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Estimation of wild boar movement and social behaviour parameters relevant for ASF control across ecological, demographic and anthropogenic gradients

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Abstract

This report offers an extensive, standardized synthesis of wild boar movement and social behaviour parameters relevant to African Swine Fever (ASF) control, derived from GPS-telemetry data spanning 13 European countries. It provides a descriptive analysis of data from 743 wild boars, totalling nearly 3.9 million GPS points collected from 2003 to 2024. The results indicated that wild boar movement is generally sedentary, with a median maximum displacement of about 1 km every 14 days, although cumulative travel distances can reach up to 50 km in the corresponding period. Movement and contact patterns show substantial variability, with a small fraction of wild boars displaying high movement and contact intensity, representing key risk factors for ASF spread. The analysis reveals notable seasonal, demographic, and environmental effects on wild boar behaviour. Movement rates and home range sizes peak in autumn and winter, especially among males, who cover larger areas and engage in more inter-group interactions than females. The landscape also plays an important role: areas with intermediate levels of forest cover and forest-agricultural mosaics tend to show higher movement rates and more frequent contacts between groups and with pig farms. Population density also influences spatial behaviour, with denser populations resulting in smaller home ranges but more frequent interactions among wild boar groups and with pig farms. The study's findings highlight the importance of considering heterogeneity in movement and contact patterns when designing ASF management strategies. The data supports targeted biosecurity measures during high-risk periods and for mobile cohorts, particularly male wild boars during the mating season. The report provides a quantitative foundation for ASF risk assessment, spatial modelling, and surveillance, emphasizing the need for ongoing data collection and more precise modelling to improve ASF control across Europe.

Key words: GPS-telemetry; Epidemiology; Hunting Disturbance; Seasonality; Population Density; Social Structure; Landscape Fragmentation

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Summary

African swine fever (ASF) remains one of the most significant threats to pig production in Europe, with wild boar (*Sus scrofa*) playing a central role in virus persistence and spatial spread. Effective ASF prevention and control therefore require robust, standardised estimates of wild boar movement, space use, social contact structure, and interactions with domestic pig holdings across diverse ecological and management contexts. However, existing knowledge is fragmented across site-specific studies and characterised by substantial methodological heterogeneity, which limits its applicability for risk assessment and policy development.

This report provides the most comprehensive, harmonised pan-European synthesis to date of wild boar movement and social behaviour parameters relevant to ASF control. Using the EUROBOAR database, we analysed GPS-telemetry data from 743 wild boar individuals monitored across 54 study areas in 13 European countries, comprising nearly 3.9 million GPS locations collected between 2003 and 2024. Movement, activity, and contact metrics were calculated using a unified analytical pipeline and summarised over a 14-day time window, a timeframe meaningful for ASF epidemiology. Parameters were evaluated across gradients of season, sex and age class, wild boar population density, forest structure, composition and fragmentation, landscape anthropization, and hunting modality.

Across Europe, wild boar displayed predominantly sedentary spatial behaviour, characterised by low median maximum displacement (approximately 1 km per 14 days) despite substantial cumulative distances travelled in the same period (~50 km). Movement and contact distributions were strongly right-skewed, indicating that while most individuals exhibited limited ranging and low contact frequency, a small proportion of animals and a limited number of biweekly windows accounted for disproportionately high movement rates, inter-group contacts, and contacts with pig farms. Seasonal patterns were pronounced: movement rates, home-range size, and nocturnality peaked in autumn–winter, while between-group contacts peaked in winter–spring, and wild boar–pig farm contacts peaked in spring and late summer. Sex- and age-specific differences were consistent, with males showing larger ranges, higher displacement variability, greater inter-group connectivity, and more frequent contacts with pig farms than females. Elevated movement and between-group contact variability was most pronounced in subadult males, while interactions with pig farms were most frequent among adult males.

Landscape configuration emerged as a major determinant of spatial and social behaviour. Intermediate levels of forest cover and forest–agricultural mosaic landscapes were associated with the highest movement rates, widest ranging, and elevated between-group and farm contact frequencies, whereas highly forested areas promoted smaller ranges and more localised movement. Increasing wild boar population density resulted in a contraction of home ranges and displacement distances but increased the frequency of wild boar–pig farm contact events. Drive hunting was associated with increases in movement, range expansion, and nocturnality, although it did not consistently increase long-term net displacement or direct contact rates. Temporal analyses of maximum displacement distances across a 2-month period confirmed strong site fidelity in most individuals, while highlighting rare but epidemiologically relevant long-distance movements (>10 km, maximum 66 km) occurring in a small subset of animals. These findings support ASF

transmission kernels dominated by local spread, punctuated by infrequent long-range dispersal events.

Overall, this report delivers a standardised, evidence-based parameter set describing wild boar movement and contact processes across Europe. The results provide a quantitative foundation for ASF risk assessment, spatial modelling, surveillance design, and targeted management, and highlight the importance of behavioural heterogeneity, seasonality, demographic structure, and landscape configuration in shaping ASF transmission risk.

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1. Introduction

Wild boar is a natural host of African swine fever virus (ASFv) (Chenais et al. 2018). Mobility of the species, including ability to travel over large distances, combined with its social behaviour can contribute to local, or even regional, spread of the disease (Chenais et al. 2019; Podgórski & Śmietanka 2018). Thus, quantifying movement patterns and contact rates in wild boar populations is essential to improve ASF risk assessment and control measures (Palencia et al. 2023). Despite relatively abundant literature (e.g. Morelle et al. 2015; Keuling et al. 2017; Scandura et al. 2021), the information is scattered, context-dependent, and methodologically inconsistent which undermines its accessibility for policy makers and managers. With this report, we aim to provide a comprehensive analysis of the wild boar movement and contact rate parameters based on the widest dataset available and standardized methodology. Presented data can help develop data-driven, evidence-based management strategies for controlling ASF spread in wild boar populations.

Overview of wild boar movement ecology, activity patterns and social behaviour

From the literature, we know that wild boar move in different ways according to specific behaviour. For example, foraging and social activity typically occur within small patches (≈25 ha), with short displacements at low speed that rarely exceed 1 km/h, and mean feeding speed ≈0.25 km/h (Spitz & Janeau 1990; Briedermann 2009; Morelle et al. 2015). When commuting between patches, animals move directionally at trotting speeds ≈1–10 km/h (Spitz & Janeau 1990; Briedermann 2009; Morelle et al. 2015). During escape, they run in short bursts up to ≈40 km/h (Morelle et al. 2015). Daily distance travelled is usually < 10 km, though longer daily distances occur in fragmented urban landscapes and under intensive hunts (Russo et al. 1997; Scillitani et al. 2010; Podgórski et al. 2013). Over 24h, individuals can traverse 45–90 % of their annual range, highlighting generally sedentary space use relative to locomotory capacity (Podgórski et al. 2013).

Home-range sizes show remarkable variation. Reported annual home ranges span ≈1 - 70 km2 (mean ≈ 4-8 km2) (Boitani et al. 1994; Keuling et al. 2008a; Podgórski et al. 2013; Maillard & Fournier 1995). Seasonal home ranges are typically half the size of annual ranges but can temporarily expand to annual extent during hunting seasons (Maillard & Fournier 1995; Keuling et al. 2008a,b, 2009; Tolon et al. 2009, 2012; Saïd et al. 2012). The smallest ranges occur in urban areas, rich habitats, and protected areas whereas the largest are reported in mountainous areas, resource-poor systems or hunting land (Singer et al. 1981; Podgórski et al. 2013; Keuling et al. 2008a; Laguna et al. 2021; Miettinen et al. 2023). Seasonal shifts in space use occur across heterogeneous landscapes (mountains, field–forest mosaics), and linear vegetation facilitates movement in open farmland (Dardaillon 1986; Keuling et al. 2009; Thurfjell et al. 2009). Studies reporting sex effects on home range size consistently indicate larger male ranges (Morini et al. 1995, Laguna et al. 2021, Cavazza et al. 2023). Males often extend movements during the rut, whereas pregnant females contract movements around parturition and expand during lactation (Singer et al. 1981; Morelle et al. 2015; Keuling et al. 2008b, 2009).

Natal dispersal may contribute to occasional long-distance movements but a majority of juveniles (≈70–80 %) remain within ≤ 5 km of natal areas; rarer dispersers move 5–30 km, mostly males, with dispersal peaking in the second year. Exceptional linear movements reach ≈50–250 km and can be achieved by young animals, adult males, and even adult females with offspring (Truvé & Lemel 2003; Keuling et al. 2010; Prévot & Licoppe 2013; Podgórski et al. 2014a; Andrzejewski & Jezierski 1978; Jerina et al. 2014).

Hunting disturbance, especially frequent drive hunts, induces escape movements, greater distances travelled, enlarged ranges, dispersion of resting sites, and range shifts; lower-intensity hunts have smaller effects (Maillard & Fournier 1995; Keuling et al. 2008b; Tolon et al. 2009; Scillitani et al. 2010; Saïd et al. 2012; Thurfjell et al. 2013; Olejarz et al. 2024). In urban systems, wild boar typically compress ranges and increase nocturnality while using riparian and shrubby corridors to move within cities (Podgórski et al. 2013; Stillfried et al. 2017a, b).

Wild boar exhibit flexible diel activity with alternating bouts of movement and rest totaling ~6 - 12 h a day, and within active time, ~45–97% foraging (Massei et al., 1997; Lemel et al., 2000; Cahill et al., 2003, Podgórski et al., 2013; Brivio et al., 2017). Activity is typically nocturnal with a biphasic pattern of activity peaking at dawn and dusk (Lemel et al., 2000; Keuling et al., 2008b). In human-dominated landscapes, a shift towards nocturnality is observed, strengthened during hunting seasons and near settlements (Boitani et al., 1994; Keuling et al., 2008b; Ohashi et al., 2013, Laguna et al. 2021). Urban populations tend to be almost exclusively nocturnal year-round, decoupled from seasonal photoperiod, to minimize human encounters (Cahill et al., 2003; Podgórski et al., 2013). Seasonal effects are observed in autumn, when increased foraging results in expanded activity time, and early-summer, when diurnality rises as lactating females adopt polyphasic schedules (Russo et al., 1997; Keuling et al., 2008b; Podgórski et al., 2013). Harsh weather (frost, drought) suppresses activity (Massei et al., 1997; Keuling et al., 2008b; Ohashi et al., 2013). Collectively, these metrics indicate that wild boar align activity to balance energetic intake with risk, switching to nocturnality and polyphasic schedules when human pressure or environmental constraints intensify (Boitani et al., 1994; Keuling et al., 2008b; Podgórski et al., 2013).

In terms of social structure, wild boar are matrilineal and group-living. Stable family groups typically contain 1-2 adult females plus subadults and juveniles; adult males are mostly solitary except during the rut, when they join female groups briefly (Dardaillon, 1988; Boitani et al., 1994; Poteaux et al., 2009). Groups are kin-structured and largely philopatric. Neighbouring groups' home ranges overlap without territorial defense, enabling routine inter-group encounters. Reported group sizes are commonly 4–10, with wider variation across habitats (Gabor et al., 1999; Rosell et al., 2004, Kaminski et al., 2005; Podgórski et al., 2014a, b).

The literature quantifying wild boar social contacts in European populations is scarce. Podgórski et al. (2018) quantified contact rates in three European wild boar populations using VHF telemetry. Dyadic contacts were determined based on simultaneous locations within 200 m and <1 hour. Contacts were strongly structured socially and spatially. Association rates were about an order of magnitude higher within social groups than between groups (0.59 ± 0.02 and 0.035 ± 0.002, respectively) and most contacts occurred between individuals in close spatial proximity (home-range centroids <1 km apart) while associations between faraway individuals (>4 km) were rare. Between-group contact rates depended largely on the physical distance, while age influenced contact occurrence and diversity: yearlings (0.5–2 years) had higher between-group connectivity and more central position in the social networks than adults, identifying them as potential "bridges" for disease spread. GPS-telemetry offers better accuracy of quantifying frequency of social contacts by providing more fine-scale data on individuals' co-locations compared to VHF-telemetry. In a recent study across a 21 European populations dataset using GPS-telemetry (co-locations at 25 m and 5 min threshold), monthly within-group contact rate averaged 0.42 (95% CI 0.39 - 0.45), while between-group averaged 0.007 (0.005 - 0.009), i.e., an order-of-magnitude difference in intensity. Frequency of within-group contacts during drive-hunt months was lower than in months with no/individual hunts (0.22 vs 0.44–0.45) but no measurable effect of hunting on between-group contact probability was observed (Podgórski et al., 2026). Spatial proximity appears to be the main predictor of between-group encounter probability (Pepin et al. 2016, Podgórski et al. 2018, Podgórski et al., 2026). Recent analysis showed that predicted monthly contact probability between groups increased from 0.18 when two groups did not share space to 0.99 when home range of two groups overlapped at >90% (Podgórski et al., 2026).

Factors influencing wild boar movement and behaviour metrics

Wild boar movement, activity, and social interactions can be influenced by a wide range of ecological, demographic, and anthropogenic factors. Based on the available literature, in this report we selected and investigated the most influential factors shaping movement and social activity: **1) land cover (proportion of forest cover)**: spatially, extensive woodland provides shelter and resources and can thus reduce travel distances and home range size; socially it leads to high cohesion within matrilineal groups and localized between-group encounters. In contrast, open landscapes force longer commutes between foraging patches, expand the span of space use, and funnel movements along linear habitat structures; **2) habitat structure (fragmentation):** creates habitat patches, edges, and corridors that may affect movement linearity and range size, and elevate variance in distance travelled as well as contact rates, **3) habitat productivity (proportion of deciduous forest):** rich and suitable habitats (i.e. deciduous forests) can reduce movement and space use while poor habitats induce longer movements and larger ranges; **4) seasonality**: seasons reorganizes time budgets, movement and contact patterns via photoperiod and weather, resource pulses (mast, crops) and species life-history events (mating, farrowing); **5) sex and age class:** adult males typically range farther, particularly during the rut, and connect otherwise weakly linked groups, whereas lactating females tend to have smaller ranges, particularly during parturition and lactation, intensifying within-group contact. Dispersing yearlings can show increased, longer-distance movements and maintain between-group connectivity. Matrilineal groups of adult females with offspring maintain stable and long-term within-group associations; **6) population abundance:** as population density rises, home range overlap between individuals can increase, elevating encounter rates. Lower movement rates and range size can also be expected under high population densities; **7) hunting modality:** repeated drive hunts induce escape movements, displace groups, enlarge ranges, and temporarily reduce within-group cohesion; **8) ecological regions**: biogeographic (ecoregional) context can influence movement ecology through climatic conditions and vegetation; **9) human footprint index:** higher anthropization can increase nocturnality and compress ranges in urban areas, yet elevate distance travelled to connect spread out shelter and foraging patches of habitat.

For more information about the influencing factors analysed in this report, see section 2.3 (Methodology and Data).

Relevance of wild boar movement and behaviour for ASF control

Host movement is an important driver of disease dynamics as it affects spatial extent of pathogen shedding as well as the number of conspecifics an individual may encounter and potentially transmit the pathogen to (Pandey et al., 2025). In case of ASF specifically, direct social contacts between infected and susceptible individuals (next to indirect transmission from infectious carcass and contaminated environment) play a key role in the persistence and transmission of the virus in the environment. Movements and social contact frequency of infected wild boar can thus contribute to the spread of the disease. Movement can be best described by various synthetic metrics such as distance travelled (displacement), area covered (range size), or nature of movement (e.g. linearity, speed) (Beumer et al., 2026). Interpretation of single metrics can sometimes be ambiguous. For example, information about the distance travelled by an animal does not inform us about the directionality of movement which can potentially have very different epidemiological outcomes: long-distance spread in case of directed movement or local transmission in case of circular movement. Therefore, it is important to consider multiple movement metrics for comprehensive description of movement behaviour and its relevance to disease spread. Table 1 presents the movement and behaviour metrics which were selected based on their high relevance to ASF epidemiology and control.

African swine fever dynamics in wild boar are tightly constrained by movement and space-use metrics that determine contact structure and carcass encounter rates. Short daily movements and generally small, sedentary home ranges concentrate infectious contacts within and among neighbouring sounders, producing steep distance-decay kernels of spread. Social organization and group living therefore become determinants of transmission (Pepin et al., 2021).

Carcass-mediated transmission links movement to an environmental reservoir with prolonged ASFV persistence. Wild boar frequently investigate conspecific carcasses (sniffing, rooting, mouthing), behaviour that can sustain transmission even when host density or direct contact rates are low (Probst et al., 2017; Gervasi et al., 2021). Hence, metrics such as core area and distance travelled can inform carcass encounter rates and the spatial kernel while range size and maximum displacement can calibrate the epidemic's “natural” perimeter for surveillance and fence design. It is worth noting that animals exhibit symptoms such as lethargy, fever, anorexia, and depression within 7–14 days post-infection and their movement capacity is severely limited (Blome et al., 2012; Rodríguez-Bertos et al., 2020; Morelle et al., 2023). Therefore, a two-week period appears to be a meaningful, yet conservative, timescale when considering wild boar movement metrics for ASF epidemiology and control and we have adopted this timescale for summarizing the movement and behavioral metrics throughout the report.

Besides movements, ASF transmission in wild boar is governed by how social structure concentrates and filters direct contacts through time and space. The social structure of the wild boar populations produces strong within-group contact intensity and sparse, overlap-dependent between-group encounters. Network and modelling studies show that most direct transmission is expected within family groups and that social structure - i.e., contact-density functions constrained by grouping - shapes epidemic size and persistence, manifested in strong local clustering and slow spatial spread under contact-only transmission (Pepin et al., 2021; Shaw et al., 2024). Contact heterogeneity across sex, age and seasons further modulates exposure: male movements during the rut temporarily bridge groups, whereas matrilineal units maintain high, stable within-group contact (Podgórski et al., 2026). Despite the fact that ASF frequently persists via carcass-mediated transmission, social contacts remain pivotal because they determine how often infectious boars are near conspecifics before death and how often susceptible animals co-use core areas where carcasses may occur (Probst et al., 2017; Gervasi et al., 2021). Because direct spread clusters within groups, culling that targets bridging individuals (e.g., roaming males) or entire infected family groups can truncate contact networks more efficiently than random removal. However, disturbance that fragments groups (e.g., repeated drive hunts) may depress within-group cohesion without creating stable new ties, risking wider movement and potential spread.

Wild boar - pig farm contact can be an important indicator of potential incursion risk of African swine fever virus transmission from the wild to domestic population. Direct physical contact is rare or impossible at commercial indoor farms but is plausible at outdoor/backyard premises. Camera-trap studies in the UK and Japan documented wild boar/feral pig visits at or within farm fences, including breaches during crop harvest, confirming spatiotemporal co-use of farm margins (Bacigalupo et al., 2022; Shichijo et al., 2024). EFSA's risk assessment concluded that outdoor pig systems carry a substantial ASF risk and identified fencing as highly effective when correctly installed and maintained (EFSA AHAW Panel, 2021). Presence of infected wild boar near pig farms may increase chances of virus incursion via indirect routes, such as contaminated bedding (straw/hay), water, vehicles, equipment and staff acting as fomites, and arthropod vectors (EFSA, 2024). Thus, proximity of wild boar to pig farms can be an indicator of the potential incursion risk.

Movement and behaviour metrics of wild boar provide an empirical basis for defining spatially explicit ASF management strategies. Estimates of range size and core areas can inform the minimum spatial extent within which infected individuals are likely to move, thereby supporting evidence-based placement of restriction zones and the delimitation of "white zones" aimed at reducing host density. Metrics of distance travelled and maximum displacement identify range, periods and ecological contexts associated with enhanced dispersal, which is crucial for setting the radius of control perimeters beyond observed cases to intercept potential spread via longer movements. The intensity of space use can further refine these decisions by indicating whether movements are clustered or directional and guiding the optimal positioning and expected effectiveness of physical barriers such as fencing. Behavioural timing, captured by the diurnality index, can improve the scheduling of surveillance and culling within designated areas, increasing efficiency and reducing effort. Finally, contact rates among wild boar, and interactions with pig farms, identify epidemiologically-relevant ecological conditions or animal attributes which elevate connectivity and environmental contamination risk, prioritising locations or periods for strengthened biosecurity and intensified population management.

Table 1. Movement and behaviour metrics which were selected based on their high relevance to ASF epidemiology and control.

Metric	Definition	Potential application for ASF control
Range size [km2]	Area which is likely to be used by an animal throughout its lifetime, estimated through the Minimum Convex Polygon 95	Information about the wild boar space requirements could help in designing appropriately sized restriction zones
Core area [km2]	Area routinely used by an animal, expressed in the units of surface area, estimated through the Minimum Convex Polygon 50	Information about areas used the most by wild boar could help in designing appropriately sized restriction zones
Distance traveled [km]	Cumulative distance between subsequent GPS locations in a given period	Can help identify high-risk periods and ecological conditions for virus shedding across the landscape, due to increased movement
Maximum displacement distance [km]	Maximum distance observed across all pairwise distances (i.e. not consecutive) in a given period	Can help identify when and where long distance movements happen and adjust control measures accordingly to limit the long-range spread of ASF
Intensity of space use	Ratio between distance traveled and the square root of the range size; higher values indicate more clustered movements, lower values indicate more straight movements	Can be useful to adjust control measures (buffer radius, fencing) depending on the degree of movement linearity.
Diurnality index **[-1 to 1]**	The relative activity during the day conditional on day length; indicating whether movement occurs mostly during the local night or day	Can be helpful in designing culling strategy to optimise allocation of hunting effort
Contact rates [number of contacts]	Frequency of direct contacts between two individuals in a given period, defined as co-occurrence in space and time	Describes connectivity between groups and could help determine conditions conducive to disease spread; could help tailor culling based on demographic, ecological and phenological characteristics of contact patterns
Wild boar – pig farm interactions [number of contacts]	Frequency of contact between wild boar and pig farm	Indicates propensity of wild boar to come near pig farms and potential for viral contamination of the environment around the farms; could help improve biosecurity

Choice of data source

The information about the movement ecology of wild boar has grown substantially in the last two decades thanks to development and application of GPS tracking. However, the information is scattered across literature and ecological context of single-site studies hamper meaningful comparisons and interpretation of large-scale patterns. Moreover, the results of published studies are often generated using different methodological approaches which complicate attempts to synthesize literature data even further and some key metrics are scarcely reported in the literature. In the absence of pan-European synthesis and common, standardized methodological framework, in this report we opted to collaborate with EUROBOAR (https://euromammals.org/euroboar/), a data and knowledge-sharing initiative established in 2015 and part of EUROMAMMALS (Urbano & Cagnacci, 2021). The EUROBOAR database currently (status on 11/12/2025) stores GPS-telemetry data from 837 individual wild boar covering 62 study areas from 15 countries. The data is shared by individual research groups on a voluntary basis and made accessible on a case-by-case basis upon request. The data is centrally managed by a data curator, ensuring standardized format, quality control and consistency across study areas. Using EUROBOAR to derive movement metrics from raw data is the most defensible route for this report's objectives because it replaces heterogeneous, site-level summaries with a harmonised, pan-European evidence base.

This approach has several advantages: **1) standardization**: a single workflow can enforce common definitions (e.g., fix screening, step length and speed from identical sampling intervals; diel activity indices; home range with specified isopleths and bandwidth; overlap indices; contacts at fixed space–time thresholds). Literature values are not directly comparable because studies use different estimators (MCP, KDE, BBMM), fix schedules, and filters, which biases synthesis (Cagnacci et al., 2010); **2) context control and scalability**: EUROBOAR aggregates individual-level series across many study areas and countries, mitigating publication/site bias and enabling scenario-specific estimates across gradients of land cover, fragmentation, population density, disturbance, management etc.; **3) recency and resolution**: modern GPS delivers fine temporal granularity; EUROBOAR allows estimation of movement metrics and contact indices by season/month/daytype (e.g., hunt vs. non-hunt) consistently across regions, something the literature cannot currently provide; **4) reproducibility**: a single, controlled pipeline - from data input (standardised, curator-checked formats) to outputs – ensures transparency and supports open-access archiving and future updates. In summary, where the literature is fragmented and methodologically inconsistent, EUROBOAR data provides opportunity for coherent, standardised, and scalable results.

1.1 Background and terms of reference as provided by the requestor

This contract/grant was awarded by EFSA to: the University of Torino

Contractor/Beneficiary: EFSA

Contract/Grant title: Wildlife and One Health: wildlife ecology, health surveillance and interaction with livestock, human population, and environment

Contract/Grant number: OC/EFSA/BIOHAW/2022/01.

1.2 Additional information

Within SC3, Work Package 6 (WP6 – ad-hoc scientific advice) refers to the providing timely support to EFSA concerning technical questions about wildlife health, ecology, and surveillance by means of systematic literature review, data collection, and analysis. Specifically, task 6.1B of SC3 aims to identify the most relevant parameters of wild boar behaviour and movement relevant for ASF control, factors influencing those parameters, and estimate their values in different ecological settings based on field data. The deliverables of this Task is Report and datasheet of parameter values to be published in Zenodo, due by January 2026.

Task 6.1B of WP3 addresses relevance of wild boar movement and behavior parameters for ASF control with the following objectives:

Terms of Reference (ToR) for Task 6.1B

The **Terms of Reference (ToRs)** for Task 6.1B as outlined in the project contract are as follows:

1. **Identification of Relevant Parameters for ASF Control**: Identification of most relevant parameters of wild boar behavior and movement for ASF influencing them (eg. land cover, density, season, ASF presence….). The choice of parameters and factors are to be presented at ASF WG before the estimation step.
2. **Estimation of Parameter Values Across Different Scenarios**: Estimation of the values of the previously identified parameters in the different scenarios (scenarios are determined by the factors as above). The estimation should be obtained from field data available (including EUROBOAR, camera traps) and grey literature.

2. Methodology and Data

2.1. Data sources

The computation of movement and behavioral metrics was based on data acquired through GPS collars from 743 individuals of wild boar, tagged at 54 study areas in 13 countries across Europe (Fig. 1). Overall, we worked with 3 869 765 GPS locations collected between 2003 and 2024 (Fig. 2, 3), with a median sampling rate of 58.5 minutes (interquartile range, 29.6 - 60.0 minutes). Tracking duration varies greatly between individuals (Fig. 3) and only 144 animals had GPS locations collected for more than 12 months.

Movement metrics were computed for 692 individuals, whose home range and core area (section 2.2.1), calculated across 14 days, were greater than 0.06 km^2. This value corresponds to a square with a side of 250m, and we believed to be unrealistic that wild boar frequented smaller areas in a time of 14 days. Rather these small values for the home range/core area have resulted from low effective sample sizes and issues with the estimation of the range distribution (Noonan et al., 2019). Moreover, when plotting movement metrics against the different types of hunting in each study area (section 2.3), data that was missing for 23 study areas, we only had data for 527 individuals.

