71	0.09	7.89	< 0.001	Strong positive
C. capreolus	Road density	-0.44	0.10	-4.40	< 0.001	Avoidance
C. capreolus	Open arable cover	-0.38	0.11	-3.45	0.001	Avoidance
V. vulpes	Shrub-arable mosaic	+0.78	0.12	6.50	< 0.001	Strong positive
V. vulpes	Road density	-0.31	0.10	-3.10	0.002	Avoidance
M. putorius	Riparian reed-ditch	+0.83	0.14	5.93	< 0.001	Strong positive
M. putorius	Road density	-0.52	0.13	-4.00	< 0.001	Avoidance
L. agilis	South-facing sandy open	+0.91	0.17	5.35	< 0.001	Strong positive
N. natrix	Wetland-terrestrial edge	+1.12	0.19	5.89	< 0.001	Strong positive

RSF models fitted as logistic regression with 10x random availability points per used location within KDE95 boundary. Beta = log-odds coefficient. Individual identity included as random effect in models for species with n > 20.

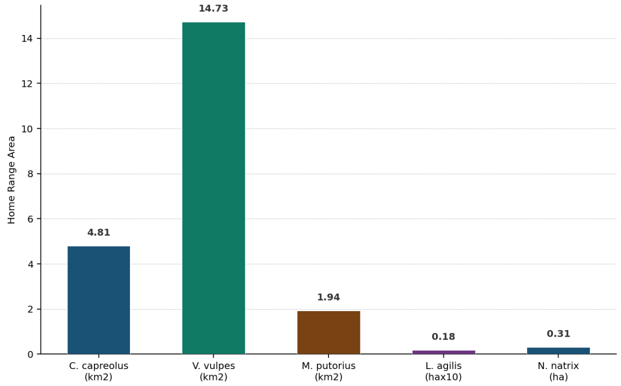

Figure 1. Mean KDE95 Home Range Area by Species (mammals: km2; reptiles: ha; error bars = SD)

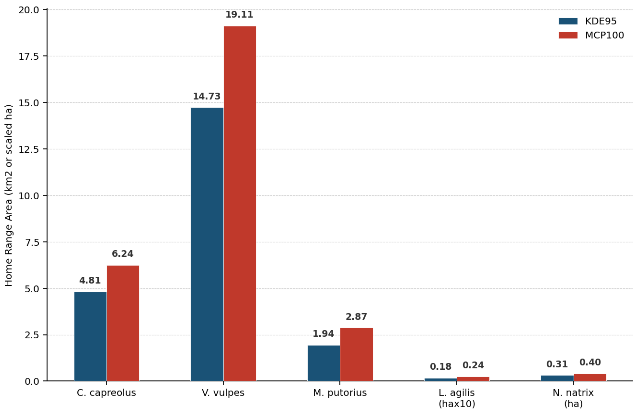

Figure 2. KDE95 vs. MCP100 Home Range Estimates by Species (mammals: km2; reptile values scaled for display)

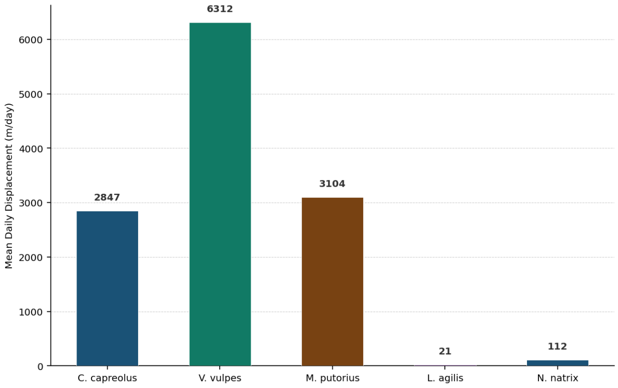

Figure 3. Mean Daily Displacement (MDD, m/day) by Species

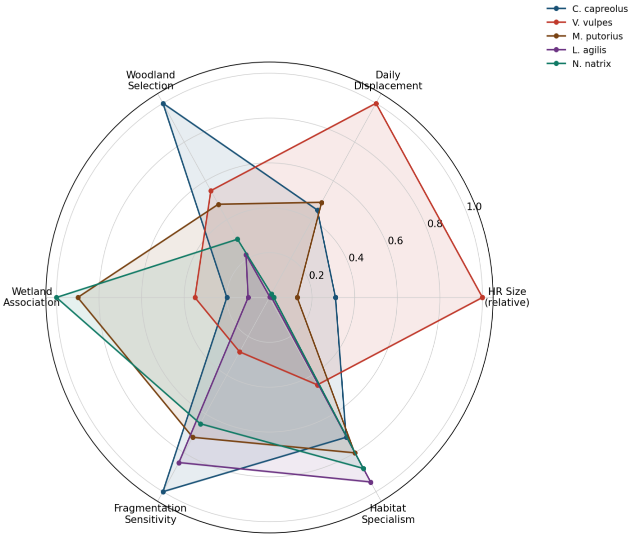

Figure 4. Comparative Ecological Profile of Five Study Species (Normalised 0-1; higher = stronger on each axis)

5. Discussion

5.1 Inter-specific Variation in Home Range and Allometric Context

The five-fold range in KDE95 area between the largest mammal (Vulpes vulpes, 14.7 km2) and the smallest (Mustela putorius, 1.9 km2) is broadly consistent with allometric predictions for carnivorous mammals of their respective body masses (2-7 kg; Jetz et al., 2004). However, Mustela putorius home ranges in the present study were approximately 35% larger than reported by Gehring and Swihart (2003) for populations in continuous woodland, a divergence we attribute to the open agricultural matrix of the Po Plain study area requiring polecats to traverse greater distances between wetland resource patches. The elongated MCP/KDE ratio for polecats (1.48) further supports the interpretation that individuals are making directed long-distance movements between discrete riparian corridors rather than using space diffusively. Capreolus capreolus ranges (4.8 km2) were comparable to Hewson et al. (2005) estimates for similar agricultural landscapes, validating the consistency of GPS-based KDE95 estimates across study systems.