The computation of contact rates was based on a subset of data from GPS collars, collected from 405 individuals tagged at 47 study areas in 12 countries. This choice was motivated by the requirement of at least 5 individuals tracked simultaneously >=1 month in a given study area to calculate contacts. These data filtering resulted in a reduced number of individuals and study areas. The final dataset after data quality check consisted of 369 individuals, 737 dyads, and 3205 dyads-biweeks time windows. An even smaller subset of telemetry data was used in the calculation of contacts between wild boar and pig farms (187 tagged individuals in 32 study areas in 8 countries). This choice was dictated by the availability of pig farm data (locations) and only GPS marked animals including at least one farm within their home range were selected for this analysis. The final dataset consisted of 837 biweekly time windows.

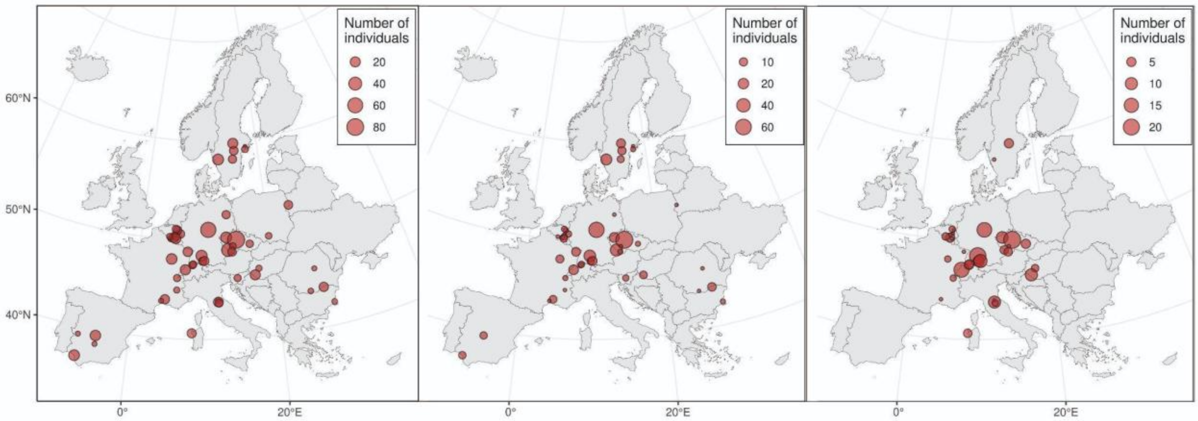


Fig. 1 - Overview of the total number of study areas where wild boars were equipped with GPS tags and where movement metrics (left), contact rates between wild boars (centre) and contact rates between wild boars and pig farms (right) were estimated. The size of each study area is proportional to the number of tracked individuals.

Females comprised 64.7% of our sample and 56.7% of individuals were adults (> more than 24 months) of age. The number of individuals tagged between 0 and 12 months was lower (15.4%), just as the number of individuals tagged in their second year of age (27.9%).

Table 2 - Number of male and female wild boars of different age classes, tagged with GPS collars, which provided data for the analysis. Values in brackets refer to the number of individuals used to estimate wild boar–wild boar contact rates.

Age class	Female	Male
0-12 months	52 (21)	55 (19)
12-24 months	103 (46)	90 (31)
> 24 months	293 (104)	99 (24)

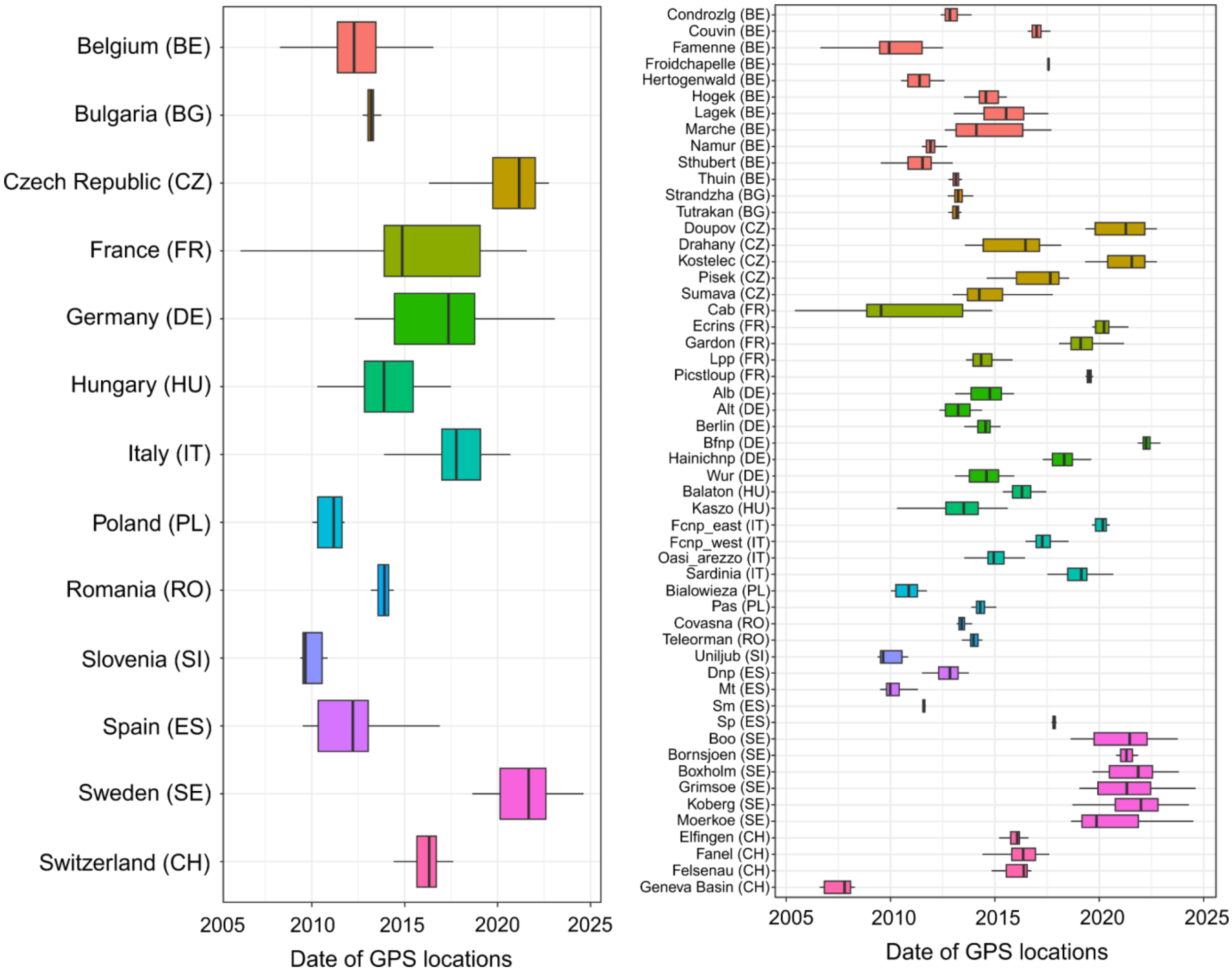


Fig. 2 - Overview of the temporal distribution of data acquisition by GPS tags, between animals from different countries (left) and different study areas (right).

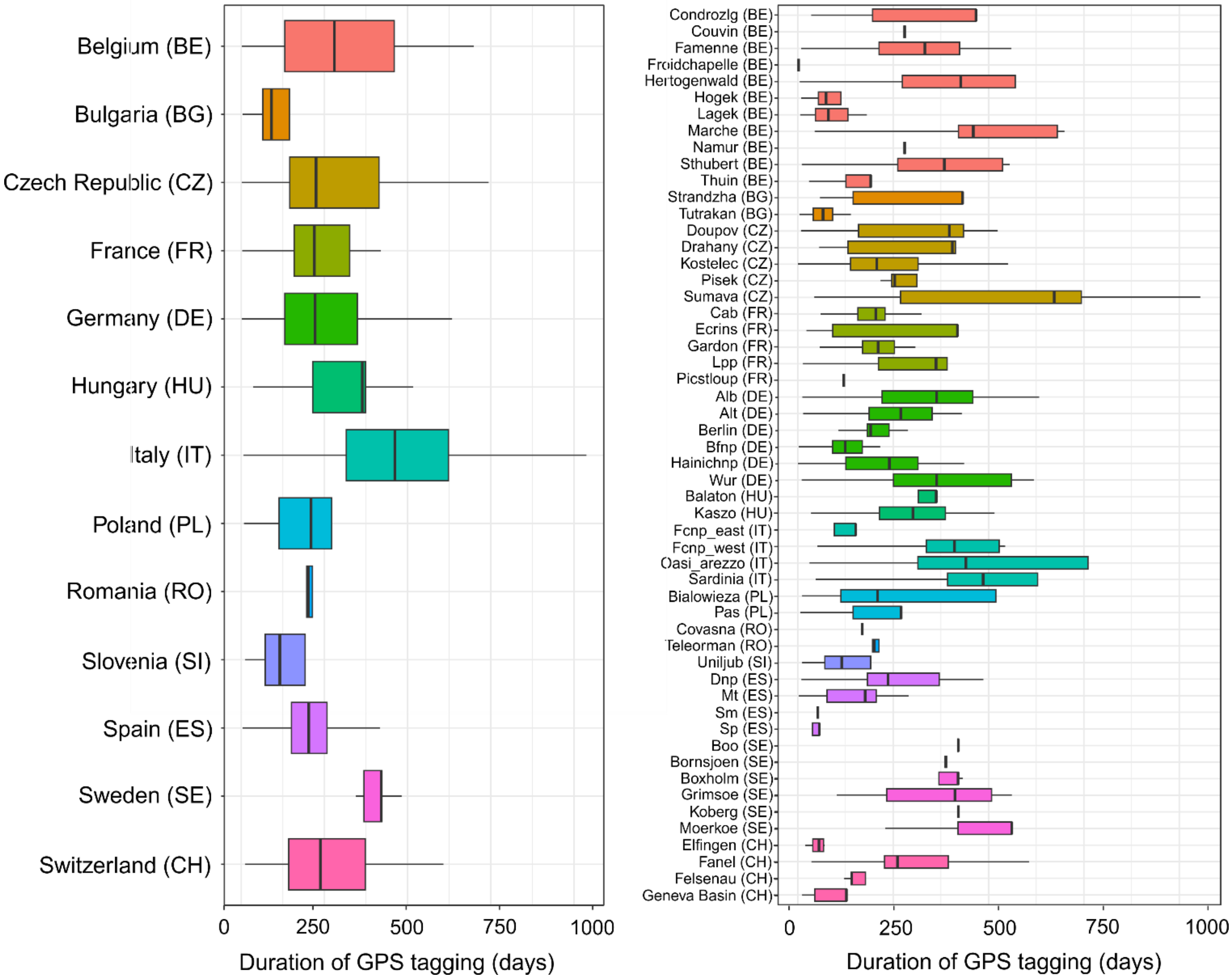


Fig. 3 - Overview of the distribution of the GPS tracking duration, between animals from different countries (left) and different study areas (right).

2.2. Calculations of movement and social metrics

In this report, all movement and social metrics were calculated using a 14-day temporal window, considered most relevant given the epidemiology of ASF.

2.2.1 Movement metrics

All the six movement metrics (home range, core area, distance traveled, maximum displacement distance, diurnality and the intensity of space use) were computed by considering GPS locations in

a time window of 14 days. Home range and core areas were computed through the Minimum Convex Polygon (MCP95, excluding 5% of the most extreme locations and MCP50, excluding 50% of locations, respectively). The displacement distance was calculated by computing the distance traveled by individuals, obtained by summing step lengths within movement tracks, at the considered time window. Maximum displacement was calculated by considering the maximum distance between two points of a movement track.
The diurnality index was computed following Hertel et al. (2019), as:

$$\text{Diurnality index} = [MD/DD - MN/DN] / [MD/DD + MN/DN]$$

Where MD and MN represent the total movement rate in 14 days, respectively during the day and night, and DD and DN are the duration of the day and night period in a time window of 14 days. Movement rates were expressed as the distance traveled by individuals. The index ranges from -1, when it indicates movements occurring entirely at night, to +1 when it corresponds to movements occurring only during the daytime.

The intensity of space use was expressed as the ratio between the distance traveled and the square root of home range size (Almeida et al., 2010), in a certain temporal window. Movement metrics were computed for each fortnight of a certain movement trajectory.

To quantify the extent of movement over time, with potential application of informing the size of restricted zones, we computed the distribution of maximum displacement distance by using time windows of different length (0-5, 0-10, 0-15, 0-20, 0-25, 0-30, 0-35, 0-40, 0-45, 0-50, 0-55 and 0-60 days). For each time window, maximum displacement was calculated as the maximum distance observed across all pairwise distances (i.e. not consecutive) using all GPS locations from an individual at a given time window. Results of this analysis could potentially inform the size of restricted zones and help assess the spatial risk of ASF spread since the outbreak onset. This analysis is also useful to assess the stability of our movement metrics, with respect to the time windows chosen to compute them (14 days).

2.2.2 Social behaviour metrics

Two types of contact data were quantified: contacts at the wild boar–wild boar interface and contacts at the wild boar–domestic pig farm interface. Wild boar contacts were calculated based on movement data from the EUROBOAR database, while domestic pig farm locations were obtained from national and regional authorities and further verified using open-access data on OpenStreetMap (https://www.openstreetmap.org) and Google Earth when exact spatial polygons of the farm perimeters were extracted. In total, 32 study areas from 8 countries (Belgium, Czech Republic, France, Germany, Hungary, Italy, Sweden, Switzerland) covered by this analysis (Fig. 1). Associated methodological details and models can be found in Morelle et al. 2026 (in press).

Wild boar–wild boar contacts were quantified at the dyadic level using GPS movement data. The analytical unit was a dyad (i.e. pair of individual wild boar) aggregated at a biweekly temporal scale. We adopted a two-step approach. First, the dyads were classified according to the inferred group membership, i.e. belonging to the same or different groups. To do so, we calculated a set of established social cohesion indices (Static interaction, Macdonald et al., 1980; Proximity, Bertrand et al., 1996; Coefficient of association, Bauman, 1998; Cole, 1949; Coefficient of sociality, Kenward et al., 1993; Half-weight association index, Atwood & Harmon P. Weeks, 2011; Correlation coefficient, Shirabe, 2006) capturing the spatial and temporal associations between individuals. These indices were combined using a clustering approach to classify dyads into within- and between-group categories, reflecting whether individuals were likely to belong to the same or different groups. Group membership was inferred probabilistically because the wild boar social structure is dynamic and direct assignment at capture is rarely possible.

Second, contact events were extracted for each dyad based on the spatiotemporal proximity. A contact event was defined as an instance in which two individuals were located within 50 m of each other within a 10 min time window, consistent with the spatial and temporal resolution of the GPS data. All such events were identified across dyads and subsequently aggregated to obtain the number of contacts per dyad at the bi-weekly level.

Wild boar–domestic pig farm contacts were quantified at the individual farm level and aggregated at a biweekly temporal scale. Because the wild boar GPS data consisted of discrete relocations with variable sampling intervals, direct detection of contact with farm polygons was not possible from the raw data alone. To increase the temporal resolution and better capture visits to farms, we used a continuous-time movement modeling framework to interpolate wild boar trajectories.

For each individual and month, GPS-telemetry data was used to fit a continuous-time movement model (Calabrese et al., 2016) and simulate the movement trajectories with a 5 min GPS-fix rate interval. To account for the uncertainty in the reconstructed paths, 100 simulated trajectories were generated per individual month. A contact event was defined as any of these simulated locations occurring within a pig farm polygon surrounded by a 50 m buffer (to account for GPS error). Consecutive locations with a time difference of less than one hour were considered as single-contact events. We counted for each individual the number of contacts with farms at the biweekly scale and finally averaged across the 100 simulated trajectories.

2.3. Calculation of environmental and anthropogenic variables attributes of each study area

We compared home range size, core area size, distance traveled, maximum displacement distance, diurnality and intensity of space use between areas with different environmental characteristics, namely different: *i*) biogeographical regions, *ii*) levels of landscape anthropization, *iii*) densities of wild boar, *iv*) percentage of forest cover (total forests and broad-leaved forests), *v*) forest fragmentation and *vi*) hunting regimes.

Environmental covariates were extracted for each study area through the following workflow (Fig. 4). First, for all wild boars tagged in a certain study area we calculated their individual range size by means of the Minimum Convex Polygon. Then we merged individual range sizes and calculated the area of the resulting polygon. Then, by using the area of this area-level polygon, we computed the radius of a circle with the same area. Finally, we generated a buffer with such radius, from the centroid of all GPS locations from animals within a certain study area. This approach allowed us to extract environmental covariates.

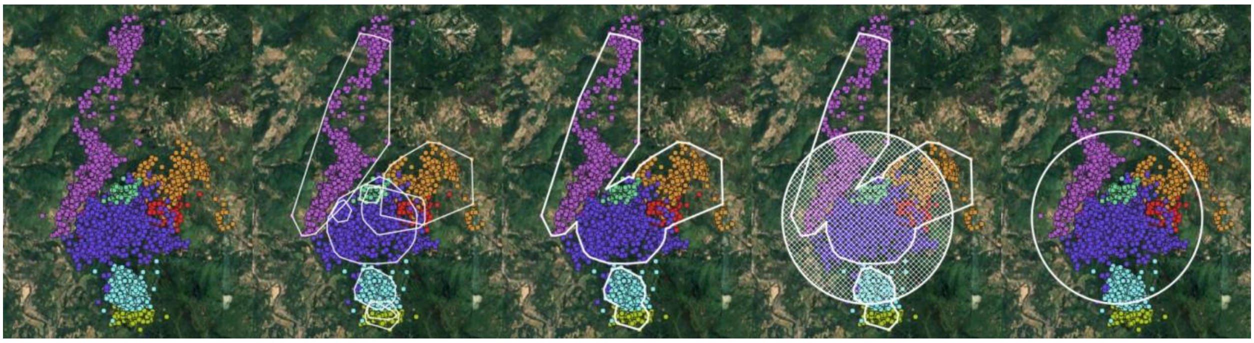


Fig. 4 - From left to right: overview of different GPS locations from tagged wild boars in a study area (individuals are color coded), estimation of individual MCPs, combination of individual MCPs into a site-level MCP, calculation of a buffer around the centroid (same area of site-level MCP), extraction of site-level environmental covariates within the buffer.

The different European Biogeographical Regions were the ones identified by the European Environment Agency (https://www.eea.europa.eu/en/analysis/maps-and-charts/biogeographical-regions-in-europe-2) and mapped by Cervellini et al. (2020). They included the Alpine, Anatolian, Arctic, Atlantic, Black Sea, Boreal, Continental, Macaronesian, Mediterranean, Pannonian and Steppic regions. These were characterized by different climates and biomes. For each study area we overlapped its boundaries to biogeographical regions and classify it accordingly.

Landscape anthropization was quantified by means of the Human Footprint Index (HFI), which combines a series of different layers about human presence and infrastructures at the landscape scale. We used the 2020 version of the HFI (https://wcshumanfootprint.org/data-access) quantified at a resolution of 1km^2. For each study area we extracted 1km^2 values of the HFI and calculated their median values

The density of wild boar was obtained from official estimates of the ENETWILD Consortium, developed by combining wild boar density estimates obtained through camera trapping with presence-background modeling (ENETWILD Consortium, 2024). The product had a resolution of 4km^2. For each study area we extracted wild boar estimates at a 4km^2 resolution and calculated their median values.

The percentage of forest cover was estimated by means of the Corine Land Cover 2018 (https://doi.org/10.2909/960998c1-1870-4e82-8051-6485205ebbac), at a resolution of 100m. Namely, we aggregated the land cover classes "*3.1.1 Broad-leaved forest*", "*3.1.2 Coniferous forest*" and "*3.1.3 Mixed forest*", to have a broad overview of the whole area covered by different types of forests. For each study area we calculated the percentage that was covered by total forests (broad-leaved species + coniferous + mixed) as well as by broad-leaved species only, as a proxy of the amount of high-quality wild boar habitat due to availability of acorns, beechnuts and chestnuts which are important part of wild boar diet, especially during mast years (Schley and Roper 2003, Ballari and Barrios-Garcia 2014).

Forest fragmentation was calculated by considering forest patches and then by calculating the ratio between their total perimeter and total area. To compute habitat connectivity we used forests as the reference class (Wang, 2014), due to their importance as movement corridors, as well as resting sites and foraging grounds for the wild boar.

Information on hunting management practices was obtained at the monthly scale by personal communication with data providers for each study area. Categories of hunting modalities included no hunting, individual hunts and drive hunts. Drive hunts have been shown to elicit stronger spatial response (flight) compared to individual hunts (Keuling et al., 2008; Thurfjell et al., 2013) and the response increased with higher frequency of drive hunts (Olejarz et al., 2024). Individual hunts (one person, silent) category included months with single hunts only, mainly hunting from hides and high-seats but also stand-stalking. The drive hunts (collective hunts, multiple people and dogs) category included months with drive hunts only as well as months when drive and individual hunts were performed simultaneously. We merged the two modalities due to the assumed stronger disturbing effect of drive hunts.We classified each bi-weekly metric in three classes of increasing disturbance: no hunting, individual hunting and drive hunts. Hunting modality information was available for 31 sites out of total 54 sites used in the report.

We also compared home range size, movement metrics and contact rates between male and female wild boars, as well as between individuals of different age classes (data from the EUROBOAR database). Finally we also compared them between different times of the year, reflecting phases of the wild boar biological cycle: the breeding period (November-January), the farrowing season (February-April), summer (May-August) and autumn (September-October).

2.4. Statistical summary

To highlight differences in the six movement metrics, in maximum displacement distances calculated in time windows of different lengths and in contact rates between wild boar of the same group and of different groups, we compared them across intervals of the main environmental covariates. Comparisons were based on the mean, the median and the range of each movement metric.

Covariates included biogeographical regions, landscape anthropization, wild boar density, percentage of total forest cover, percentage of broad-leaved woodlands, fragmentation of forest patches, hunting regimes. We also compared seasons and wild boars of different ages and sex. Namely, we compared movement metrics between female and male wild boars of different age classes (0-12 months, 12-24 months, more than 24 months).

The individuation of classes for landscape anthropization, wild boar densities, total forest cover, cover by broad-leaved woodlands and the fragmentation of forest patches was decided upon the graphical exploration of their distribution (Fig. 5, see below).

With respect to landscape anthropization, expressed as the normalized Human Footprint Index, study areas were classified as having a low levels of landscape anthropization (HFI < 35), an intermediate level of anthropization (HFI between 35 and 60) and high level of anthropization (HFI > 60).

With respect to wild boar densities, expressed as the median number of wild boars per km^2, study areas were classified as having very low wild boar densities (< 3 individuals/km^2), low wild boar densities (3 - 5 individuals/km^2), high wild boar densities (5 - 7 individuals/km^2) or very high wild boar densities (> 7 individuals/km^2).

With respect to broad-leaved forest cover, expressed as the percentage of each study area that was covered by broad-leaved woodlands, study areas were classified as having a very low forest cover (25%), low forest cover (25-50%), high forest cover (50-75%) or very high (forest cover >75%). The same rules were used for dividing the percentage of broad-leaved forest cover.

With respect to forest fragmentation, expressed as the ratio between the perimeter and the area of each forest patch, study areas were classified as having a very low forest fragmentation (< 40 m/m^2), low forest fragmentation (40 - 65 m/m^2), high forest fragmentation (65 - 80 m/m^2) or very high forest fragmentation (> 80 m/m^2).

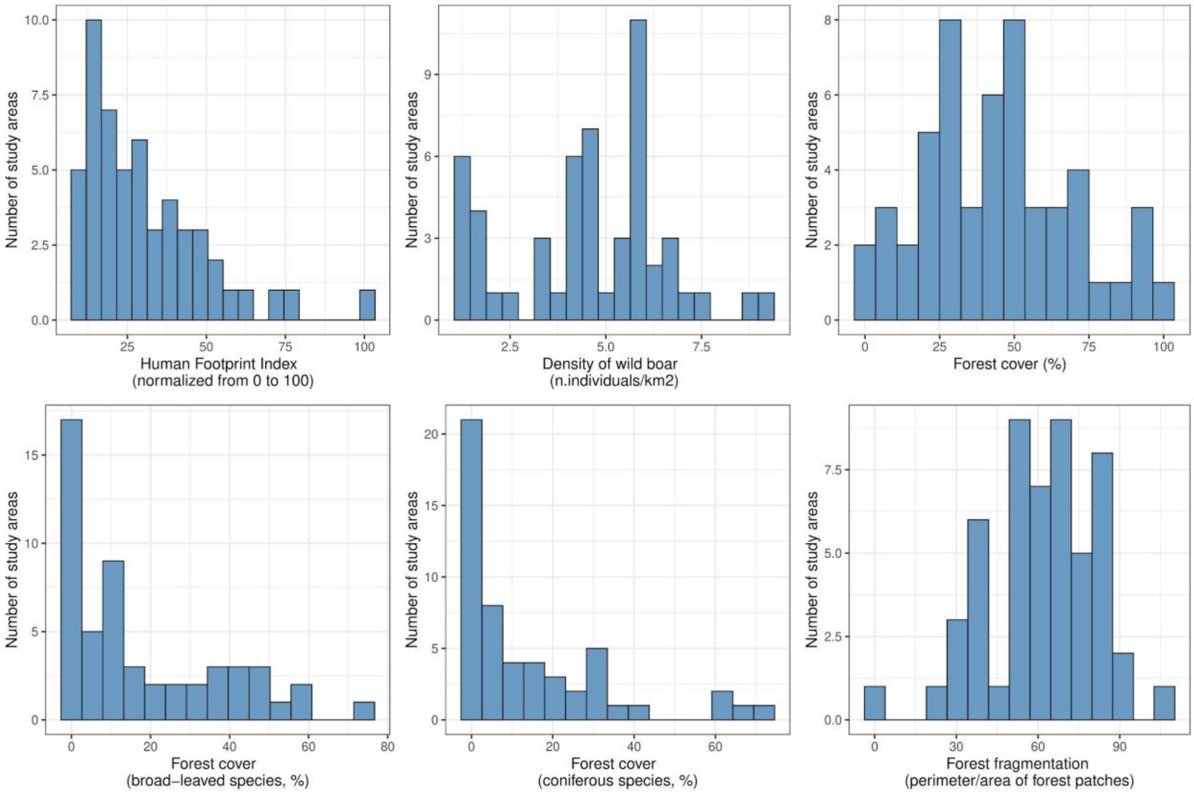


Fig. 5. Distribution of the Human Footprint Index, the density of wild boar, the percentage of forest cover, the percentage of broad-leaved woodlands, the percentage of forest cover and forest fragmentation between study areas.

The correlation matrix among landscape and anthropogenic predictors (Fig. 6) highlights several structured relationships. Human Footprint Index is moderately negatively correlated with total forest cover ($\rho = -0.59$) and weakly negatively with broad-leaved cover ($\rho = -0.26$), while showing a positive association with forest fragmentation ($\rho = 0.29$). Wild boar density exhibits slight positive correlations with total forest cover (ρ = 0.31) and broad-leaved cover (ρ = 0.27), and a weak positive relationship with fragmentation (ρ = 0.13) and a weak negative correlation with human footprint (ρ = −0.15). Forest cover metrics (% cover and % broad-leaved) are moderately positively related (ρ = 0.42) and both decline with increasing fragmentation (ρ = −0.40; −0.19, respecitvely).

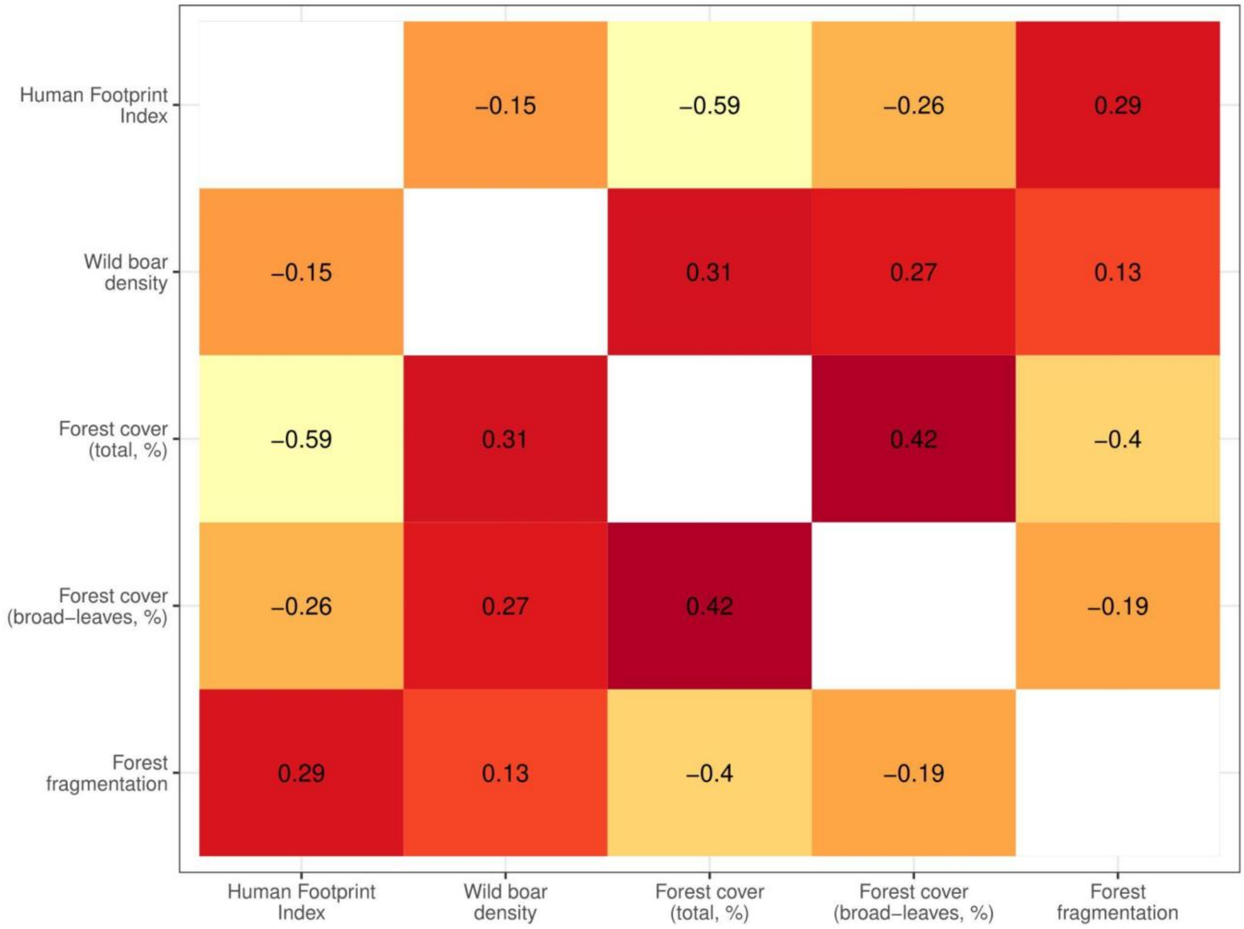


Fig.6. Spearman’s correlation coefficients illustrating relationships among five continuous landscape and anthropogenic predictors: Human Footprint Index (HFI), wild boar density, total forest cover (%), broad-leaved forest cover (%), and forest fragmentation. Values represent pairwise rank correlations across study units and over a time window of 14 days, with color intensity indicating the strength and direction of associations.

3. Assessment/Results

3.1. Overall summary statistics

Distributions of biweekly movement and space-use metrics were moderately to strongly skewed (Fig. 7). Home range, core area, and maximum displacement distance were strongly right-skewed, with most values small and a few extreme large values, indicating occasional long-range movements or extensive space use. Home range sizes ranged from 0.12 to 485.98 km², with a mean (± s.d.) of 5.24 ± 11.85 km², while core areas were smaller (min-max: 0.06-239.26 km²; mean: 1.43 ± 4.57 km²). Maximum displacement distances were generally low (mean: 1.59 ± 2.3 km), indicating limited net displacement despite occasional long movements (maximum distance: 66.62 km). Distance travelled displayed a broader, near-unimodal distribution with a right tail, suggesting moderate typical movement punctuated by rare long distances. Total distance travelled varied from 4.02 to 195.56 km, averaging 48.98 ± 21.45 km. The diurnality index was centred on negative values (mean: -0.48 ± 0.33), indicating predominantly nocturnal activity, with <20% of movement activity occurring during daylight. Intensity of space use was moderately right-skewed, indicating that most individuals displayed more linear, directed movements, with occasional highly circular space use patterns. Intensity of space use ranged from 3.88 to 77.2 with a mean of 24.65 ± 9.59.

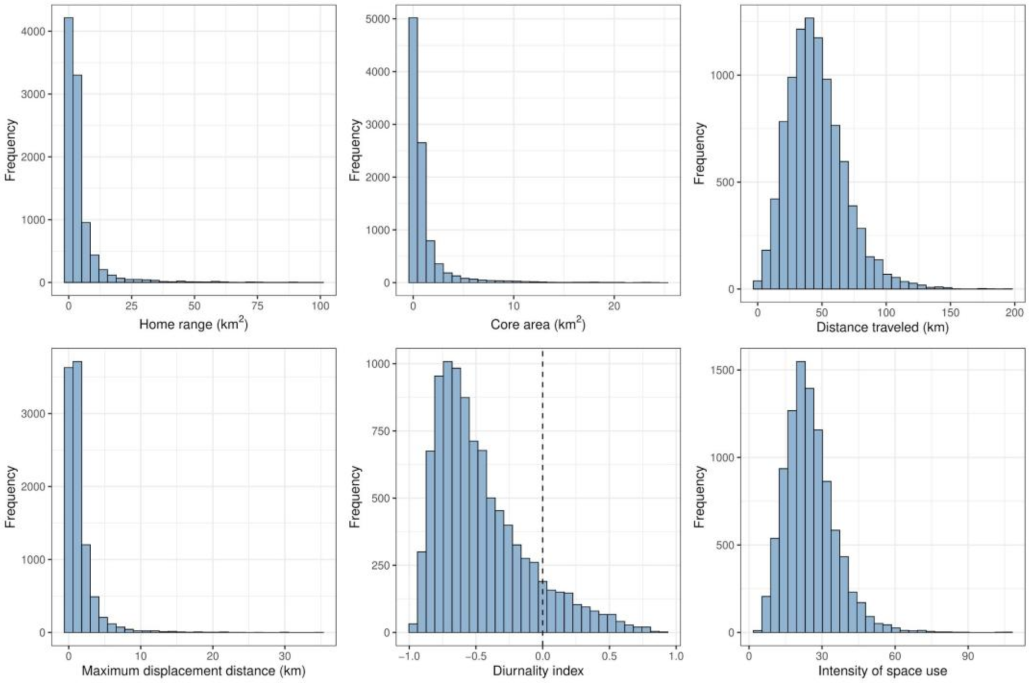


Fig. 7 - Distribution of the six movement metrics, calculated over a time window of 14 days: home range, core area, distance travelled, maximum displacement distance, diurnality index, intensity of space use.

The distribution of contacts between wild boar (Fig. 8) was different when considering dyads between individuals from the same social group or from different social groups. When considering time windows of 14 days, most dyads between wild boars from different social groups (87.9%) did not contain any contact (Fig.9). This percentage was much lower (14%) when considering dyads between wild boars from the same social group. The distribution of the number of contacts in dyads calculated by considering wild boars from different social groups, after having discarded dyads without any contact, was much more skewed than the distribution of the number of contacts in dyads calculated by considering wild boars from the same social group (Fig. 8,9).

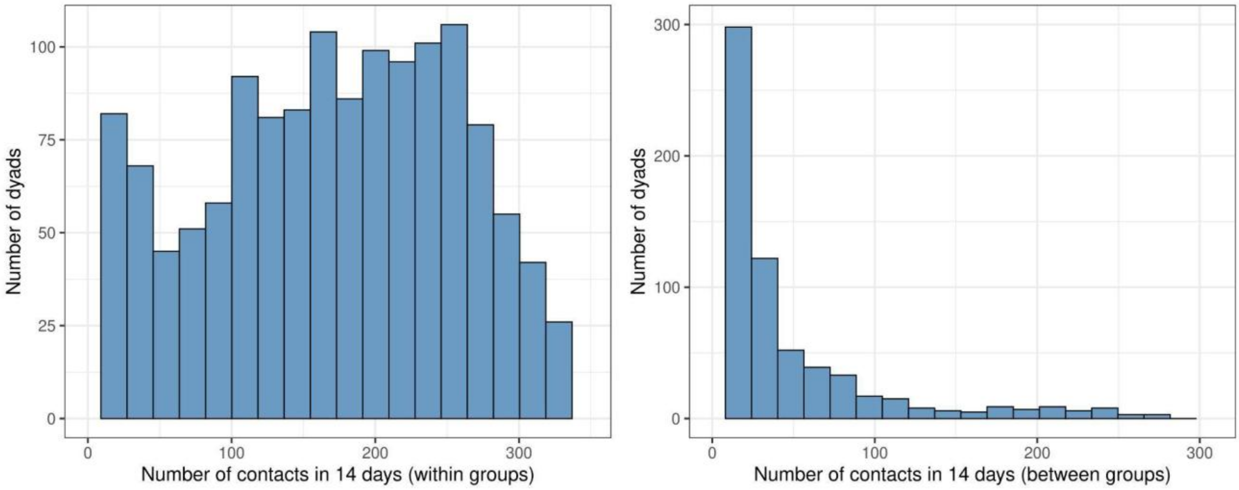


Fig. 8. Distribution of the number of contacts between wild boars from the same group (left) and different groups (right), calculated over a time window of 14 days. The frequency is expressed as the number of dyads, representing interactions between two individuals.

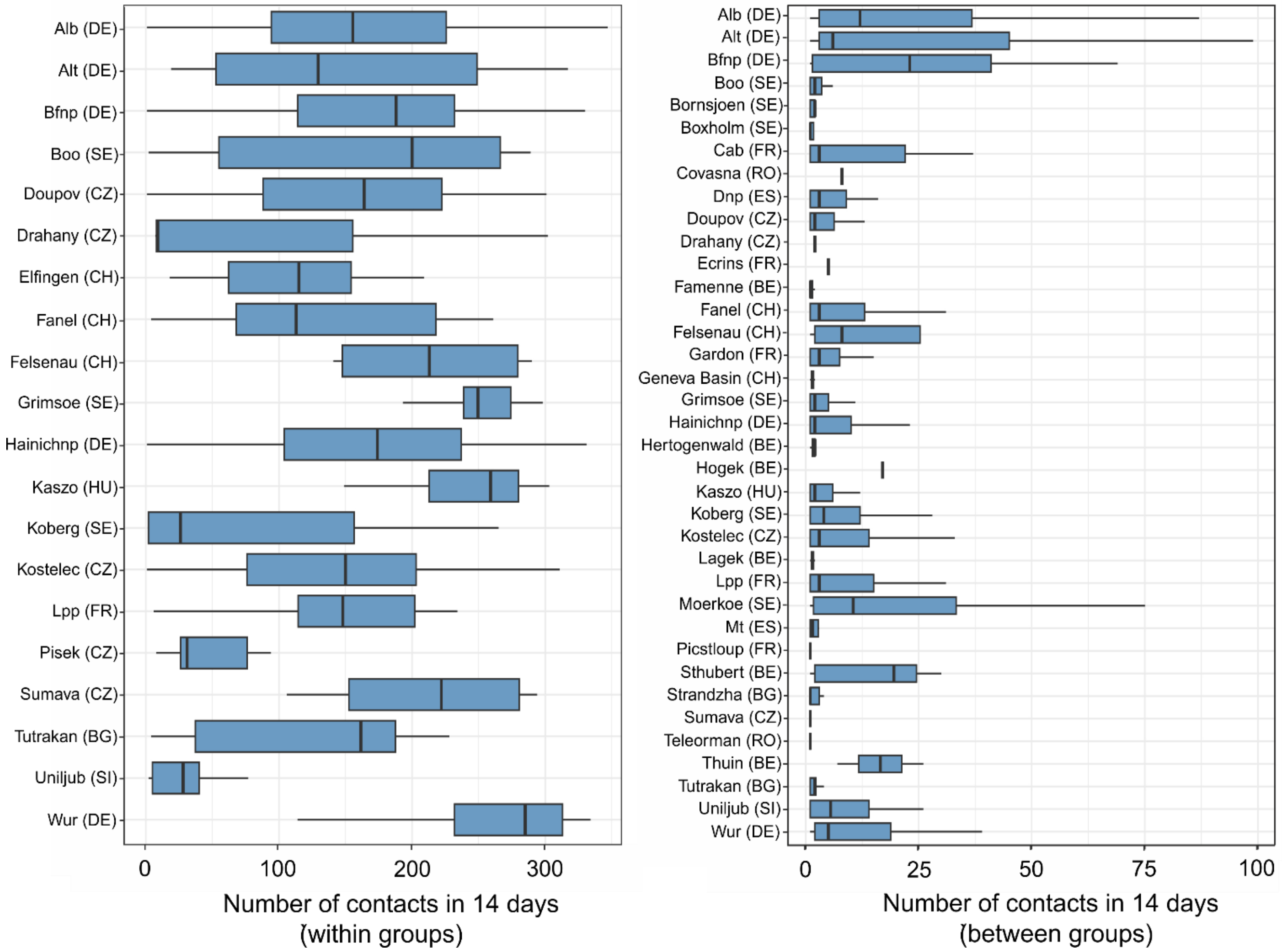


Fig. 9. Distribution of the number of contacts between wild boars from the same social group (left) and from different social groups (right), calculated from boar/boar dyads in the different study areas.

The distribution of the number of contacts between wild boar and pig farms over 14-day windows is markedly right-skewed, indicating that low contact rates predominate across wild boar-farm dyads while high-contact events are comparatively rare (Fig. 10). The highest frequencies are concentrated in the two lowest bins of 0–10 contacts per 14 days. Higher contact rate counts occur progressively less often, forming a long upper tail. Only a small proportion of dyads exhibit high-intensity contact windows, with occasional extreme values extending beyond 50 contacts and rare observations above 100 contacts per 14 days.

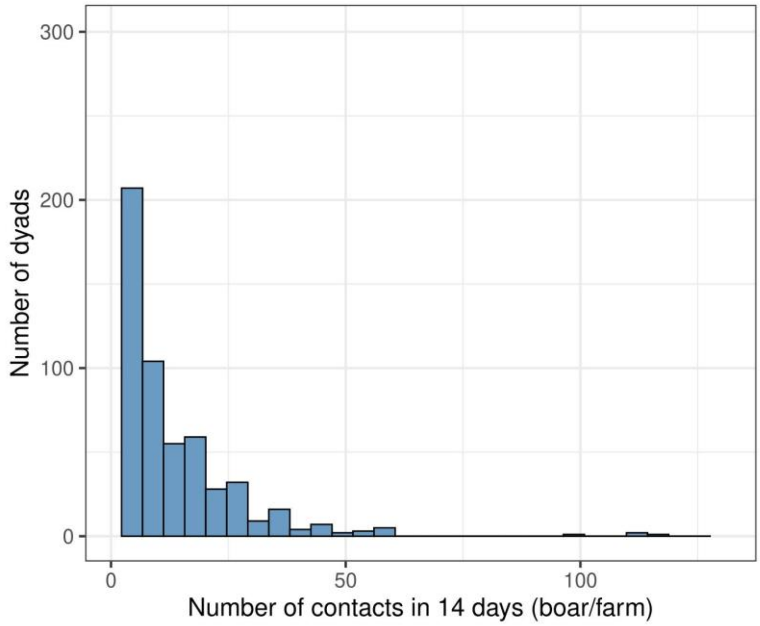
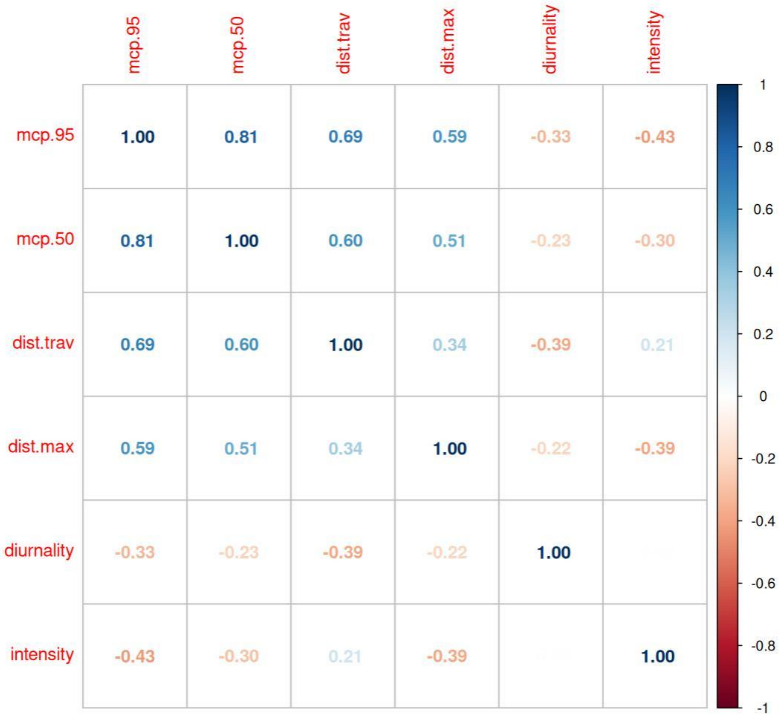


Fig. 10 Distribution of the number of contacts between wild boar and pig farms, expressed as the number of boar/farm dyads. Dyads without contacts were removed.

The correlation matrix between movement and space use metrics (Fig. 11) reveals some relationships among the six movement metrics calculated over 14-day windows. Home range (mcp.95) and core area (mcp.50) are strongly positively correlated ($\rho = 0.81$), indicating close coupling between overall and core space use. Both metrics are also strongly associated with distance traveled (mcp.95–dist.trav: $\rho = 0.69$; mcp.50–dist.trav: $\rho = 0.60$) and moderately correlated with maximum displacement distance (mcp.95–dist.max: $\rho = 0.59$; mcp.50–dist.max: $\rho = 0.51$). Distance traveled and maximum displacement show a weaker positive relationship ($\rho = 0.34$). Diurnality index shows relatively weak negative correlation with all movement metrics ($\rho = -0.22$ to -0.39), indicating that increased movement and space use are associated with more nocturnal activity. Intensity of space use is negatively related to home range and displacement ($\rho = -0.30$ to -0.43), but weakly positively correlated with distance traveled ($\rho = 0.21$).



	mcp.95	mcp.50	dist.trav	dist.max	diurnality	intensity
mcp.95	1.00	0.81	0.69	0.59	-0.33	-0.43
mcp.50	0.81	1.00	0.60	0.51	-0.23	-0.30
dist.trav	0.69	0.60	1.00	0.34	-0.39	0.21
dist.max	0.59	0.51	0.34	1.00	-0.22	-0.39
diurnality	-0.33	-0.23	-0.39	-0.22	1.00	[illegible]
intensity	-0.43	-0.30	0.21	-0.39	[illegible]	1.00

Fig. 11 - Spearman's correlation coefficient, representing the correlation between the six movement metrics, calculated over a time window of 14 days: home range (mcp.95), core area (mcp.50), distance traveled (dist.trav), maximum displacement distance (dist.max), diurnality index (diurnality), intensity of space use (intensity).

3.2. Temporal variation in movement metrics and contact patterns

Figures 12 and 13 demonstrate seasonal variation in movement, space use, and activity patterns across biweekly periods. Home range size is smallest during the farrowing period, particularly in females (median 1.79 km²; Fig. 12, 13; Appendix A) and increases steadily through summer and autumn, reaching peak during the mating season, particularly in males (median 4.03 km²; Fig. 12, 13; Appendix A). Males consistently used larger home ranges than females across all seasons (e.g. mating: males 4.03 (median) km² vs females 2.44 km²; autumn: males 3.79 km² vs females 2.62 km²; Fig. 13; Appendix A). Core area size follows a similar temporal pattern, with median value of 0.44 km² during farrowing to 0.6 and 0.58 km² during late autumn and mating. Male core areas were approximately 1.5–2 times larger than those of females in all seasons (Fig. 13).

Distance travelled showed the highest values during the autumn and early winter (Fig. 12), rising from ~30–35 km per 14 days during farrowing to ~40–45 km in summer and reaching a maximum in autumn and mating (~50–60 km). Males travelled farther than females in every season, with the largest sex gap during mating (males ~50 km; females ~40 km). Maximum displacement distance remains relatively low (with median values around 1 km, Fig. 12) and stable across the year, with medians generally between 0.67 and 1.57 km, but shows a modest increase during late summer and mating, when upper values exceed 3–4 km (Fig. 12). Male displacements exceeded female values by ~0.3–0.5 km (Fig 13).

The diurnality index was consistently negative throughout the year, indicating predominantly nocturnal activity. Values were closest to zero in early summer (≈ −0.3 to −0.4) and most negative in autumn (median: −0.67), reflecting stronger nocturnality during periods of increased movement. Females were slightly less nocturnal than males in all seasons. Intensity of space use was relatively stable across the year, with slightly higher values, i.e. more circular movements, in late summer and autumn (Fig. 12) The lowest values of intensity of space use were observed during mating season in males, reflecting expanded and more exploratory movements of males in this period (Fig 13). It is worth noting that this metric had a very large variation throughout the year.

Overall, periods of increased movement and expanded space use coincide with stronger nocturnality and higher intensity of space use, highlighting tightly coupled seasonal shifts in spatial and temporal behavior.

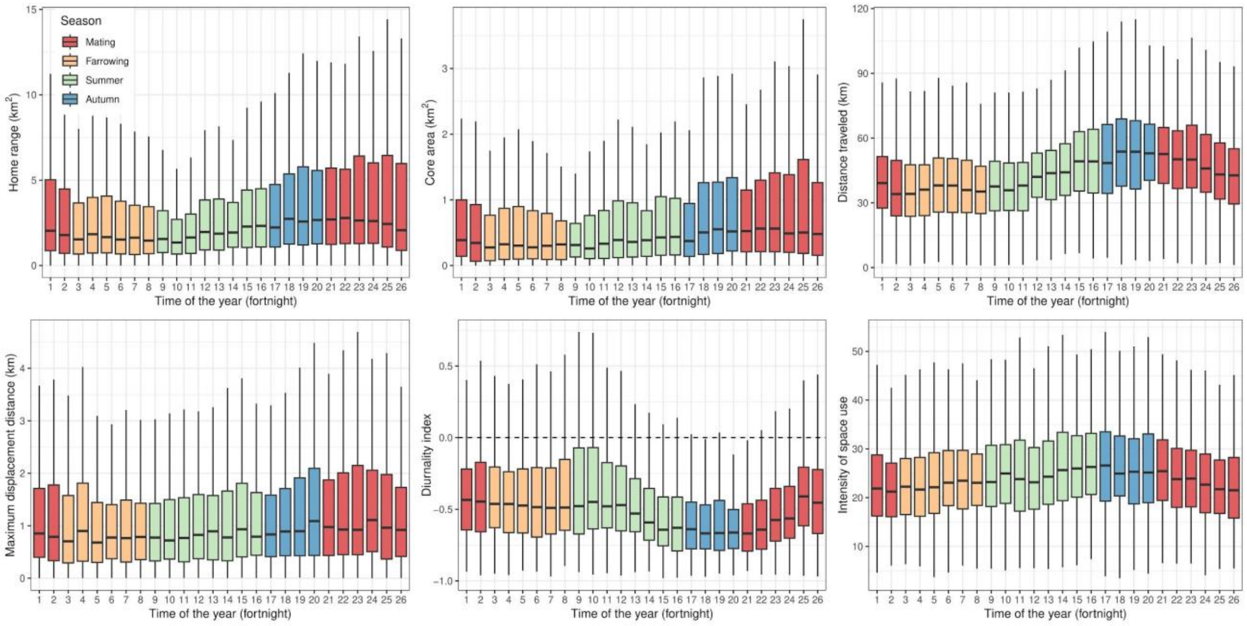


Fig. 12 - Distribution of the six movement metrics, calculated over time windows of 14 days and all sex and age classes, between different seasons: mating (November-January), farrowing (February-April), summer (May-August) and autumn (September-October)

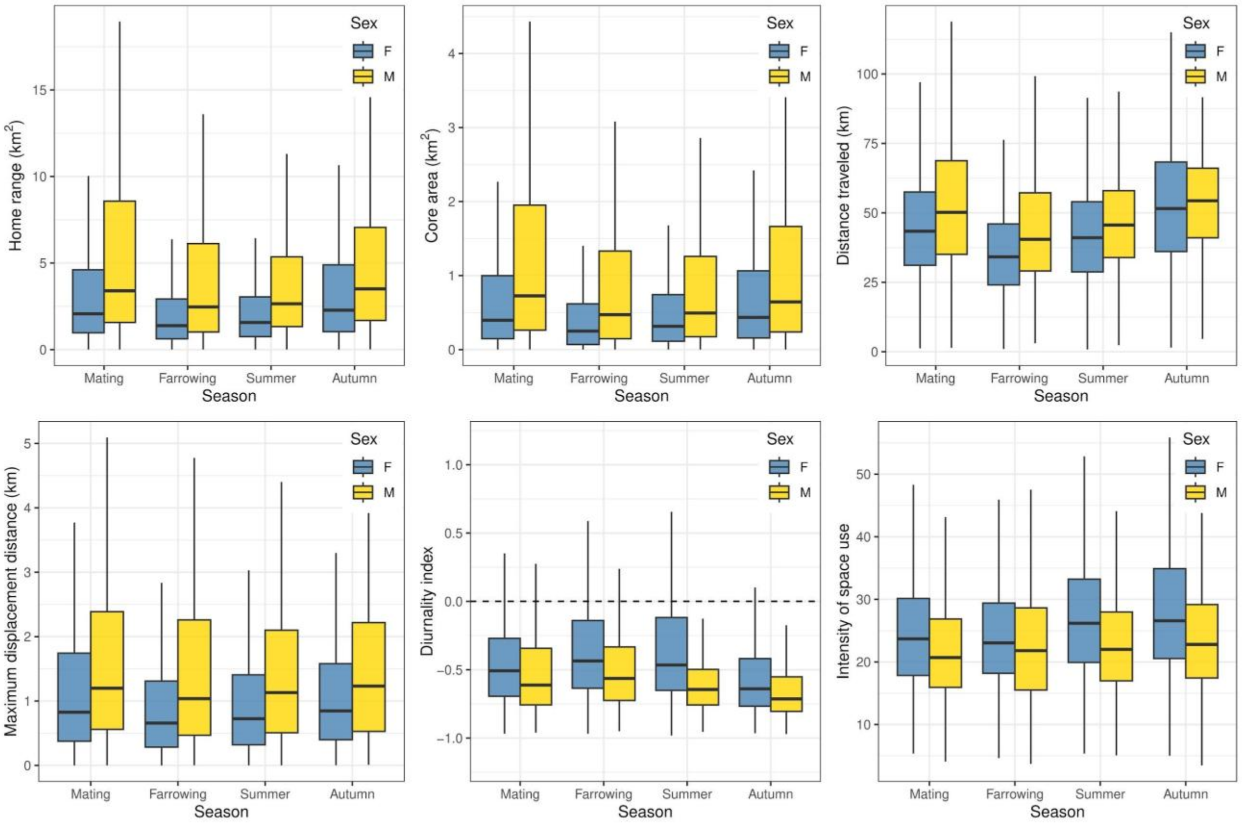


Fig. 13 - Distribution of the six movement metrics, calculated over a time window of 14 days, between different seasons: mating (November-January), farrowing (February-April), summer (May-August) and autumn (September-October). Different colours represent the sex (M = male, F = female wild boars).