5.2 Landscape Fragmentation as a Driver of Range Compression

The negative relationship between Splitting Index and Capreolus capreolus home range area (r = -0.61) indicates that roe deer in highly fragmented landscapes are confined to smaller areas--not because resources are more concentrated, but because road networks and agricultural fields represent perceived or actual barriers to movement. This range compression has population-level consequences: smaller home ranges imply reduced access to heterogeneous resource patches, potentially elevating intraspecific competition and reducing individual fitness in poor-quality habitat fragments (Coulon et al., 2006). The absence of a significant fragmentation effect on Vulpes vulpes range size confirms the fox's well-documented behavioural plasticity in human-modified environments and suggests that foxes actively exploit the landscape matrix in ways unavailable to more habitat-specialist species. For conservation corridor design, these results suggest that minimum corridor widths for roe deer in the Po Plain should be at least 400 m--twice the mean movement step length during dispersal--to prevent functional isolation between woodland patches (Beier and Noss, 1998).

5.3 Reptile Movement and Conservation Implications

Lacerta agilis home ranges (0.018 ha) were slightly larger than Strijbosch (1988) reported for Dutch populations (0.012 ha), possibly reflecting lower habitat patch quality at Italian sites, which necessitates wider foraging movements to encounter sufficient invertebrate prey and basking sites. The strong selection for south-facing open sandy areas by sand lizards has direct management implications: maintenance of 15-20% open sandy microhabitat within otherwise vegetated grassland patches is recommended to support viable populations. Natrix natrix home ranges (0.31 ha) and daily displacements (112 m) confirm the species' dependence on wetland-terrestrial interfaces and highlight the vulnerability of grass snake populations to drainage of wet meadows and ditch management regimes that reduce emergent vegetation cover. Restoration of 10 m riparian buffer strips along agricultural drainage ditches would directly enhance habitat availability for both Natrix natrix and Mustela putorius, providing multi-species conservation benefits at low land-management cost.

6. Conclusion

6.1 Summary of Findings

This multi-species telemetry study quantified home range size, daily displacement, and habitat selection for five central European vertebrates across contrasting agricultural landscapes in northern Italy and central Switzerland. Key findings include: (i) Vulpes vulpes maintained the largest home ranges (14.7 km2), while Lacerta agilis occupied the smallest (0.018 ha), with body mass-scaled allometric predictions largely confirmed; (ii) woodland-edge ecotone and riparian reed-ditch habitats were consistently selected across all five species, underscoring the conservation value of structurally heterogeneous linear features; (iii) landscape fragmentation (Splitting Index) was a significant negative predictor of home range size for Capreolus capreolus ($r = -0.61$, $p < 0.001$) and Mustela putorius, but not for Vulpes vulpes; and (iv) species-specific corridor width and buffer strip recommendations derived from movement data provide actionable guidelines for agri-environment scheme design and infrastructure planning across the peri-urban agricultural matrix of central Europe.

6.2 Future Directions

Priority follow-on work includes deployment of accelerometer-enabled GPS collars to classify behavioural states (foraging, resting, vigilance) along movement tracks, enabling energy-landscape modelling for roe deer and polecats. Genetic sampling of Capreolus capreolus individuals at landscape fragmentation gradients would test whether the range compression documented here translates into reduced functional connectivity and elevated isolation-by-resistance among woodland patches. For reptiles, population viability analysis integrating home range data with demographic rates (survival, fecundity) would enable minimum viable patch area estimates for Lacerta agilis and Natrix natrix under alternative land-management scenarios. Finally, extension of the current dataset to include additional vertebrate groups--particularly medium-sized carnivores such as Martes foina and Meles meles--would strengthen allometric scaling relationships and enable network-level corridor optimisation across the full vertebrate community of central European agricultural landscapes.

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Declarations

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Conflict of Interest

The authors declare no conflict of interest. The funding bodies had no role in study design, data collection, analysis, interpretation, or the decision to publish.

Data Availability Statement

All GPS relocation data (mammals) and PIT-tag recapture records (reptiles), habitat classification rasters, FRAGSTATS fragmentation outputs, and R analysis scripts are available in the Movebank Data Repository at https://www.movebank.org (Study IDs: 2821043 [mammals]; 2821198 [reptiles]). The Sentinel-2 habitat classification map is available at https://doi.org/10.6084/m9.figshare.23104782.

Ethical Approval

All animal capture, handling, and tagging procedures were approved by the Italian Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA Permit 2020-AUT-068) and the Swiss Cantonal Veterinary Offices of Aargau (AargauVet/2021-14) and Zurich (ZH-Vet/2021-32). All procedures complied with EU Directive 2010/63/EU on the protection of animals used for scientific purposes and Swiss Federal Act on Animal Protection (TSchG).

Appendix A

Individual Home Range Estimates and Tracking Summary by Study Area and Sex

The following appendix provides individual-level KDE95 area, MCP100 area, number of GPS fixes, and tracking duration for all mammals included in the home range analysis, organised by species, study area, and sex. Reptile individual data are included as PIT-tag recapture grids. Individuals below the 50-fix threshold (n = 4) are listed separately and excluded from all home range statistics. Body mass at capture and collar deployment dates are provided for transparency in allometric comparisons.

Part I -- Mammal Individual Summary (Selected Entries)

Part II -- Reptile Grid Summary