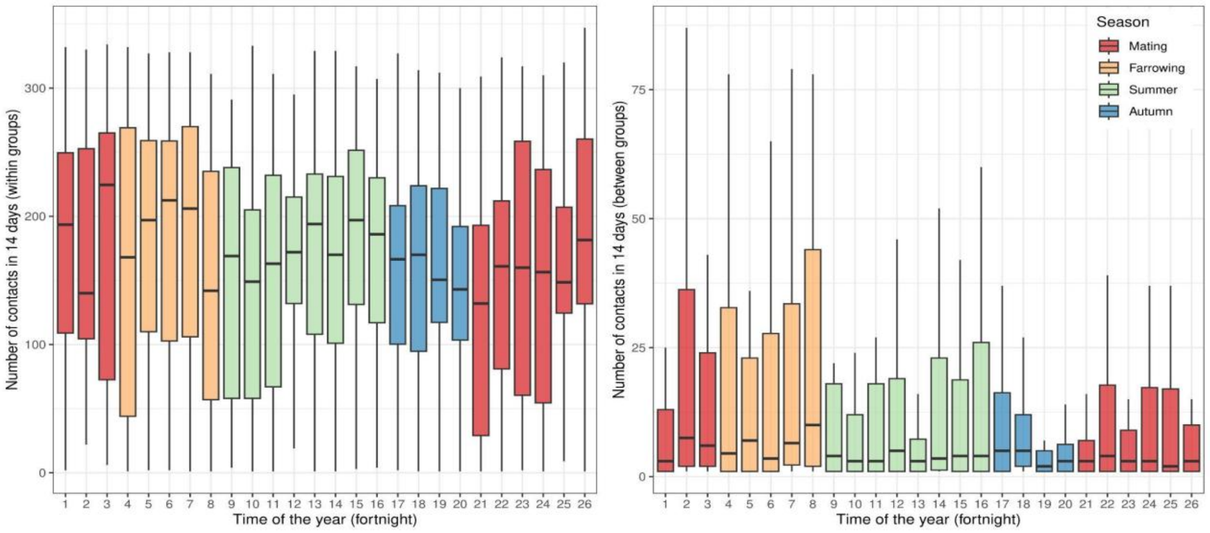


Fig. 14- Number of contacts between wild boars from the same group (left) and different groups (right), calculated over time windows of 14 days, between different seasons: mating (November-January), farrowing (February-April), summer (May-August) and autumn (September-October).

Across the year, contacts among individuals within the same group were consistently much higher than contacts between different groups. Within-group contacts ranged broadly from around 100 to 250 contacts per 14 days, showed marked variability and no clear seasonal pattern (Fig. 14). Between-group contacts were an order of magnitude lower compared to within-group contacts (medians were around 1-5 contacts per 14 days) but they showed more pronounced seasonality. Higher values of between-group contacts were observed during late mating (January) and farrowing (February-April) when upper values occasionally reached 60–80 contacts, and medians rose to 5–10, suggesting episodic but intense inter-group mixing. During summer (May–August), between-group contacts declined, with medians typically ≤3 and maxima rarely exceeding 50. The lowest levels were observed in autumn (September–October) with medians typically ≤3 and maxima rarely exceeding 25, while onset of mating (November-December) marked slight increase in medians to about 2–5, while maxima rose sharply, reaching approximately 30–50, indicating occasional bursts of inter-group interactions.

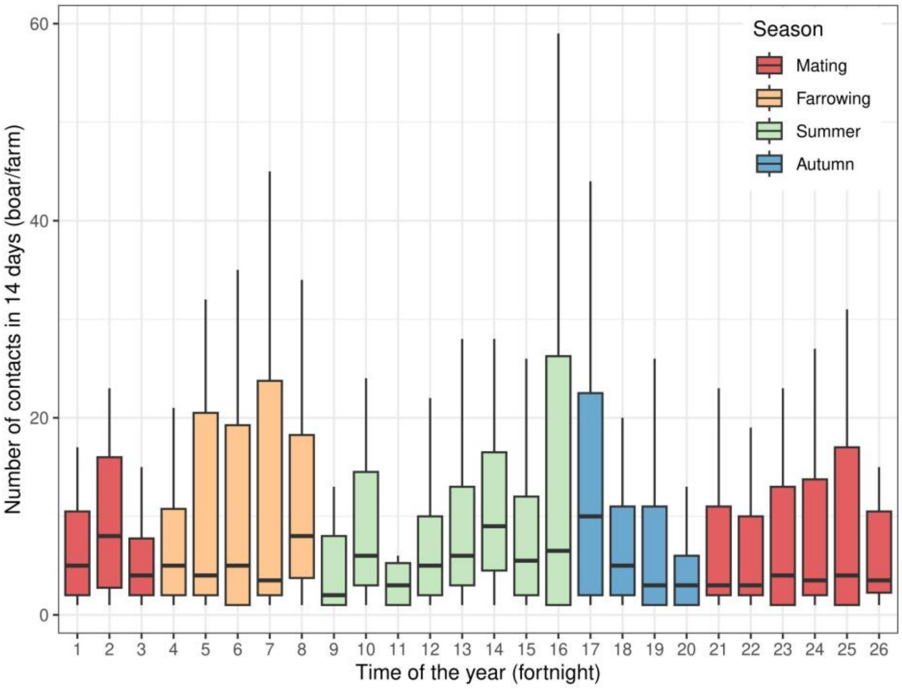


Fig. 15 - Number of contacts between wild boar and pig farms over time windows of 14 days, between different seasons: mating (November-January), farrowing (February-April), summer (May-August) and autumn (September-October)

When contacts between wild boar and pig farms were examined over 14-day windows across the year, the overall distribution was consistently right-skewed: most biweekly windows showed few contacts, but sporadic peaks produced much higher values (Fig. 15), particularly March, April, late August and early September, with greater variability (upper of interquartile range >30 contacts per

14 days) than in the other parts of the year. This pattern is reflected in the seasonal summary statistics. At the seasonal level, the highest averages, medians and extreme values were observed during farrowing (Feb-Apr: mean ± SD = 13.52 ± 19.97; median = 5; range = 1–131 contacts per 14 days) and summer (May-Aug: mean ± SD = 10.40 ± 15.42; median = 5; range = 1–115 contacts per 14 days) (Appendix I).

3.3. Demographic factors

3.3.1. Influence of individual sex and age on movement metrics and contact patterns

Across all movement metrics, clear sex- and age-specific patterns emerged (Fig. 16). Across all age classes, males consistently exhibited larger home ranges than females. Male home range size averaged 7.17 ± 12.35 km², whereas females used significantly smaller areas (4.30 ± 11.48 km²; Appendix A). Age-dependent variation was evident in males. Juvenile males (up to 12 months) had the largest home ranges (9.63 ± 13.78 km²), showing high variability up to 132.77 km². Home range size then decreased slightly in yearling males aged 12–24 months (5.97 ± 11.98 km²) and >24 months (6.93 ± 11.80 km²), although variability remained high. Females showed smaller and more stable home ranges across age classes, with the highest values and variability in the 0–12-month class (5.28 ± 7.630 km²) (Fig. 16, Appendix A). Patterns in core area size mirrored those of home range, with males showing larger core areas than females in all age classes. Yearling males (0–12 months) exhibited the highest medians and the widest interquartile ranges, suggesting increased exploratory behavior during this life stage. In contrast, females displayed consistently smaller and less variable core areas, pointing to more localized space use.

Distance travelled over 14 days was consistently higher in males 52.39 ± 23.13 km vs 47.32 ± 20.37 km in females, in particular juvenile males (<12 months) which traveled the greatest distances (56.54 ± 25.56 km) (Fig. 16; Appendix A). A similar sex-difference was evident for maximum displacement, where males - particularly up to 12 months - reached greater displacement distances, reflecting longer excursions away from activity centers.

The diurnality index remained consistently negative across all age classes and both sexes, with median values around -0.64 to -0.40, indicating predominantly nocturnal activity. Slight shifts toward less nocturnality were visible in older females, suggesting marginal increases in daytime activity with age.

Finally, intensity of space use was slightly higher in females across all age classes. This indicates a more concentrated use of space, whereas males, especially subadults, used space more diffusely. Overall, the combined metrics highlight a trade-off between range expansion and spatial concentration, driven by sex and life stage, with yearling males exhibiting the most extensive and variable movement behavior.

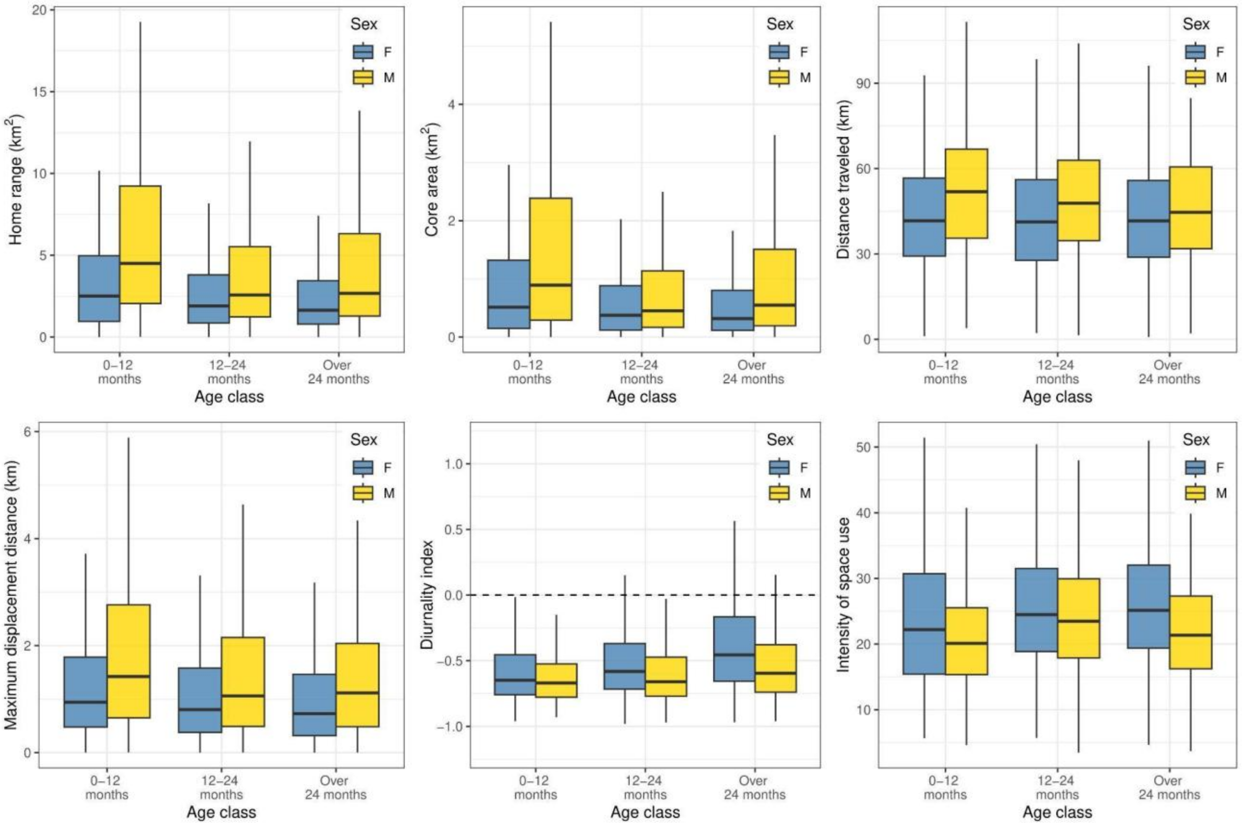


Fig. 16 - Distribution of the six movement metrics, calculated over a time window of 14 days, for male and female wild boar of different age classes.

Within social groups, contact intensity was consistently high across all sex and age dyad types, with medians generally ranging between 140 and 200 contacts per 14 days (Fig 17). Female–female dyads showed the highest values, particularly among adults (>24 months), consistent with matrilineal social structure of the species. The lowest values were observed in yearling (12-24 months) male-male dyads (Appendix G). These are often dispersing individuals, losing social connections with group members. Overall, sex and age effects on contact rates within groups were rather weak as neither sex nor age class produced clear segregation within groups which is in line with strong social structuring and cohesion of wild boar groups. Between social groups, contact rates dropped by an order of magnitude. Medians typically ranged from 3 to 10 contacts per 14 days, with strong right-skewed distributions. Male-male associations, especially in younger age classes, showed the highest values and variability, while the lowest values were observed among adult females (Fig. 18; Appendix H), again consistent with matrilineal social structure of the species. Thus, age and sex can structure between-group interactions, with juvenile and yearling males acting as the main connectors among groups.

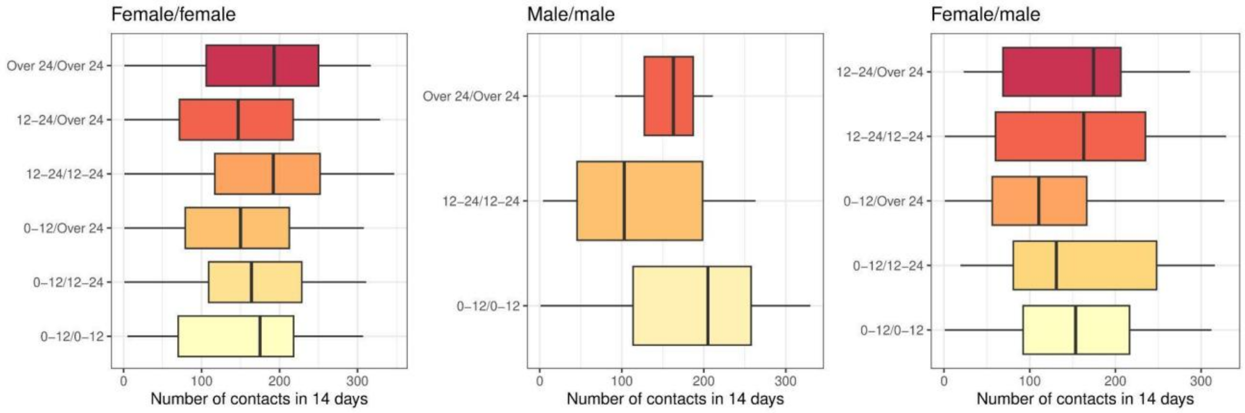


Fig. 17 Number of contacts between dyads of wild boars from the same social group, between wild boars of different age classes (0 - 12, 12-24 and more than 24 months of age) and sex over a 14-day time window. Each bar represents the number of contacts in a pair of individuals of different or the same age class or sex (female-female, male-male, or mixed dyads).

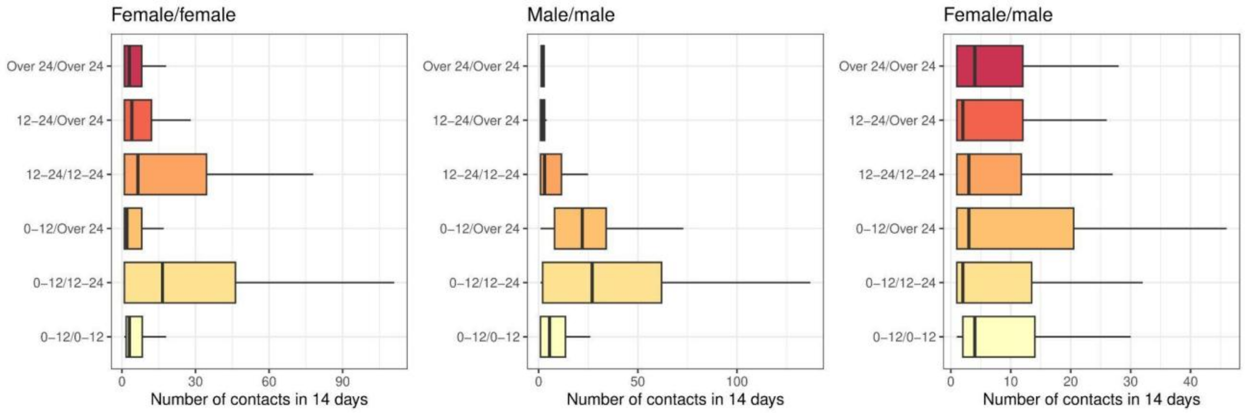


Fig. 18 Number of contacts between dyads of wild boars from different social groups, between wild boars of different age classes (0 - 12, 12-24 and more than 24 months of age) and sex over a 14-day time window. Each bar represents the number of contacts in a pair of individuals of different or the same age class or sex (female-female, male-male, or mixed dyads).

Number of contacts between wild boar and pig farms did not exceed median of 10 contacts per boar/farm dyad across all 14-day periods but was strongly right-skewed (Fig. 19), with occasional high values (up to 131), as also suggested by the long upper whiskers in the boxplots. Males generally showed higher contact rates than females (male: N = 58, mean ± SD = 10.87 ± 13.19, median = 5, range = 1–100; female: N = 75, 8.36 ± 13.57, median = 4, range = 1–131). Adult males showed particularly high number of contacts with pig farms (N = 20, 15.20 ± 13.84, median = 12, range = 1–60), compared to adult females (N = 48, 9.57 ± 15.39, median = 5, range = 1–131) and especially other age classes (Fig. 19).

Seasonally, mean contacts were highest during farrowing (Febr.–Apr.; N = 41, 13.52 ± 19.97, median = 5, range = 1–131) and summer (May–Aug.; N = 75, 10.40 ± 15.42, median = 5, range = 1–115), and lowest during mating (Nov.–Jan.; N = 68, 7.97 ± 9.57, median = 4, range = 1–58). This seasonal signal was most pronounced in males during farrowing (male farrowing: N = 25, 16.32 ± 20.45, median = 5, range = 1–100), while females were consistently lowest during mating (female mating: N = 40, 6.70 ± 8.29, median = 3, range = 1–55).

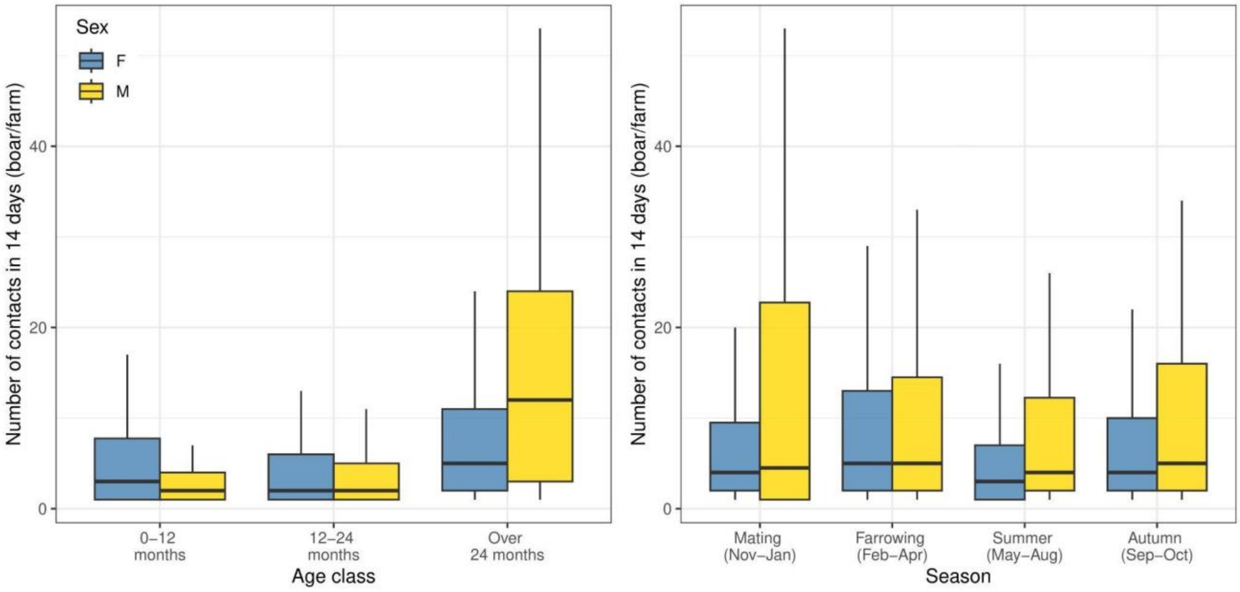


Fig. 19. Number of contacts between wild boar and pig farms over time windows of 14 days, for male and female wild boar of different age classes. between different seasons: mating (November-January), farrowing (February-April), summer (May-August) and autumn (September-October)

3.3.2. Influence of wild boar population density on movement metrics and contact patterns

Wild boar density showed a consistent association with space-use and movement metrics (Fig. 21). Study areas were grouped into four density classes (very low: <3 ind./km²; low: 3–5; high: 5–7; very high: >7; Fig. 20). Across these classes, the typical (median) range size contracted as density increased: median home range declined from 3.08 km² at very low density to 1.51 km² at very high density, while median core area decreased from 0.63 to 0.35 km² (Fig. 21; Appendix A, B).

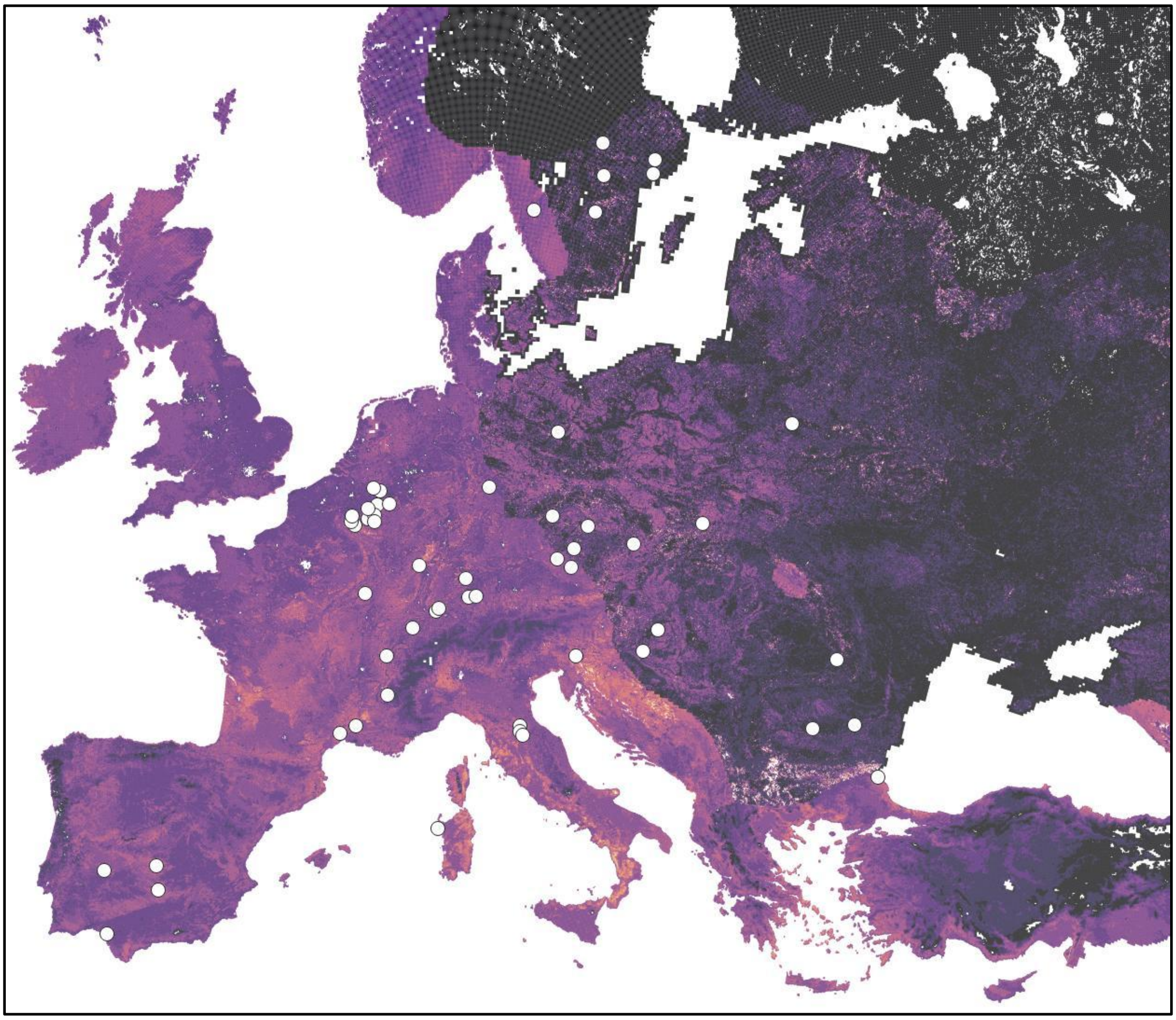


Fig. 20 - Distribution of the different study areas (n = 54) across different densities of wild boar. Darker areas have lower densities.

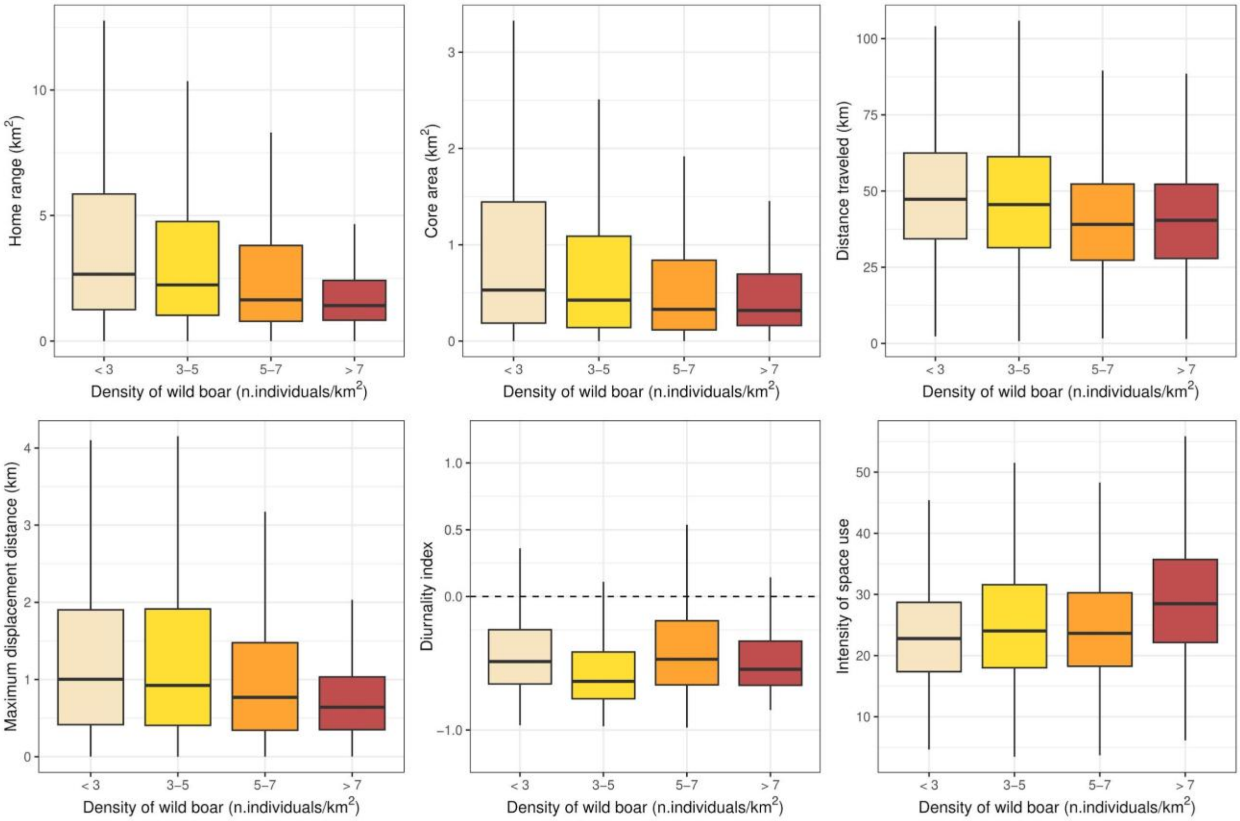


Fig. 21 - Distribution of the six movement metrics across a gradient of wild boar population densities.

A similar pattern emerged for movement metrics. Median distance travelled over 14-day windows decreased from 49.31 km (very low density) to 42.00–42.20 km (high to very high), and median maximum displacement declined from 1.12 km to 0.72 km, indicating that animals in denser populations tend to move within a more spatially constrained space (Appendix C, D; Fig. 21). This density-related contraction in displacement is further illustrated by the distribution of the intensity of space use values across density classes. Intensity of space use increased at very high densities (median 28.09 vs 22.40–23.74 in the other classes), suggesting more clustered and circular movement—consistent with repeated use of a smaller space (Appendix F; Fig. 21). In contrast, diurnality showed no clear density-dependent trend: median diurnality values varied across classes (−0.49 to −0.65) but remained consistently negative, indicating predominantly nocturnal activity regardless of density (Appendix E; Fig. 21).

Contact patterns were structured by social organisation and showed different patterns for within- and between-group contacts across a gradient of wild boar densities. Within-group contacts declined with increasing density. At the lowest densities (<3 ind./km²), within-group contacts had the highest median (229 contacts/14 days), with a wide range extending from near zero to 302. At intermediate densities (3–5 and 5–7 ind./km²), medians decreased to 171 and 155 contacts, respectively, while variability remained high, with upper values still exceeding more than 300. At the highest densities (>7 ind./km²), within-group contacts dropped sharply, with a low median (60) and many observations close to zero, indicating reduced cohesion or more fragmented contact patterns (Fig. 22; Appendix G). Between-group contacts were much less frequent overall but increased at intermediate densities. At <3 ind./km², medians were very low (2 contacts/14 days). Contacts increased at 3–5 ind./km² (median 3) and peaked at 5–7 ind./km², where the median reached 7 contacts. At >7 ind./km², between-group contacts declined again (median 3)(Fig. 22; Appendix H). Overall, increasing density is associated with reduced within-group contacts but elevated, more variable between-group contacts at intermediate densities.

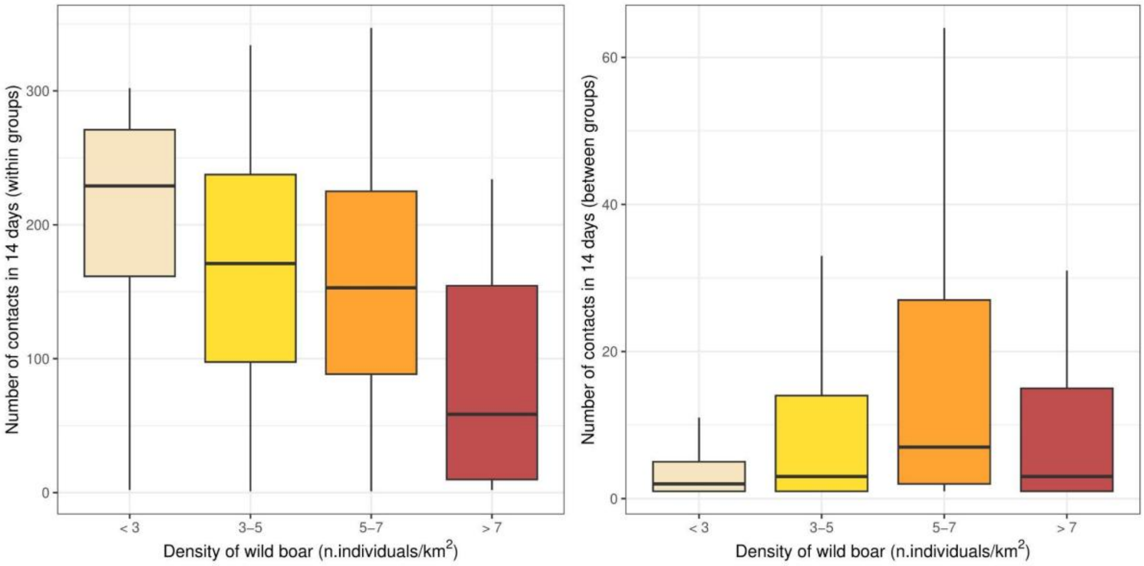


Fig. 22. Distribution of the number of contacts between wild boars from the same group (left) and different groups (right) across a gradient of wild boar population densities.

The frequency of contacts between wild boar and pig farms increased with the density of wild boar population. At the very low (<3 individuals/km²) and low (3-5 individuals/km²) wild boar densities, contacts were typically rare, with a median of 4 and 3 contacts per 14 days, respectively (Appendix I). At the high density (5–7 individuals/km²), contact frequency was markedly higher with a median of 6 and the average twice as high as in the lower density populations (mean 12.65 vs 5.81 contacts per 14 days, Appendix I). The variation in contact frequency was also the highest in high density populations (Fig. 23), with the upper limit of the range at 131 contacts per 14 days.

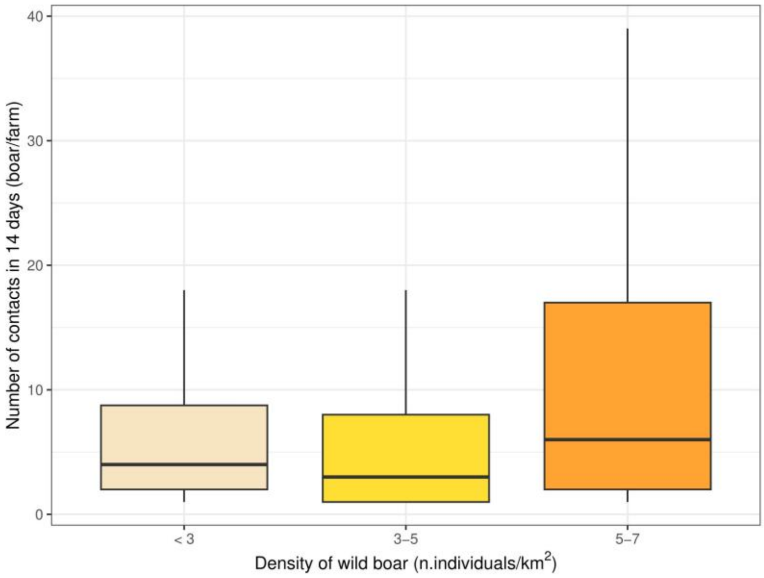


Fig. 23. Distribution of the number of contacts between wild boars and pig farms across a gradient of wild boar population densities.

3.4. Ecological factors

3.4.1. Influence of biogeographical regions on movement metrics and contact patterns

Movement and contact metrics showed marked variation but no distinct patterns across European biogeographical regions (Fig. 25). This suggests that broad-scale differences in climate and habitat composition context may not reflect local, study-site specific variation well.

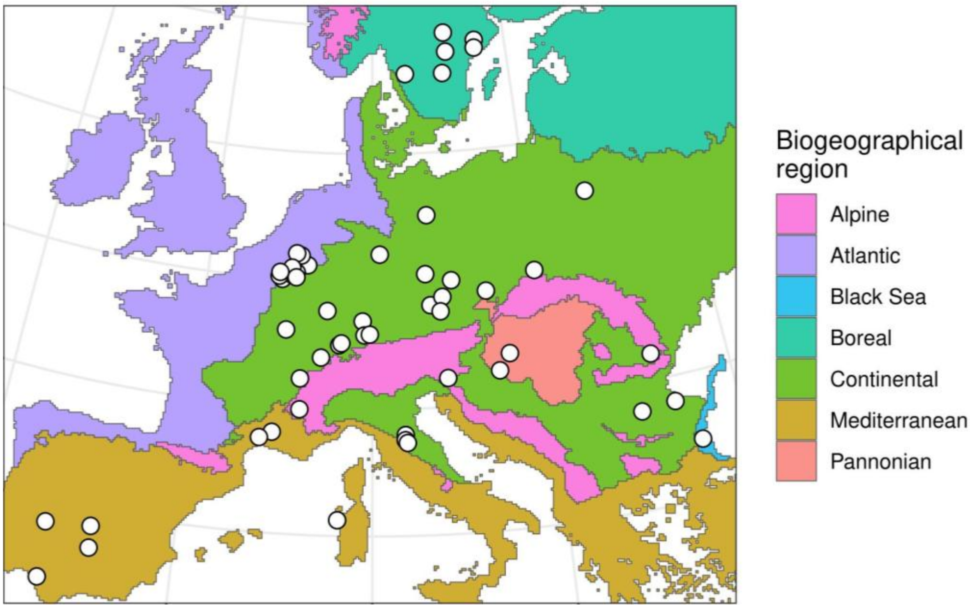


Fig. 24 - Distribution of the different study areas (n = 54), between the different biogeographical regions of Europe.

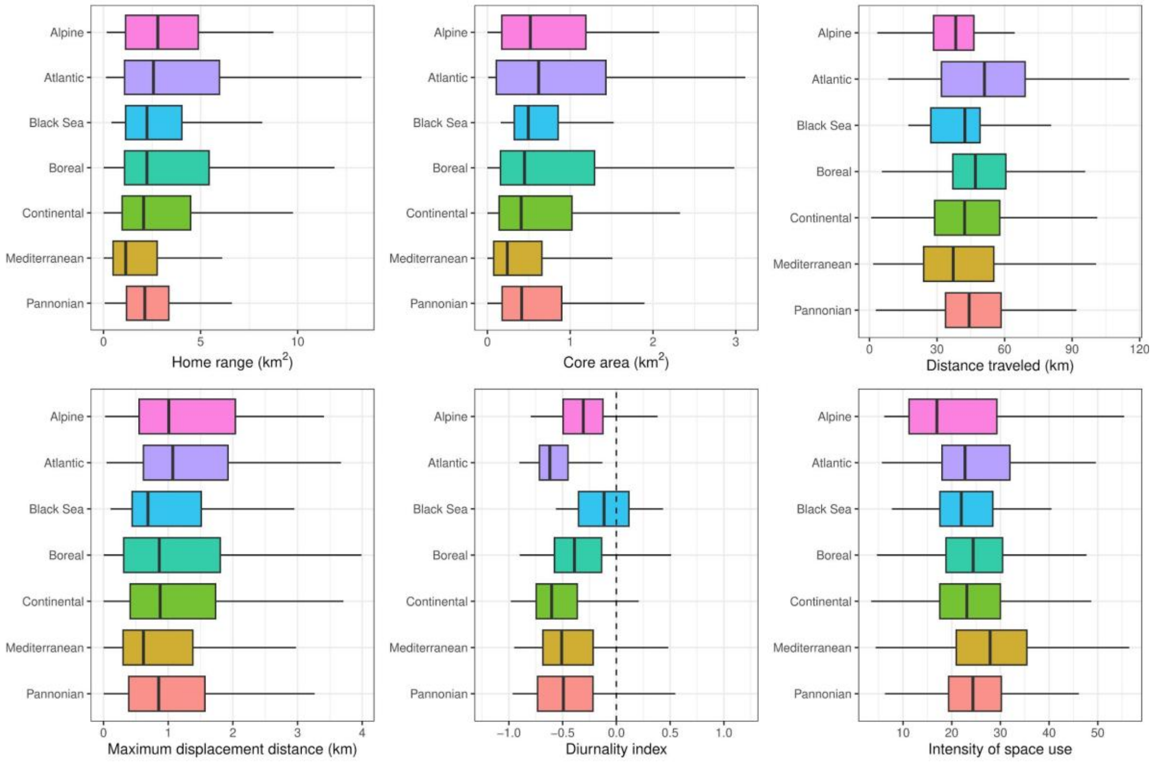


Fig. 25 - Distribution of the six movement parameters, between the different biogeographical regions of Europe.

Size of the home range and core area showed broad overlap and no clear differences across biogeographical regions and their values were within a range of 0.12-485.98 km² and 0.06-239.26 km², respectively. Patterns in movement metrics aligned with the space-use results. Median distance travelled over 14-day windows ranged from 38.31 km (Alpine bioregion) to 54.85 km (Atlantic), while median maximum displacement ranged from 0.69 km (Black Sea) to 1.26 km (Atlantic) (Fig. 25, Appendix A, B, C, D). The values of movement metric showed large variability and broad overlap across biogeographical regions. In parallel, the highest intensity of space use was observed in the Mediterranean bioregion, consistent with repeated use of a smaller area as indicated by the lowest values of home range size (median: 1.47 km²) and core area (median: 0.36 km²) found in this bioregion. The lowest intensity of space use was found in the Alpine bioregion, indicating more straight, directed movements and space use in this environment.

Activity was predominantly nocturnal across all regions (negative medians), with some regional differences: animals in the Atlantic and Continental sites were mostly nocturnal (median -0.62), whereas animals in the Black Sea sites had almost equal proportion of daylight activity (median -0.11; Fig.25, Appendix E).

Social contact patterns by biogeographical region broadly overlapped (Fig. 26). Within group contacts were similar across 3 bioregions for which data was available, with medians ranging from 166 to 259 and high overlap in variability (Fig. 26, Appendix G). Between groups, medians of contacts were uniformly low (1-6) (Appendix H). Continental bioregion showed the greatest variation, extreme values and average (median 4; mean 20.93 ± 42.86; range 1–307, *n*=186). Other regions showed lower values and variation (Fig. 26).

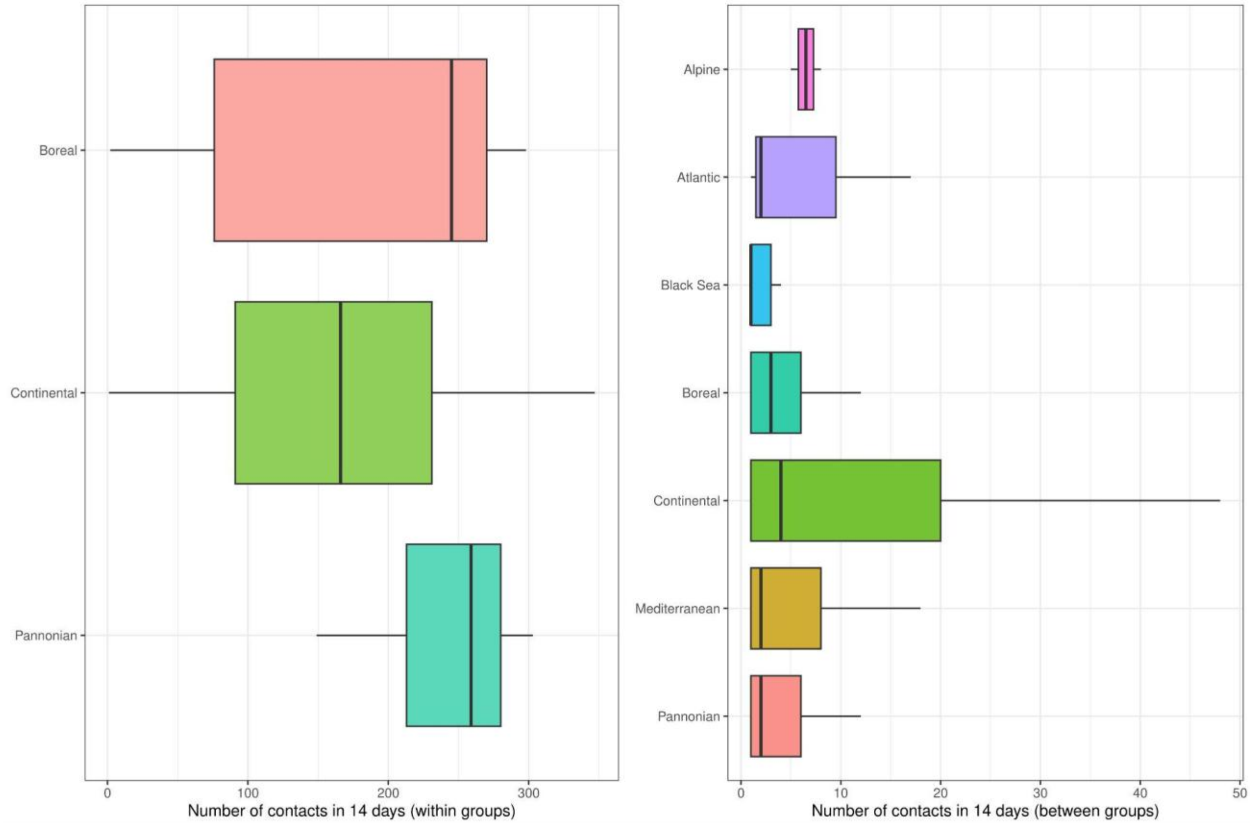


Fig. 26. Distribution of the number of contacts between wild boars from the same group (left) and different groups (right) across biogeographical regions.

The frequency of wild boar–pig farm contacts differed across biogeographical regions, mainly in typical (median) contact levels and in the magnitude of extreme values (Fig. 27). Boreal sites showed the lowest contact rates, with a median of 1 contact per 14 days (mean ± SD = 2.87 ± 4.39, N = 6) and a limited range (1–18). The Continental region had a higher central tendency (median = 4; 9.35 ± 14.06, N = 109) and the widespread overall, including the highest recorded maximum (range 1-131), indicating occasional very intense contact windows. Mediterranean and Pannonian regions exhibited the highest typical contact levels (medians of 9 and 7, respectively), with mean values of 14.67 ± 13.72 (N = 4; range 1–47) and 10.31 ± 9.8 (N = 12; range 1–55), respectively, suggesting that contacts were more frequent in many 14-day windows in these regions, although sample sizes, particularly for Mediterranean, were small and should be interpreted cautiously.

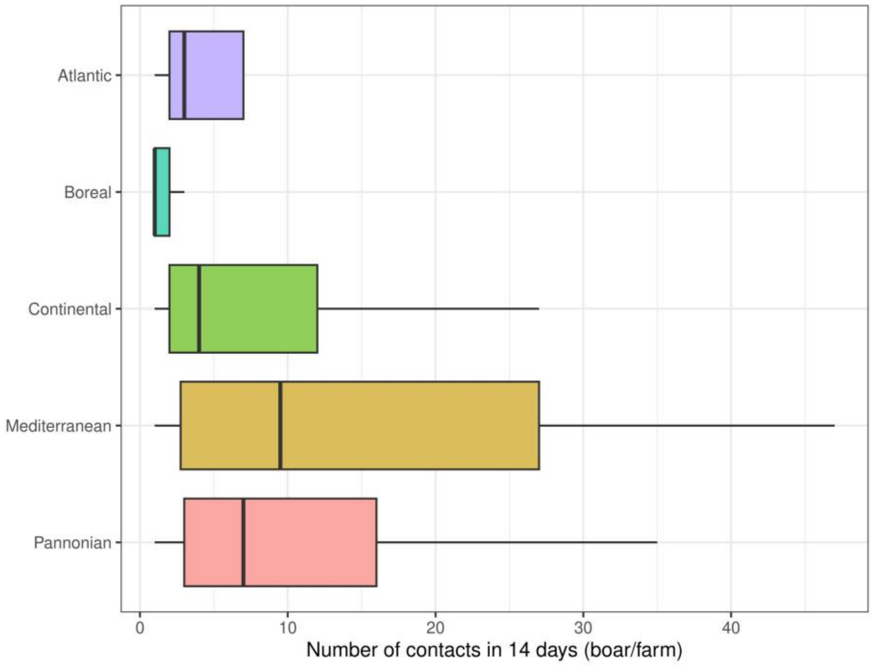


Fig. 27. Distribution of the number of contacts between wild boars and pig farms across biogeographical regions.

3.4.2. Influence of forest cover, type and fragmentation on movement metrics and contact patterns

Forest structure and composition was consistently associated with differences in wild boar space use, movements and activity timing (Fig. 28).

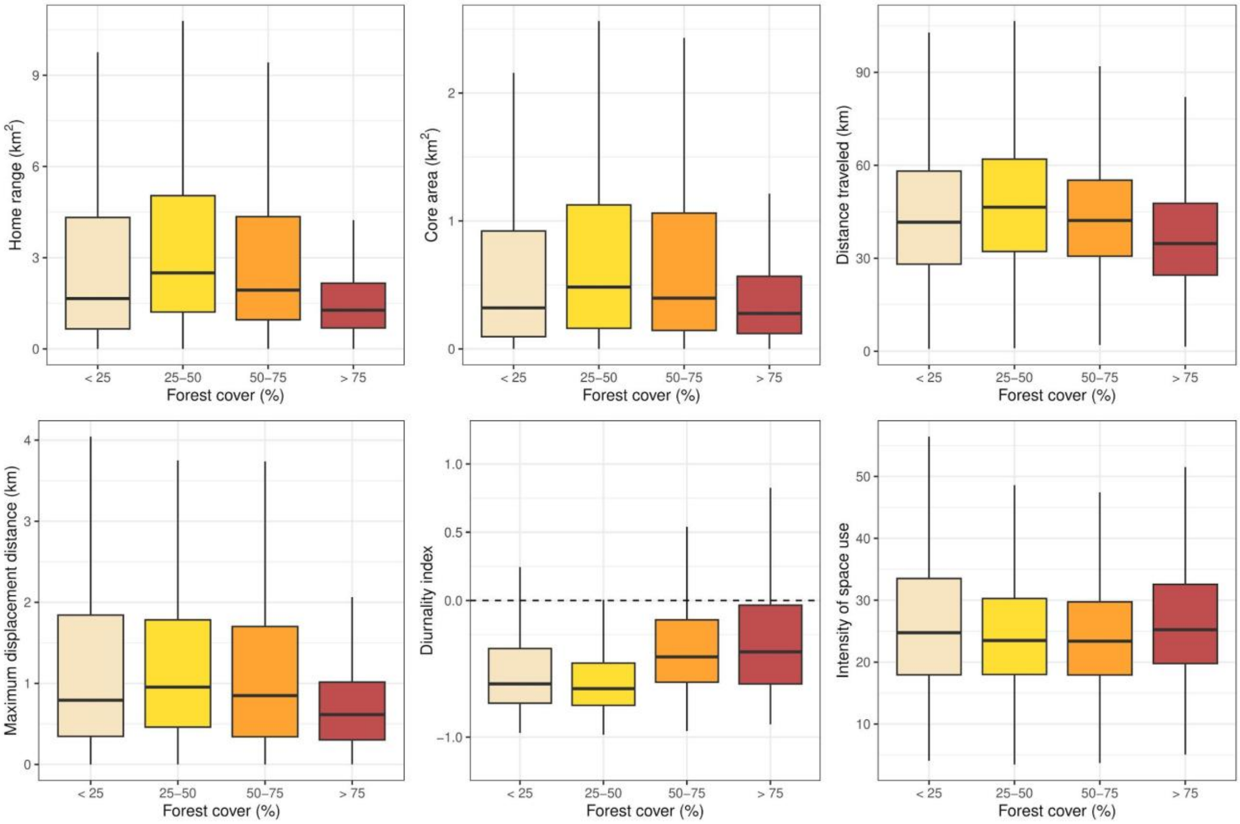


Fig. 28 - Distribution of the six movement metrics across gradients of the percentage of forest cover.

Across forest-cover classes, median ranges were smallest in the most forested sites. Median home range declined to 1.45 km² in areas with 75–100% forest cover, compared with 2.19 – 2.84 km² in the other classes; median core area similarly decreased to 0.33 km² (vs 0.44 – 0.59 km²; Fig. 28; Appendix A, B). Movement distances followed a similar pattern: median distance travelled decreased to 37.8 km with 75–100% forest cover (vs 44.27 - 49.2 km in other classes), and median maximum displacement decreased to 0.67 km (vs 0.97 – 1.06 km; Fig. 28, Appendix A, B, C, D). Activity timing shifted with forest cover: diurnality became less negative with increasing forest cover (median -0.64 at 0–25% vs -0.31 at 75–100% of forest cover), indicating that animals were generally less nocturnal in highly forested landscapes (Fig. 29). There was little effect of the forest cover on the intensity of space use.

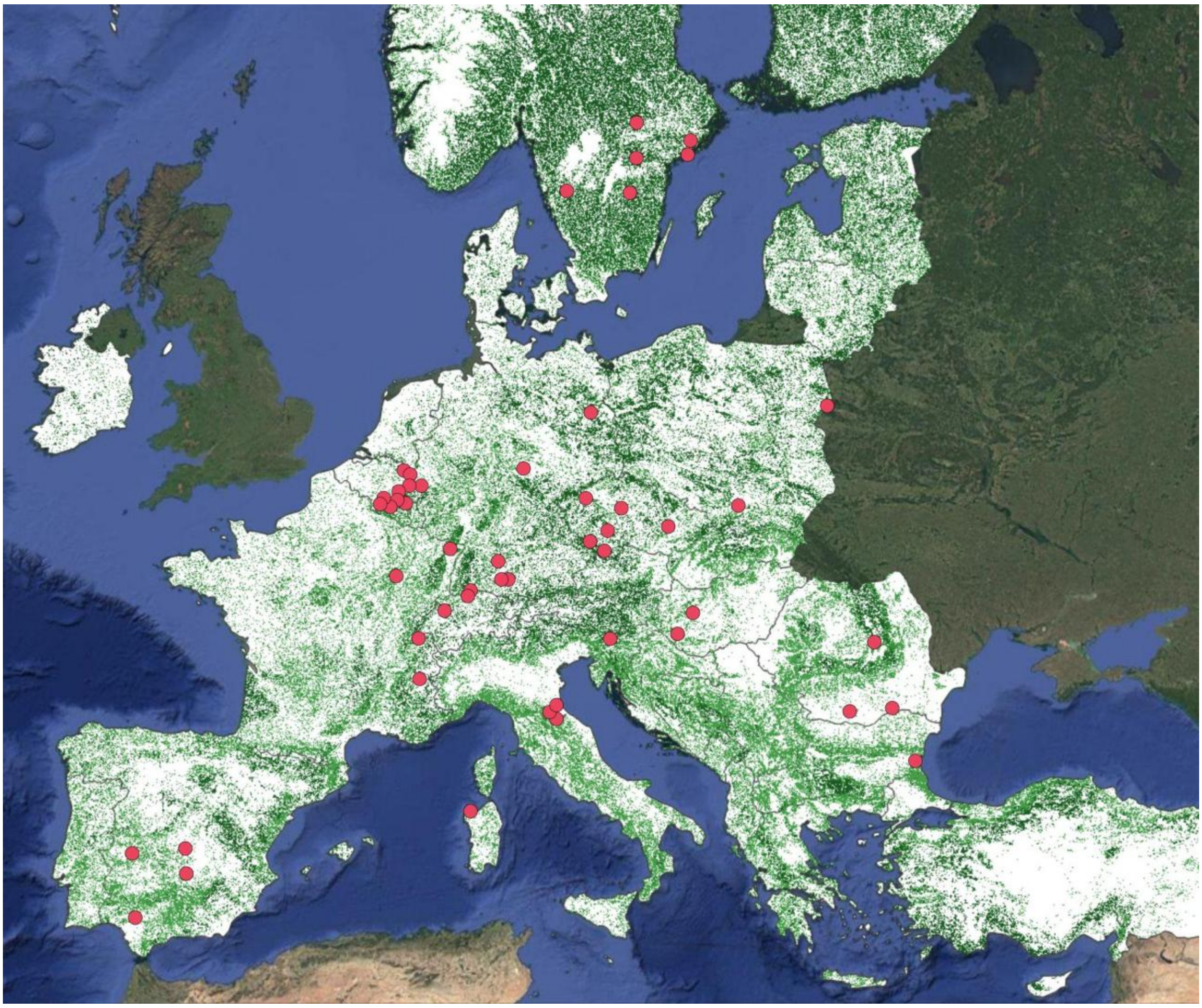


Fig. 29 - Distribution of the different study areas (n = 54) across proportion of forest cover. Coloured pixels represent forest cover, at a resolution of 1km. Light green squares represent broad-leaved species, whereas dark green patches represent coniferous species.

Forest type, represented by the proportion of broad-leaved tree species, had a comparable effect on the movement and space use metrics to overall forest cover (Fig. 29). With increasing broad-leaved forest cover, medians declined for home range (from 2.48 to 1.49 km²; Appendix A), core area (from 0.50 to 0.38 km²; Appendix B), daily distance travelled (from 46.72 to 31.41 km; Appendix C), maximum displacement (from 1.00 to 0.76 km, Appendix D), while activity shifted towards diurnality (from -0.57 to -0.22; Fig. 30, Appendix E). Intensity of space use showed slightly lower values, i.e. more linear space use pattern, in forest with a dominant proportion of broad-leaved tree species (20.96 - 23.61, Fig. 30)

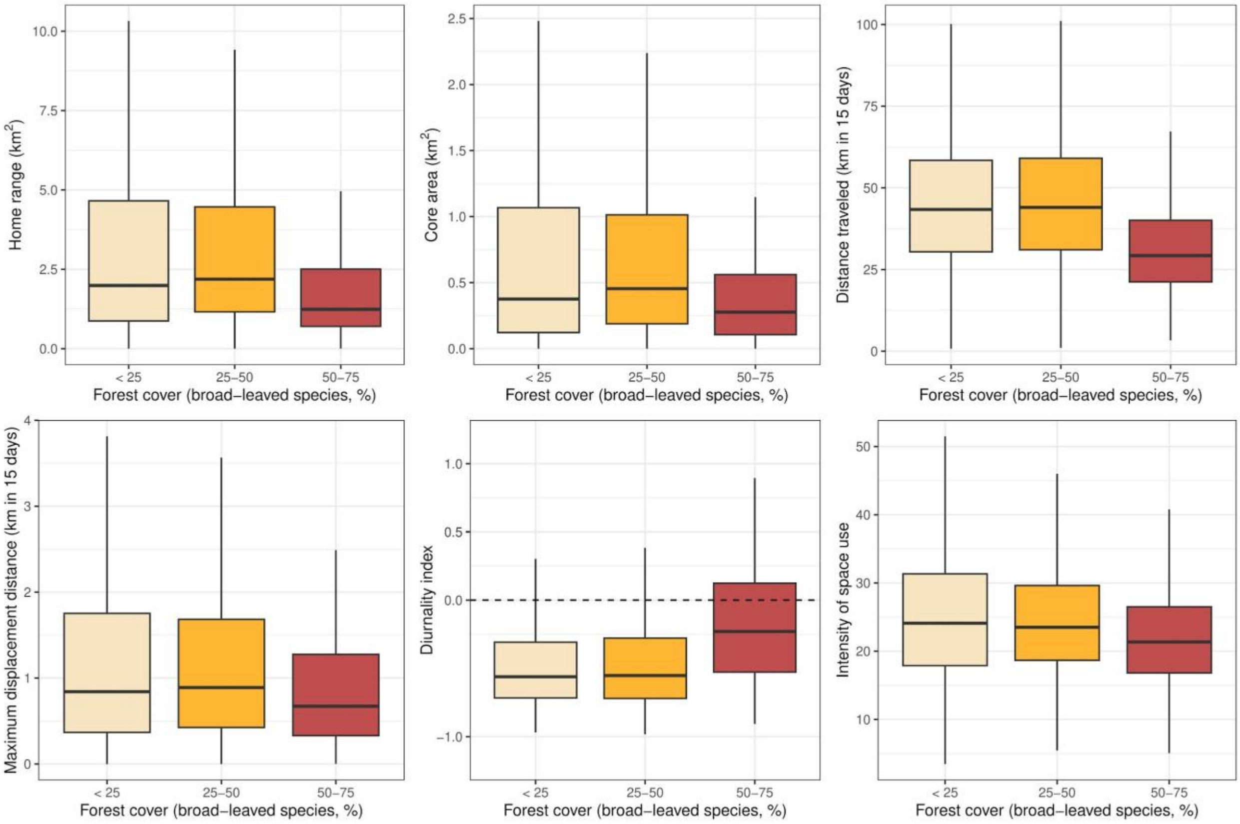


Fig. 30 - Distribution of the six movement metrics across a gradient of the percentage of cover from broad-leaved species.

Increasing forest fragmentation tended to result in smaller ranges (decline by 36.78% from the lowest to the highest fragmentation), core areas (31.34% decline) and lower movement rates (decline by 11.39% and 12.82% distance travelled and maximum displacement, respectively, Fig. 31). Consequently, intensity of space use increased slightly (from 23.01 at the lowest fragmentation to 24.03 at the highest), indicating more clustered and spatially concentrated movements in highly fragmented landscapes (Fig. 31). Diel activity pattern appeared to be independent of the landscape fragmentation (Fig. 31).

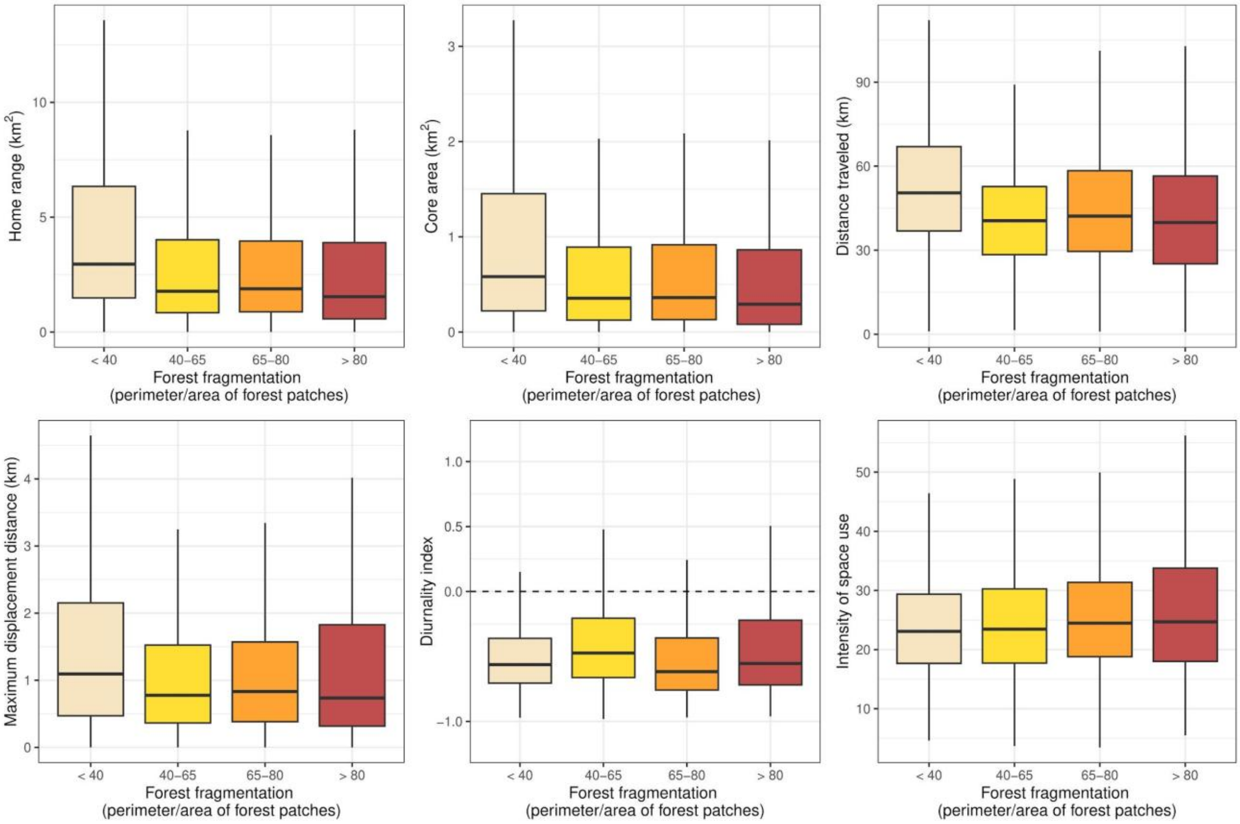


Fig. 31 - Distribution of the six movement metrics across a gradient of forest fragmentation.

Across the forest-cover gradient, contacts within groups showed large variation, broad overlap, and no consistent pattern, with median values ranging between 148 contacts/14 days at the most forested sites (>75%) and 222 contacts per 14 days at the lowest forest cover (<25%; Fig. 32, Appendix G). Variability was high in all classes, with upper values exceeding 347 contacts, particularly at low to intermediate forest cover. Between-group contacts had low medians across all classes (3-5 contacts per 14 days; Fig.32, Appendix H). Variability remained high with forest cover, especially in more forested sites, with upper values occasionally reaching even 307 contacts, indicating sporadic but substantial inter-group interactions.

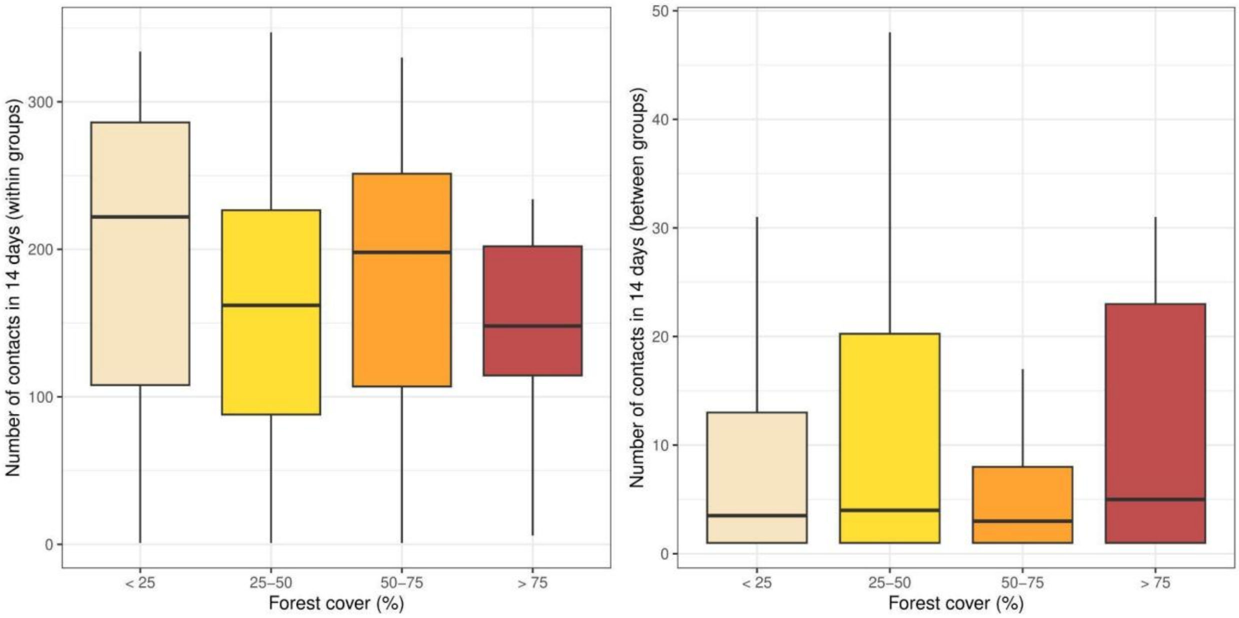


Fig. 32. Distribution of the number of contacts between wild boars from the same group (left) and different groups (right) across the gradient of forest cover.

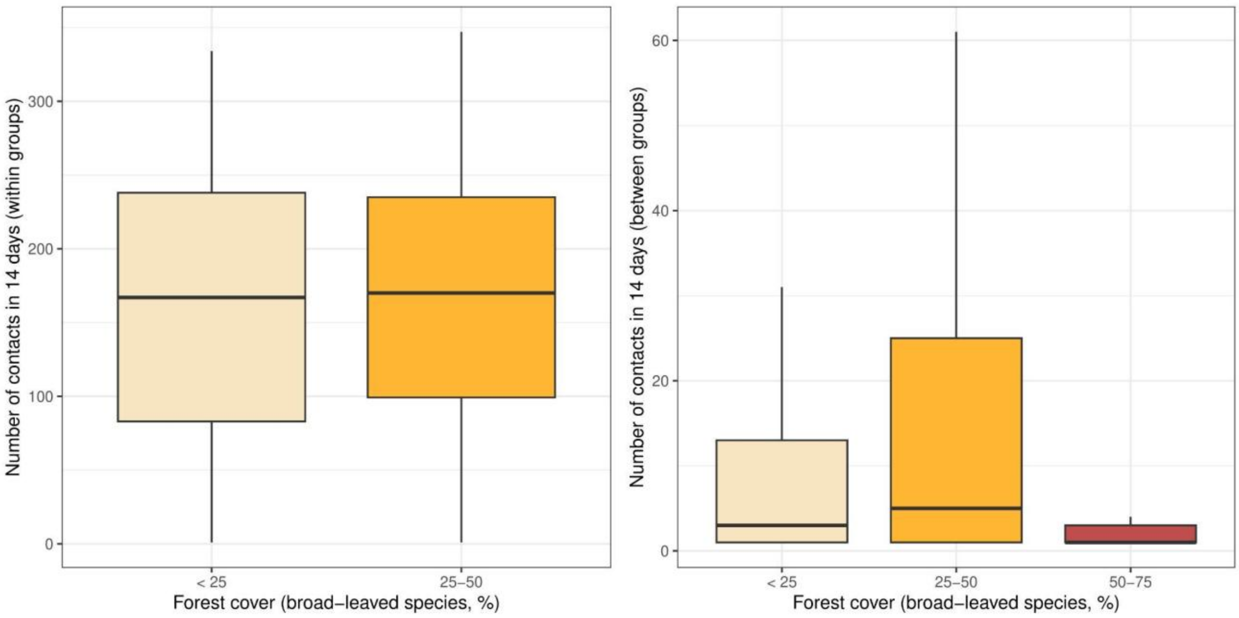


Fig. 33. Distribution of the number of contacts between wild boars from the same group (left) and different groups (right) across the gradient of the percentage of cover from broad-leaved species.

Across the forest-composition gradient (Fig.29), contacts within groups did not show difference with increasing proportion of board-leaved tree species. Between-group contacts had low medians across all classes (1-5 contacts per 14 days; Fig. 33, Appendix H) and showed greater variability at a very low (0-25%) share of broad-leaved species, with maximum values of 307 contacts per 14 days. Forest fragmentation had no marked effect on within-group contacts (Fig. 34), with broad overlap of the value distributions and medians ranging between 157 and 183. Between-group contacts tended to reach much higher average and maximum values at the low levels of forest fragmentation (40-65%) (Appendix H).

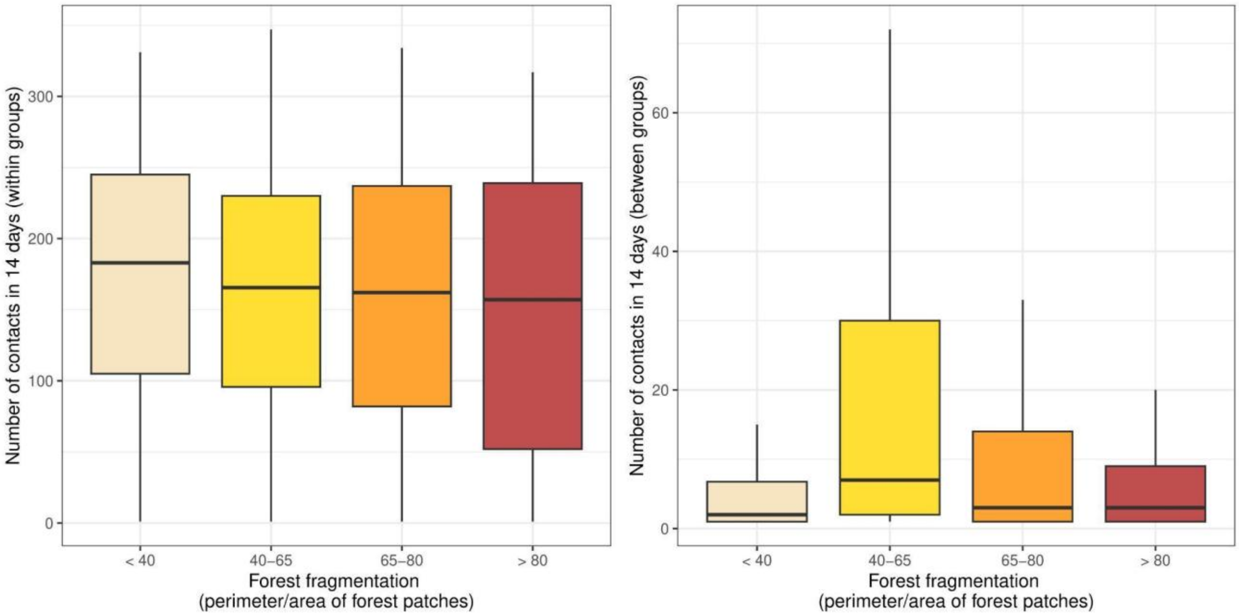


Fig. 34. Distribution of the number of contacts between wild boars from the same group (left) and different groups (right) across the gradient of forest fragmentation.

Frequency of contacts between wild boar and pig farms across the gradient of forest cover peaked at high (50-75%) forest cover (Fig. 35). In sites with up to 50% of the forest cover, contacts were typically low (median = 3 contacts/14 days), although occasional extreme windows occurred (range 1–100). Similarly low values were observed in sites with very high forest cover (75-100%) (median = 2; range 1–16) but inference is limited by the small sample size (N = 3). The highest values were observed at 50–75% forest cover, with a median of 9 and range 1-131 contacts/14 days (Appendix I).

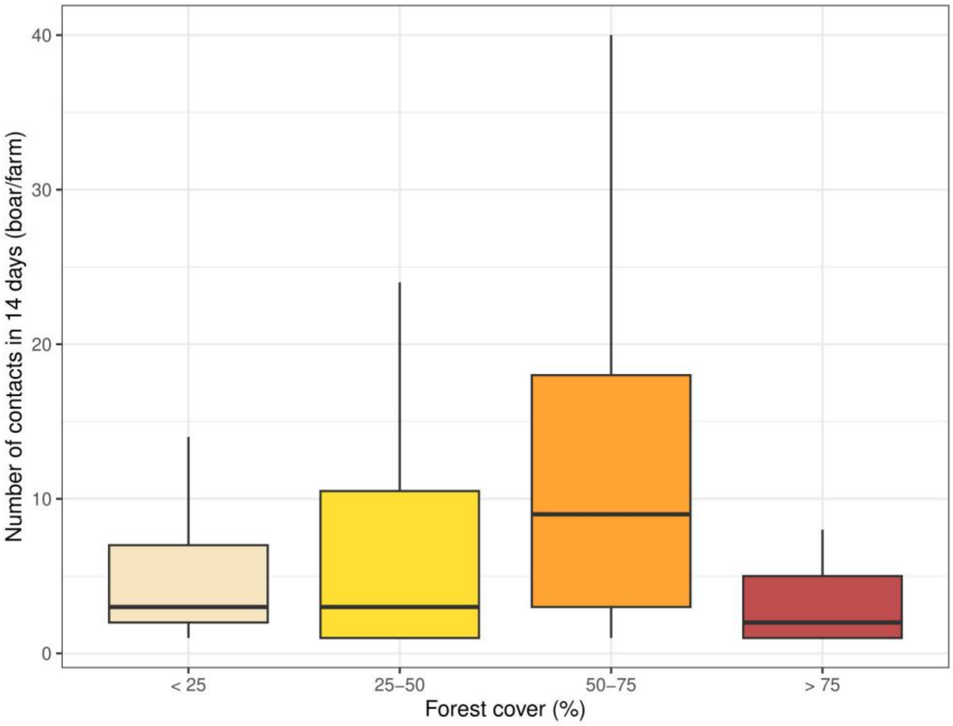


Fig. 35. Distribution of the number of contacts between wild boars and pig farms across a gradient of forest cover.

A similar pattern was observed for broad-leaved forest cover: typical contact levels were highest at intermediate broad-leaved cover (25–50%; median = 6; range 1–131) compared with 0–25% (median = 3; range 1–100). The 50–75% class showed low values (median = 2; range 1–16), but this class was sparsely represented (N = 2) (Fig. 36, Appendix I).

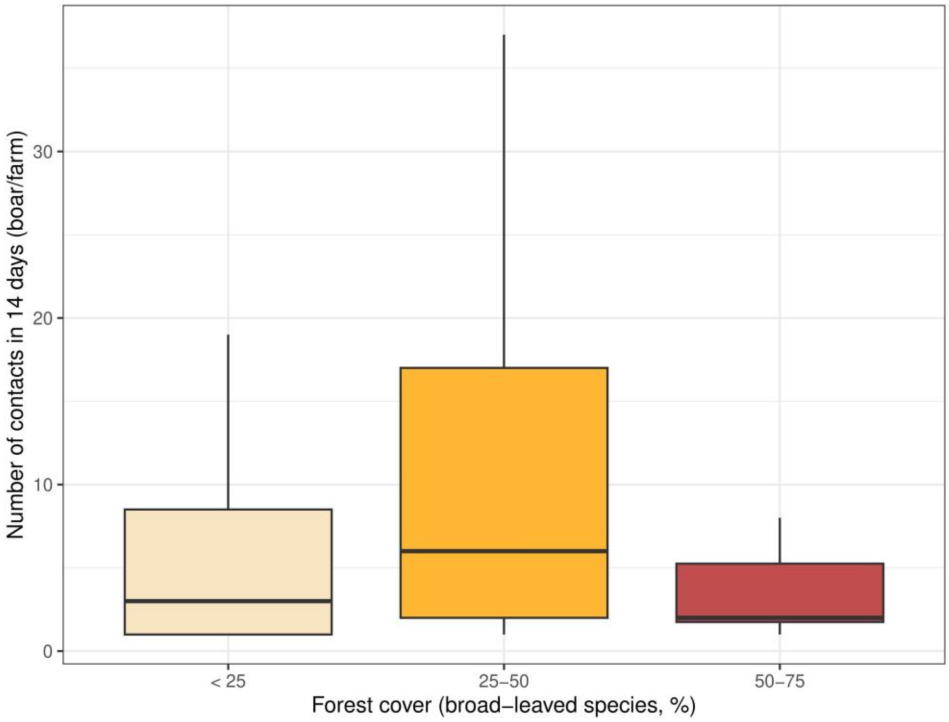


Fig.36 Distribution of the number of contacts between wild boars and pig farms across a gradient of the percentage of cover from broad-leaved species.

Forest fragmentation showed the clearest contrast: contacts were lowest at very low fragmentation (median = 2; N = 15; range 1–19), peaked at medium low and medium high fragmentation levels (median 3 and 6, ranges 1–60 and 1-131, respectively), and then decreased at high forest fragmentation (median = 2; range 1–100) (Fig. 36, Appendix I).

Overall, intermediate levels of forest cover, composition and fragmentation were associated with higher typical boar–farm contact rates, while all classes retained occasional high outliers.

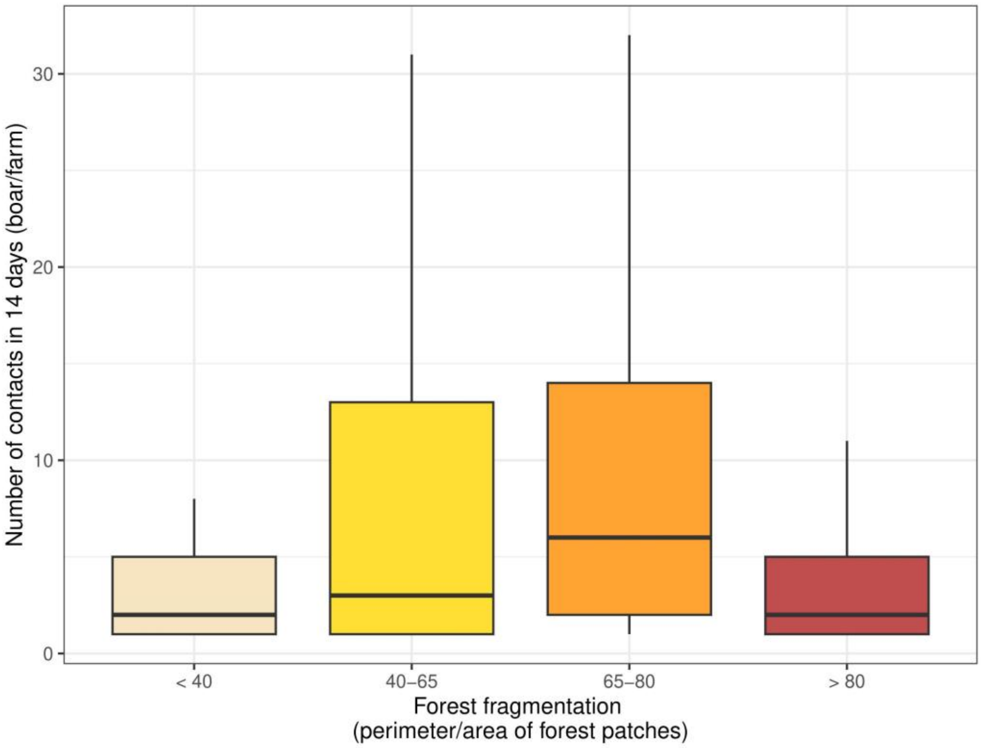


Fig. 37. Distribution of the number of contacts between wild boars and pig farms across a gradient of forest fragmentation.

3.5. Anthropogenic factors

3.5.1. Influence of hunting modalities on movement metrics and contact patterns

Hunting modality was associated with systematic differences in space use, movements and activity timing, with the clearest contrasts between periods with drive hunts and with no hunting or individual hunting (Fig. 38, Appendix A, B, C, D, E). Overall, wild boar exposed to drive hunts displayed larger home ranges and core areas, greater distance travelled and displacements, and higher variability across individuals, consistent with broader ranging and more extensive relocations under episodic disturbance.

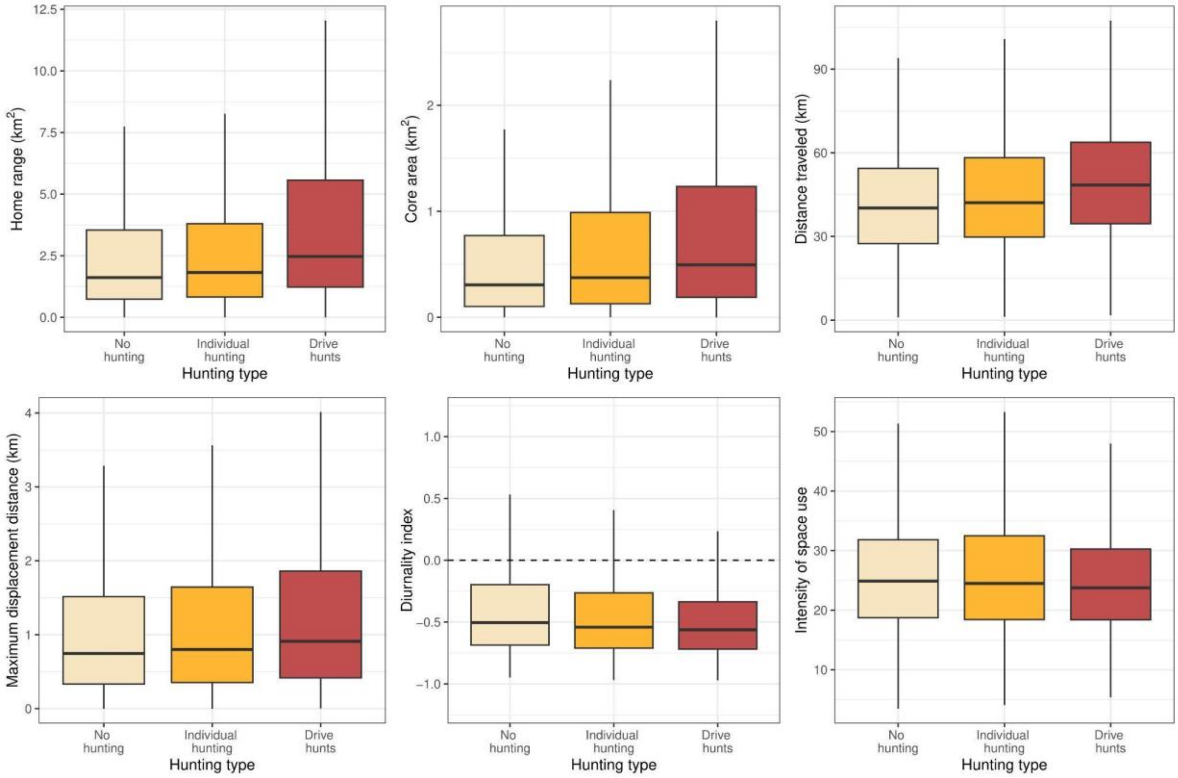


Fig. 38 Distribution of the six movement metrics across different hunting modalities.

Movement metrics varied consistently across hunting modalities, with a general increase in space use and movement rates from no hunting to individual hunting and drive hunts (Fig. 38). Home range size showed a clear gradient among hunting types. Median home range increased from 2.01 km² under no hunting (mean ± SD = 4.20 ± 9.43 km²), to 2.19 km² during individual hunting (4.89 ± 8.83 km²), and was largest during drive hunts (median = 2.71 km²; mean ± SD 6.29 ± 16.61 km²). Variability increased markedly under drive hunts, as reflected by broader interquartile ranges and extreme upper values (Fig. 38, Appendix A).

A similar pattern emerged for core area size. Median core area expanded from 0.41 km² under no hunting (1.09 ± 3.09 km²) to 0.50 km² with individual hunting (1.42 ± 3.24 km²), and 0.57 km² during drive hunts (1.74 ± 6.89 km²). As with home range, drive hunts were associated with the greatest dispersion and extreme values (Fig. 38, Appendix B).

Distance travelled and maximum displacement showed parallel increases across hunting modalities (Fig. 38), with higher medians and longer upper tails under drive hunts, indicating more extensive and episodic movements. Distance travelled over 14-day windows increased from 43.46 km (no hunting) and 45.59 km (individual hunting) to 50.48 km under drive hunts (mean ± SD: 46.61 ± 21.15, 48.23 ± 19.77, 53.44 ± 22.66 km, respectively), while maximum displacement increased from 0.86 km (no hunting) and 0.97 km (individual hunting) to 0.98 km under drive hunts (mean ± SD: 1.45 ± 1.97, 1.64 ± 2.53, 1.68 ± 2.73 km, respectively).

The diurnality index was consistently negative across all hunting types, indicating predominantly nocturnal activity. However, values shifted slightly downward under hunting, with drive hunts showing the most negative medians (-0.57 vs. -0.56 during individual hunting and -0.52 with no hunting), suggesting a modest decrease in daytime activity (Fig.38; Appendix E). Finally, intensity of space use was broadly similar among hunting types, but showed slightly lower values during biweeks with drive hunting (Fig. 38; Appendix F), consistent with more heterogeneous and expanded space-use patterns.

Contact data were not stratified by hunting modality in a substantial way (Fig. 39; Appendix G, H). Within-group contacts overlapped broadly with a narrow range of medians (162 to 182 contacts per 14 days). Between-group contacts also showed relatively broad overlap with a slight decrease under drive hunts (median 3 contacts per 14 days in all categories; mean = 9.35 vs. 18.21 at drive vs. individual hunt and 14.64 at no hunting), likely a consequence of dispersion and escape movements during disturbance.

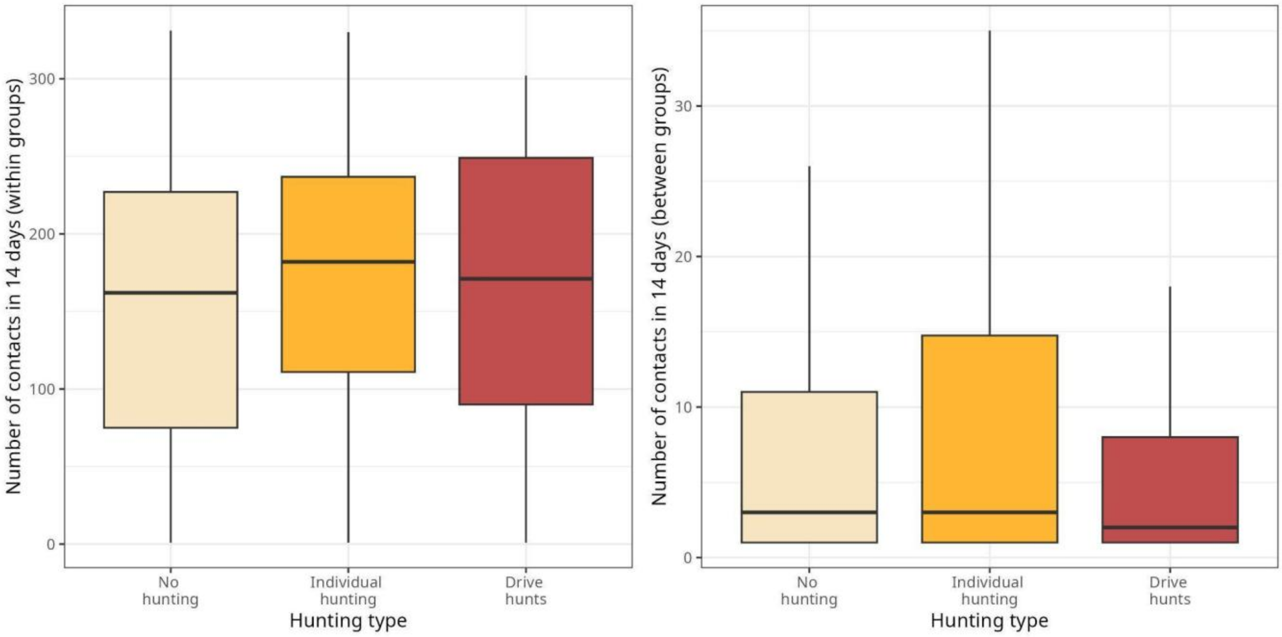


Fig. 39. Distribution of the number of contacts between wild boars from the same group (left) and different groups (right) across different hunting modalities.

Wild boar - pig farm contact rates were broadly similar across periods with different wild boar hunting modalities (Fig. 40). Overall, medians differed only modestly (3–5), and distributions overlapped substantially, suggesting no strong systematic effect of hunting type on contact frequency (Appendix I).

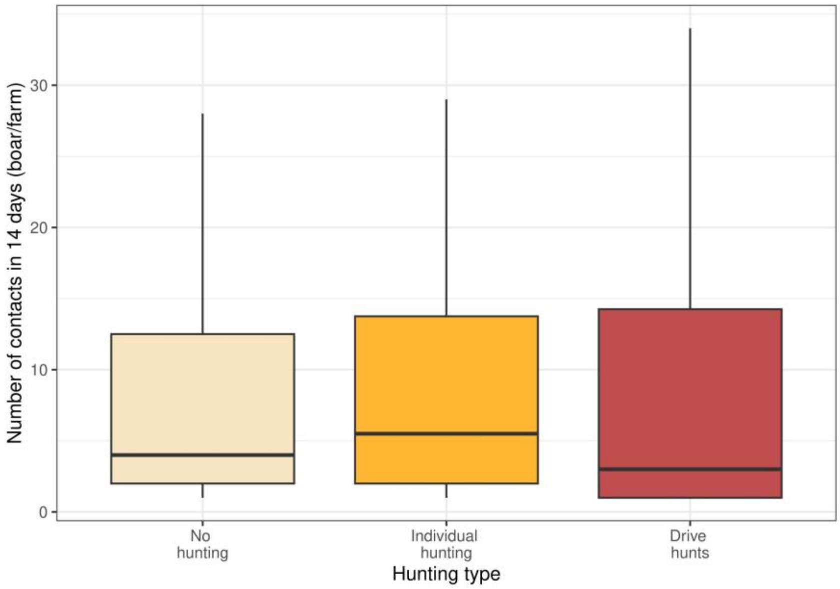


Fig. 40. Distribution of the number of contacts between wild boars and pig farms across periods with different hunting modalities.

3.5.2. Influence of anthropization on movement metrics and contact patterns

Study areas spanned a broad anthropization gradient across Europe (Fig. 41). Study areas were grouped into three anthropization classes based on normalized Human Footprint Index (HFI): low: HFI < 35; intermediate: 35–60; high: > 60.

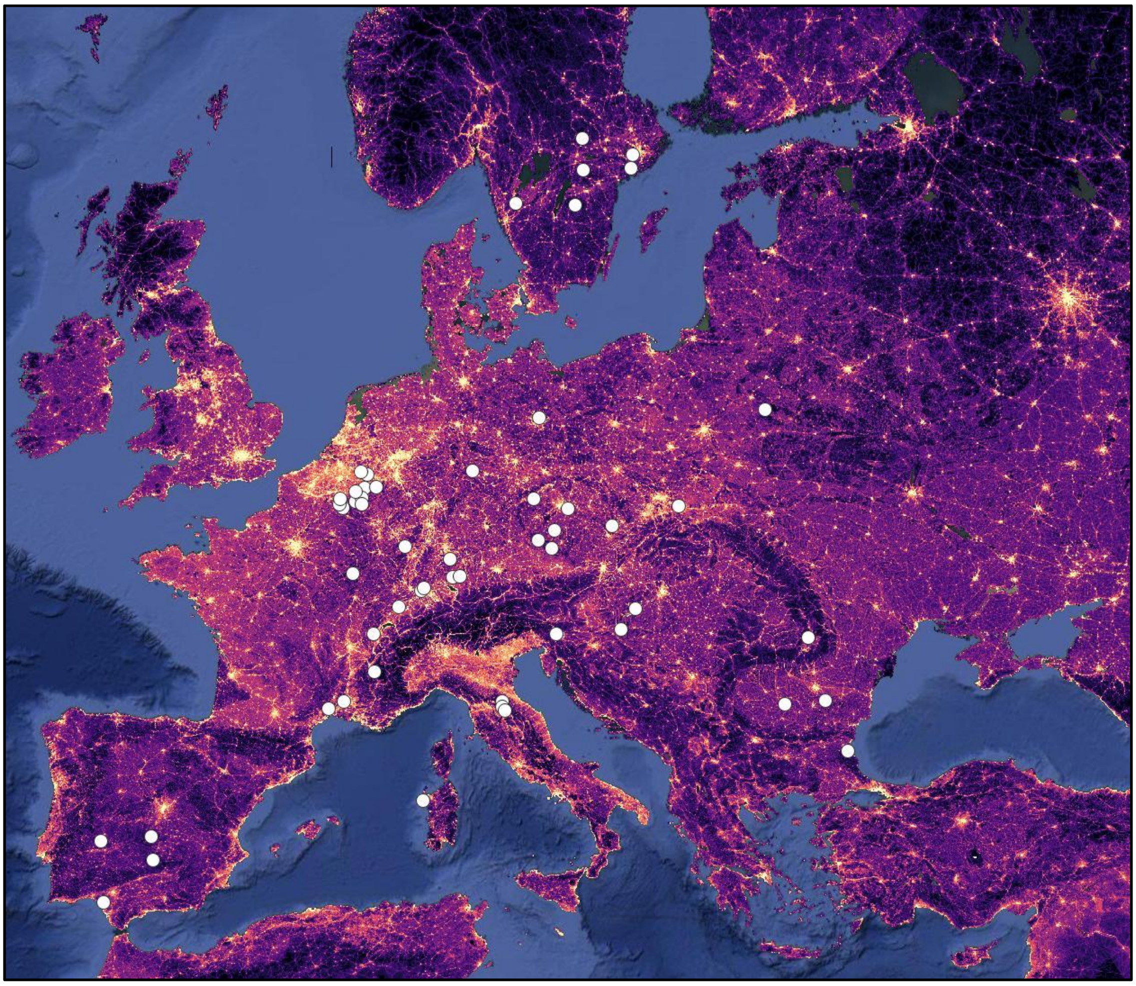


Fig. 41 - Distribution of the different study areas (n = 54), between areas with different levels of landscape anthropization, represented by the Human Footprint Index (HFI). Values of the HFI are normalized, with the maximum value equating to 100. Darker areas have a lower level of landscape anthropization (lower HFI).

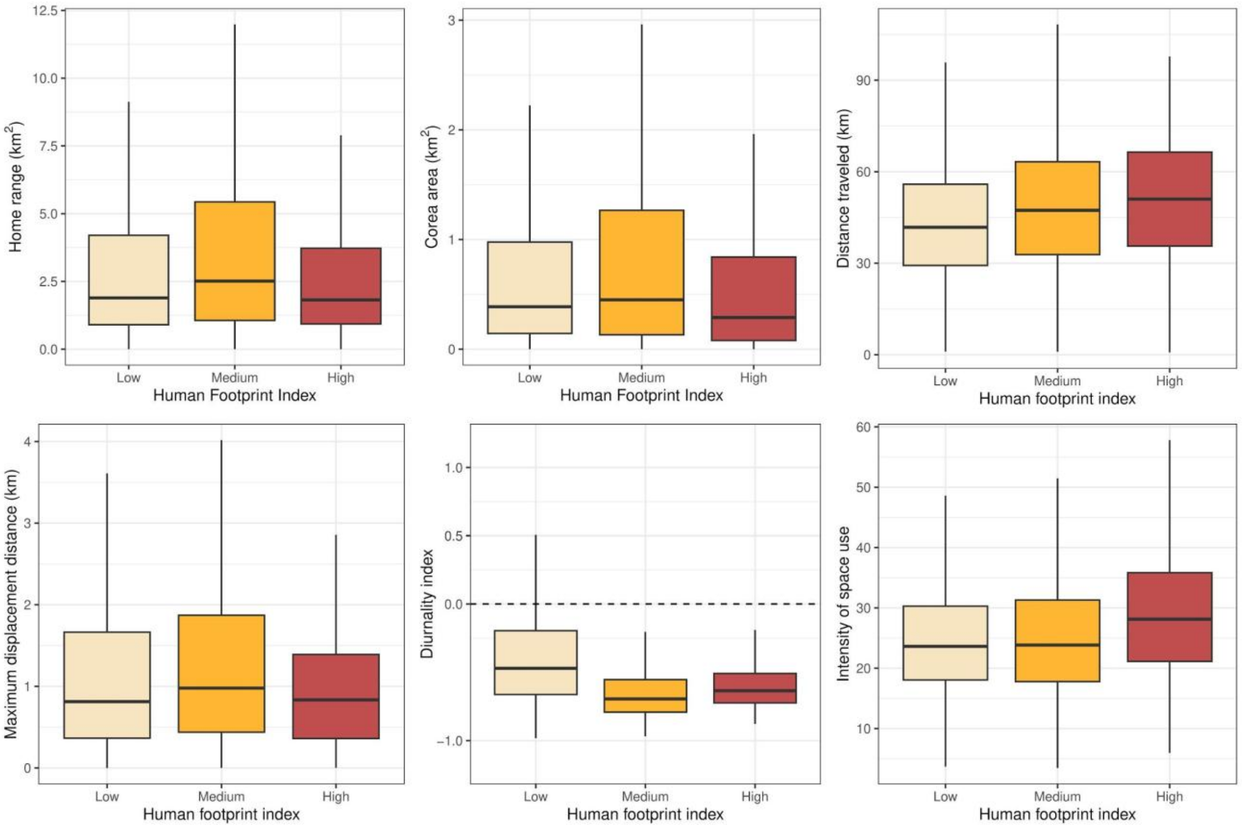


Fig. 42 - Distribution of the six movement metrics, between areas with different levels of landscape anthropization, represented by the normalized Human Footprint Index.

Landscape anthropization (normalized Human Footprint Index, HFI) was associated with some differences in movement behaviour (Fig. 42). Range size responded non-linearly to anthropization. Median home range was smallest at both low and high HFI (2.22 and 2.38 km², respectively) and highest at intermediate HFI (3.03 km²; Appendix A). When considering average values, the smallest home ranges were observed in highly anthropized areas (low HFI: 5.02km², medium HFI: 6.03km², high HFI: 3.93km², Appendix A). Core area showed the same pattern (median 0.48 and 0.47 km² at low and high HFI vs 0.59 km² at intermediate HFI; Appendix B). Average core areas were the smallest in human dominated landscapes (Appendix B). Distance travelled increased with HFI (median 14-day distance: 44 km at low, 51 km at intermediate and 54 km at high HFI; Appendix C), but maximum displacement did not show a corresponding increase (medians 0.92, 1.11 and 0.96 km, respectively; Appendix D; Fig. 42). Activity timing also differed across the anthropization gradient. Animals were least nocturnal at low HFI (median diurnality -0.49) and more nocturnal at intermediate and high HFI (-0.7 and −0.64, respectively; Appendix E, Fig. 42). Intensity of space use showed the highest values at high levels of HFI, suggesting that high levels of landscape anthropization tends to constrain movements, consistent with previous results on the effect of forest fragmentation.

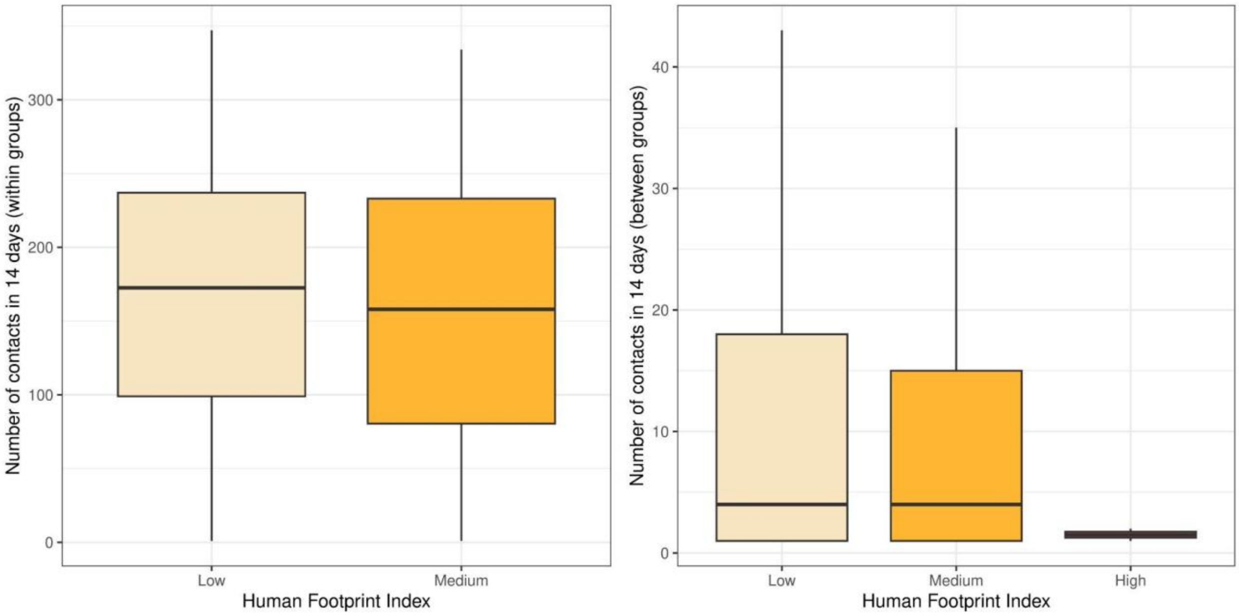


Fig. 43. Distribution of the number of contacts between wild boars from the same group (left) and different groups (right) across a gradient of landscape anthropization, represented by the normalized Human Footprint Index.

Contact distributions overlapped broadly between HFI classes (Fig. 43) and were vastly similar across low and medium HFI, both within- and between-groups (Appendix G, H), suggesting no strong effect of anthropization on overall contact rates. Between-group contacts were much lower at the highest levees of HWI but low sample size (N = 2) precludes meaningful inference.

Contact between wild boar and pig farms were higher at low HFI (median 6 contacts per 14 days) compared to intermediate HFI (3 contacts per 14 days) and high HFI (2 contacts per 14 days) (Fig. 44). At low Human Footprint Index, contact rates showed the highest mean (± SD) of 12.16 (±16.14, N = 75), with occasional very high biweekly contact counts (range 1–131), indicating that most 14-day windows had relatively few contacts but rare periods exhibited intense farm visitation. At intermediate HFI, contacts were lower and less variable overall (5.67 ± 6.31; range 1–38; N = 33), consistent with a tighter distribution and fewer extreme peaks. In the high HFI class, contact frequency was typically low (median 2 contacts per 14 days) and a narrower spread (range 1-25), however sample size was relatively low (N = 3), so the value for high HFI should be interpreted cautiously.

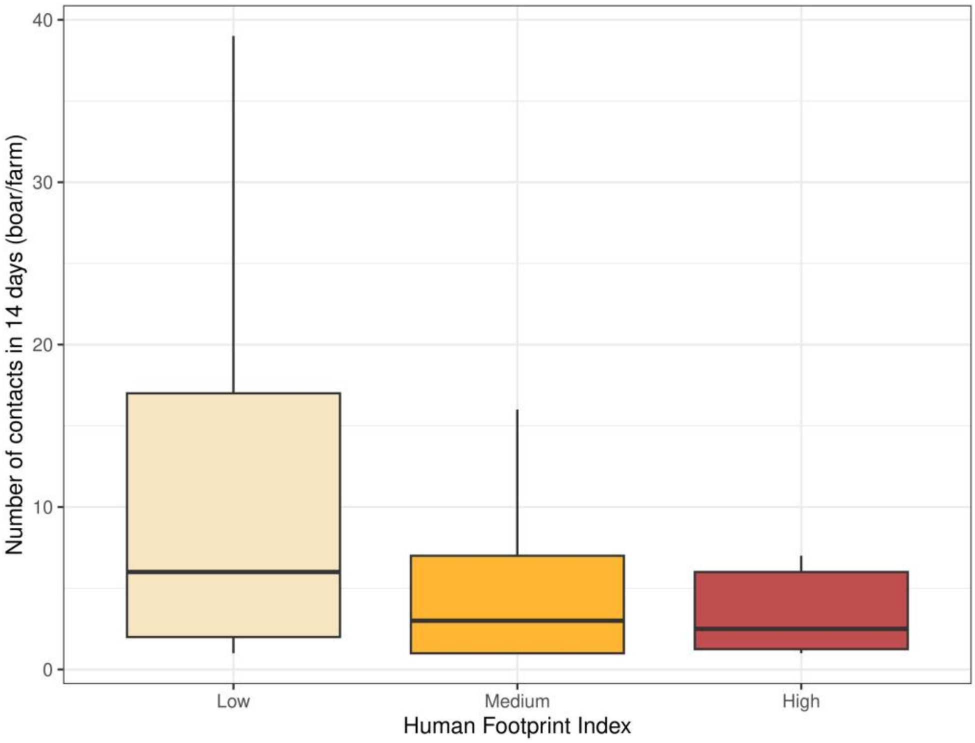


Fig. 44. Distribution of the number of contacts between wild boars and pig farms across a gradient of landscape anthropization (represented by the normalized Human Footprint Index).

3.6. Temporal analysis of maximum displacement distance

Our analyses indicate minor variation in the maximum displacement distance covered by individuals over time when calculated with GPS locations in different time windows.

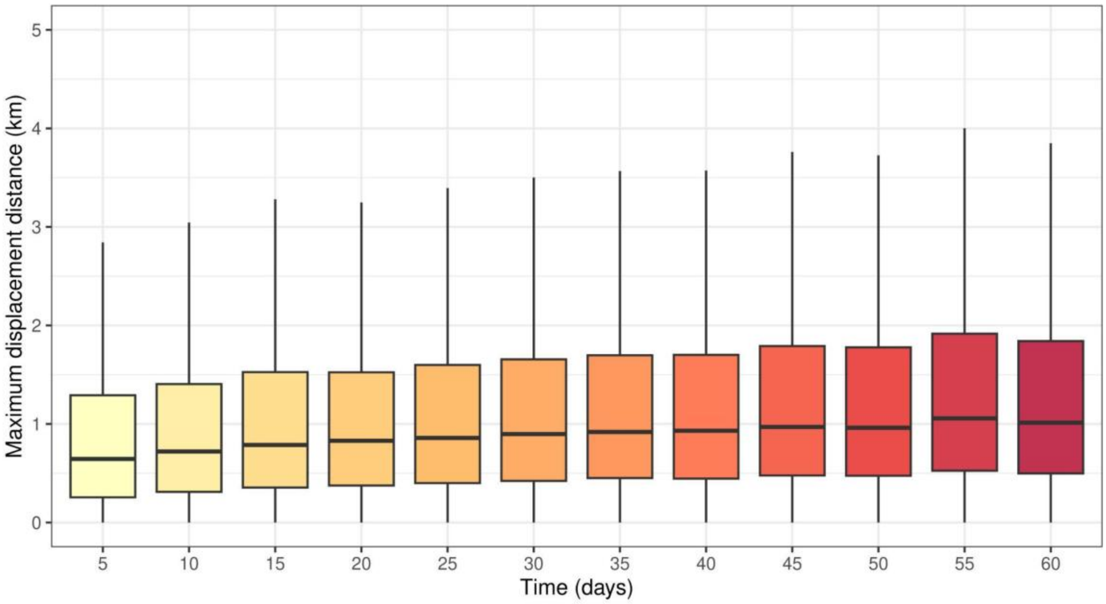


Fig. 45 - Distribution of maximum displacement distance, over different time windows. For each time window, maximum displacement was calculated as the maximum distance observed across all pairwise distances using all GPS locations from a given time window. The size of each time window corresponds to the number of days elapsed from day 0 (i.e. 5 days, 10 days, 15 days, etc.)

The distribution of maximum displacement distance increased ever so slightly yet steadily with longer time windows. At 5 days, the median maximum displacement was 0.6 km, with an interquartile range of 0.25-1.25 km and occasional values approaching 2.8 km. In the 25 days period, the median increases to about 0.8 km, with upper values at 3-3.5 km. At 55–60 days, median maximum displacement reaches about 1.0–1.1 km, with the highest observed values approaching 4 km. Overall, both central tendency and variability increase with time window length, indicating that spatial extent of movement progressively increases over time. Nonetheless, the increase is relatively minor in terms of absolute values, from 0.6 km observed at 5 days to 1.1 km at two months period, confirming the sedentary nature of wild boar spatial behaviour. However, Fig. 6 shows that extreme values of maximum displacement (>10 km, with maximum of 66km; outliers were not included in the above Fig.45) can occur and, while infrequent, indicate a risk of long-distance movements within a 14 day period.

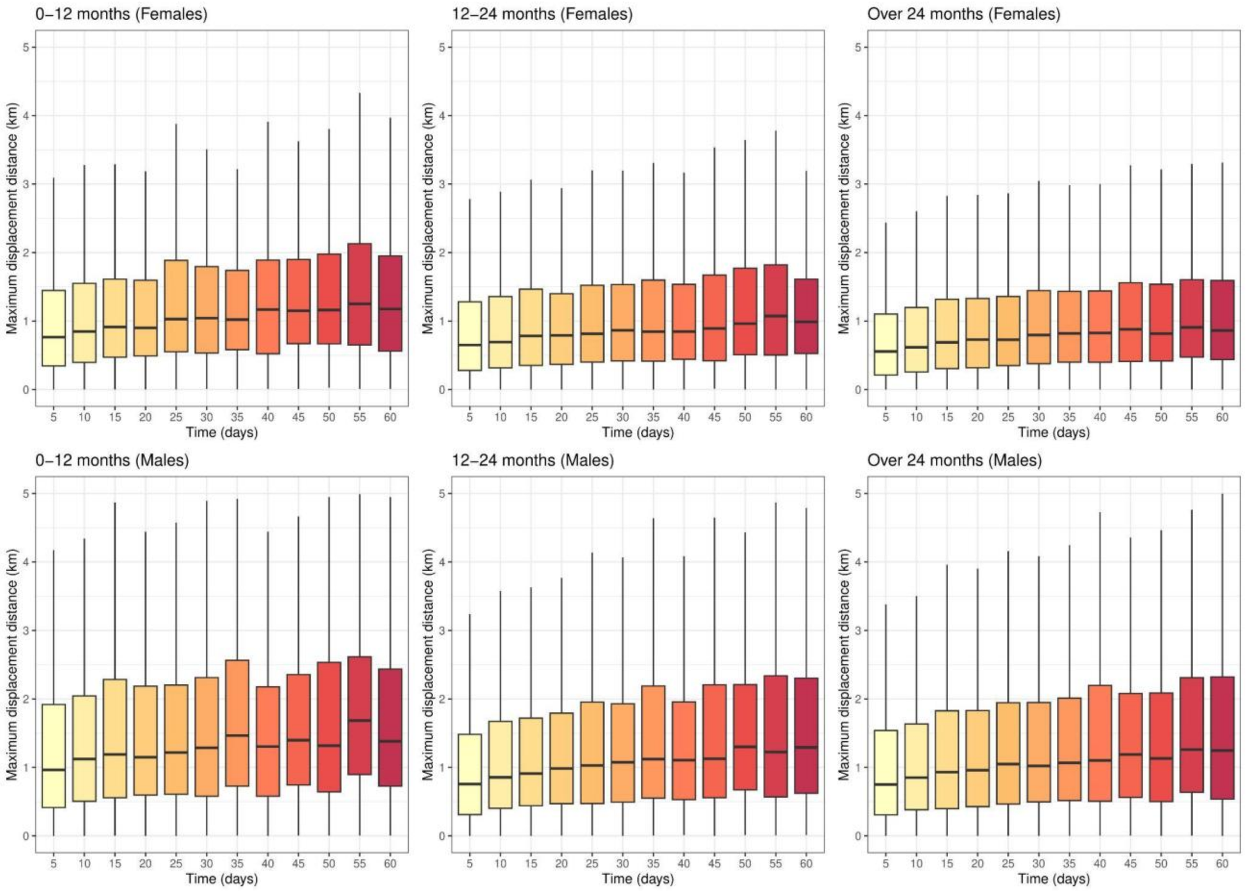


Fig. 46 - Distribution of maximum displacement distance, over different time windows, between wild boar of different sex and age classes.

Across all sex and age classes, maximum displacement increased with longer time windows, albeit at a relatively low rate, consistent with the overall pattern (Fig. 46). Overall, males showed slightly higher values and greater variability across all age classes but particularly at 0-12 months with median max displacement increasing from 1km at 5-day window to 1.5km at 2-months period and interquartile range from 0.4-1.5km to 0.8-2.6km, respectively. Adult males (>24 months) showed slightly lower values compared to younger age classes (medians rising from 0.7 to 1.3km) yet still higher than adult females which showed the lowest overall displacement across time windows, with medians not exceeding 1km throughout and low variability. Overall, juveniles and yearlings, particularly males, displayed more variable movements, with higher median values and upper extremes. However, the rate of change, as well as absolute values, of maximum displacement remained relatively low over a 2-month period across all sex and age classes.

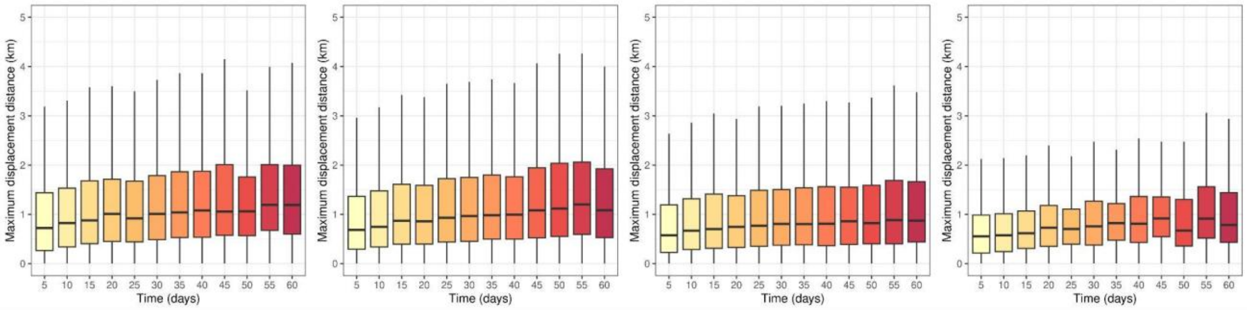


Fig. 47 - Distribution of maximum displacement distance, over different time windows, across a gradient of wild boar population densities. From left to right: areas with a low (< 3 boars/km^2), medium-low (3-5 boars/km^2), medium-high (5-7 boars/km^2) and high (> 5 boars/km^2) density of wild boar.

Maximum displacement increased with time across all density classes, but spatial extent varied slightly with density (Fig.47). At low and medium densities, max displacements had higher absolute values and greater variability (medians from 0.7 to 1.3km and upper values near around 4 km across 2 months period) compared to very high density populations (medians <1km and upper values around 3km). While the rate of increase over time varied from 70% at low densities, 60% at medium-low, 50% at medium-high, to 80% at high densities over a 2-month period, the change in absolute values was relatively minor across all classes. These results suggest that in sparsely populated landscapes, wild boar expand their movements over time, whereas in high density areas movement is more constrained.

All regions exhibit slightly increasing maximum displacement with longer time windows, but the rate and magnitude differed (Fig. 48). Some regions showed relatively small rate of increase over a 2-month period (Atlantic: 11%, Alpine: 33%, Continental: 40%, Pannonia: 40%), while others showed larger increases (Black Sea: 80%, Mediterranean: 80%, Boreal: 67%). Nevertheless, in terms of absolute values, the change in max displacement over time was minor across biogeographical regions, with medians <1km and upper values <4km at the highest points. This indicates that regional landscape structure and ecological conditions have a rather weak modifying effect on the baseline time–displacement relationship.

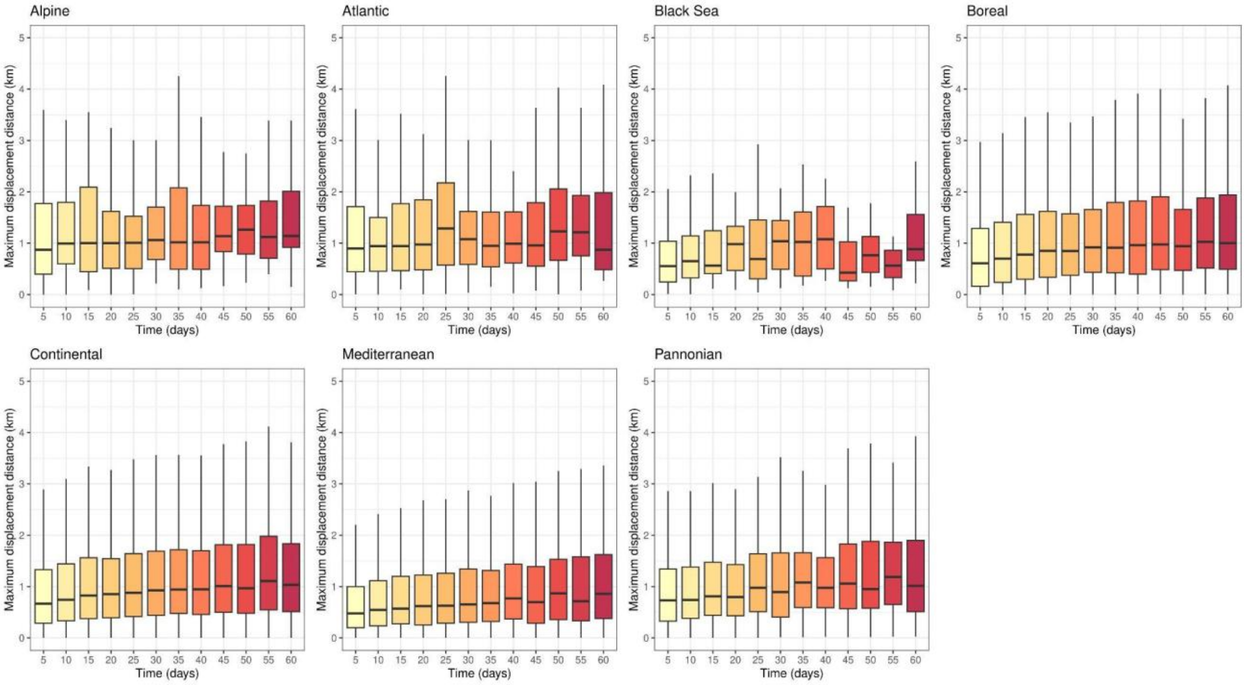


Fig. 48 - Distribution of maximum displacement distance, over different time windows, between different biogeographical regions.

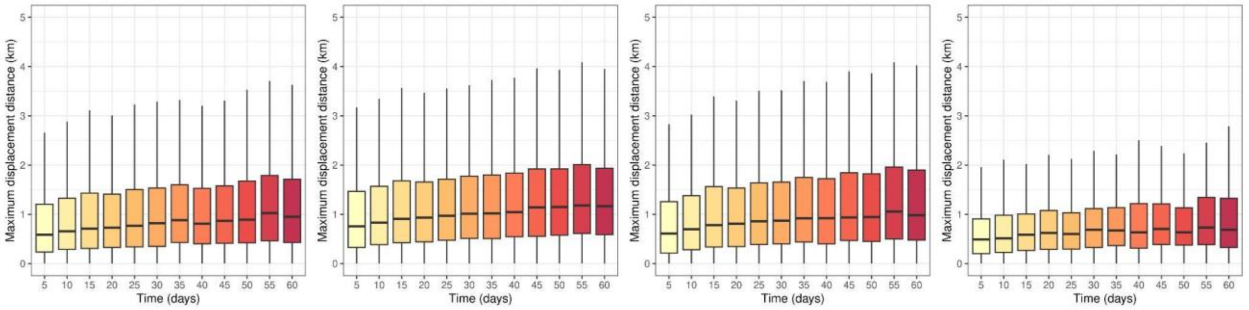


Fig. 49 - Distribution of maximum displacement distance, over different time windows, across a gradient of forest cover. From left to right: areas with a low (< 25%), medium-low(25-50%), medium-high (50-75%) and high (> 75%) forest cover.

Maximum displacement increases with time across all forest cover classes, but landscapes with low to medium forest cover (<50%) showed slightly higher medians (up to 1.2km) and greater variability over a 60 day period (Fig.49). Highly forested areas (>75%) displayed lowest medians (0.5–0.7 km) and narrower ranges. This suggests that open or mixed landscapes allow wider-ranging movements over time, strengthening the time–displacement relationship, whereas dense forest cover constrains spatial extent of movement.

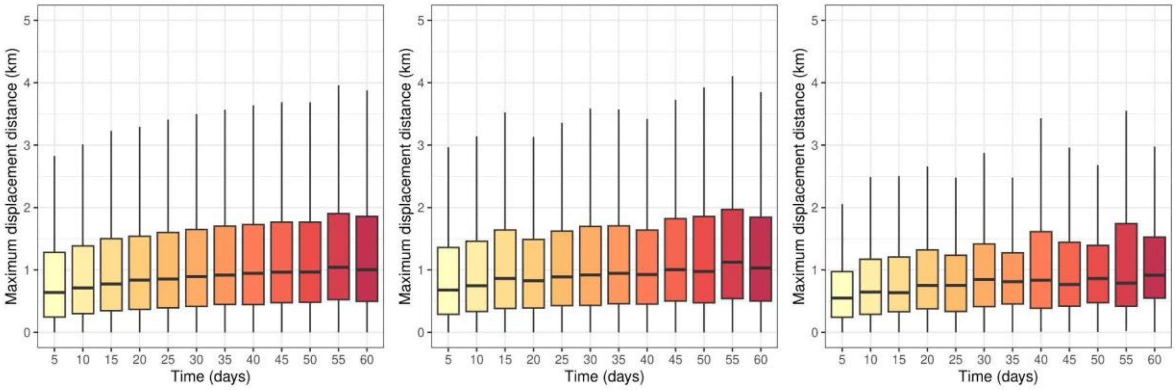


Fig. 50 - Distribution of maximum displacement distance, over different time windows, across a gradient of cover from broad-leaved forests. From left to right: areas with a low (< 25%), medium-low (25-50%), medium-high (50-75%) proportion of broad-leaved tree species.

Across all proportions of broad-leaved forest, displacement increases with time, but areas with low to medium broad-leaved cover show slightly higher medians and wider distributions than areas dominated by broad-leaved species (Fig. 50). In high broad-leaved cover landscapes (>75%), medians remain closer to <0.9 km even at longer windows, with fewer extreme values. This indicates that vegetation composition modifies movement potential, with less broad-leaved dominance facilitating greater spatial spread over.

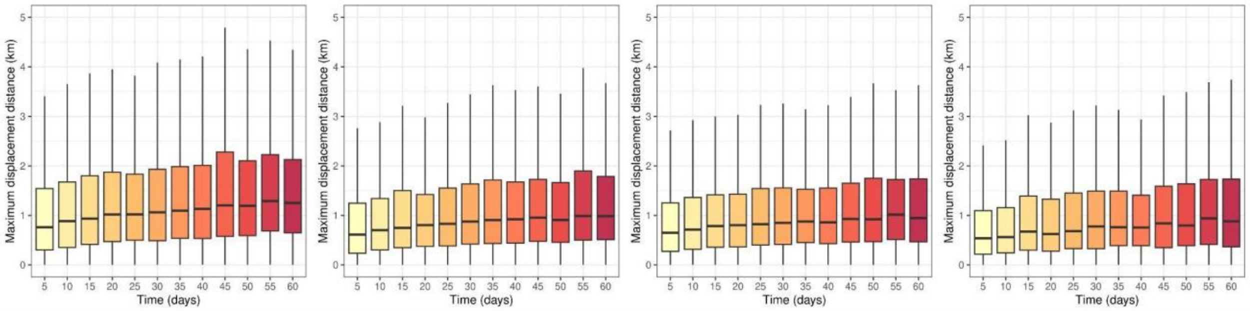


Fig. 51 - Distribution of maximum displacement distance, over different time windows, across a gradient of forest fragmentation. Expressed as the ratio between the perimeter and area of forest patches. From left to right: areas with a low (< 40), medium-low (40-65), medium-high (65-80) and high (> 80) ratio between the perimeter and area of forest patches.

Displacement increases with time across all fragmentation levels, but landscapes with low forest fragmentation show higher medians and greater upper extremes, while high-fragmentation landscapes showed slightly more constrained movements (Fig. 51). Fragmentation therefore curtails the overall time–displacement relationship, suggesting that patchy forest structures inhibit wider-ranging movements.

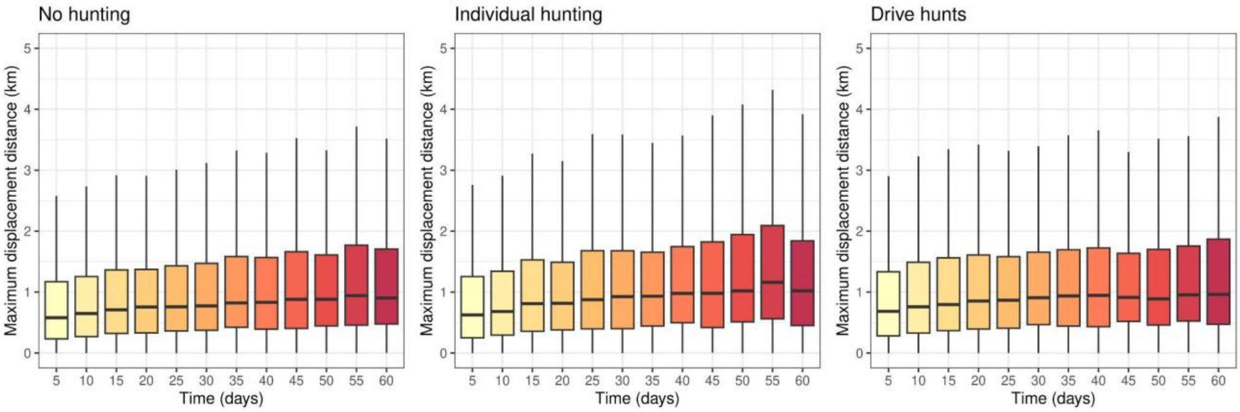


Fig. 52 - Distribution of maximum displacement distance, over different time windows, across different hunting modalities.

All hunting modalities show increasing displacement with time, but there was very little difference in changes of max displacement across windows of varying length (Fig. 52). This indicates that hunting disturbance has little effect on the baseline time–displacement relationship.

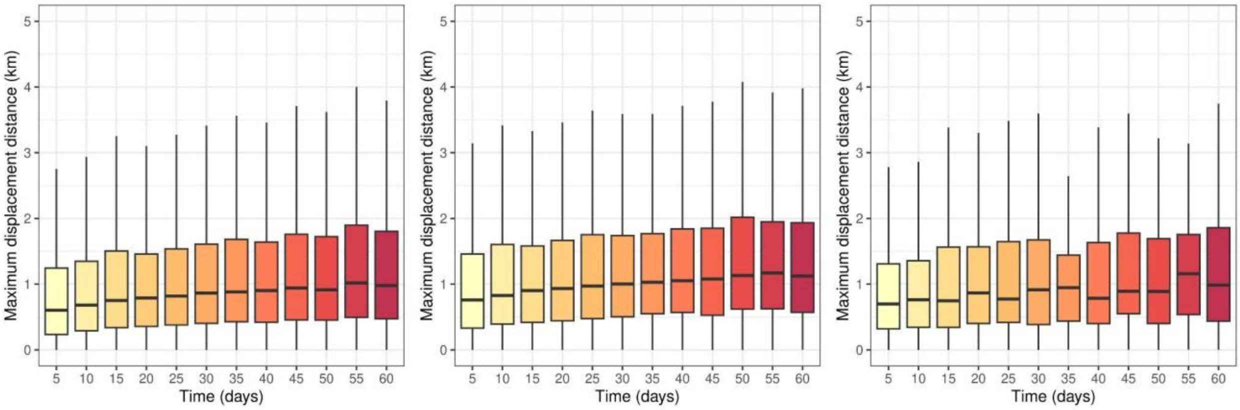


Fig. 53 - Distribution of maximum displacement distance, over different time windows, across a gradient of landscape anthropization, represented by the normalized Human Footprint Index. From left to right: areas with a low, intermediate and a high level of landscape anthropization.

Similarly to hunting modality, maximum displacement increases with time showed little variation across anthropization levels, with slightly higher medians and upper extremes in low anthropization areas (Fig. 53). This suggests that human-dominated landscapes can constrain movement, weakening the overall time–displacement relationship, whereas more natural landscapes allow broader spatial expansion over time.

4. Conclusion

This report provides the most comprehensive, standardised, pan-European synthesis to date of wild boar movement, social contact structure, and interaction with pig farms, derived from harmonised GPS-telemetry within the EUROBOAR framework (692 individuals; 54 study areas; 3.87 million GPS fixes).

Across 14-day windows, wild boar generally shows sedentary spatial behaviour, as evidenced by space use and movement metrics, which showed relatively low absolute values compared to movement capacity of the species, e.g. substantial cumulative travel distance. However, movement metrics showed large variation across the dataset indicating that some individuals displayed high movement rates and space coverage and thus represent disproportionately high risk of ASF spread across the landscape. Similarly, distributions of social contacts between group and wild boar-pig farm contacts were highly right-skewed (Fig. 7, 9), indicating low overall frequency of those contacts, with a small fraction of individuals or biweekly temporal windows showing high contact intensity. Additionally, variation in movement metrics and contact rates was structured by some influencing factors analysed in the report. Specifically, variation in movement and space use metrics was structured by time of the year, sex and age class, population density, forest cover and structure, and hunting modality. Contact rates between groups showed temporal variation and were influenced by sex and age class, and habitat structure, while within-group contacts were more stable and rather insensitive to influencing factors. Variation in contacts between wild boar and pig farms was structured by time of the year, sex/age class of wild boar, population density, habitat structure and level of landscape anthropization.

4.1. Movement metrics

Temporal factors

Movement and space use roughly matched the annual cycle of breeding, farrowing, and resource dynamics. The data showed a consistent seasonal signature with the smallest ranges and core areas during farrowing which expanded toward autumn and mating (Nov-Jan) when the largest ranges were observed. Distances travelled followed a similar seasonal pattern, rising from roughly 30-35 km/14 days during farrowing to 50–60 km in autumn/mating. Activity switched more towards nighttime during periods of intense movement (Sep-Jan). Net displacement remained comparatively stable across the year, with typical values around 1km/14 days, but with uptick in autumn and mating season, when greater variability and higher values (often >3-4 km), reflecting occasional longer excursions. Seasonal variation in movement metrics was sex-specific. While both sexes followed similar seasonal patterns, males consistently used larger ranges, travelled longer distances and showed more linear space use patterns, with the largest sex gap during mating season. These results are consistent with the annual cycle of wild boar life-history. Movement capacity of females is reduced during farrowing and early lactation and the resource use is more localized. During autumn, intense foraging for mast can elevate the movement rates, while mating-driven excursions of males result in high values observed in winter. Altogether, autumn and winter are the periods of increased movements, space use, and nocturnality, particularly among males, and the risk of spatial spread of ASF virus can be higher in this period.

Demographic factors

Males consistently use larger areas, travelled longer distances, and showed greater displacements, consistently 40-80% higher, than females and male variability peaks in the 6–12 month and, to lesser degree 12-24 months, age classes. Subadult males are expected to show higher movement rates due to natal dispersal and exploratory behaviour (Scandura et al., 2020). Females display smaller, more stable ranges consistent with matrilineal cohesion and energetic constraints around reproduction. The data also shows that intensity of space use tends to be higher in females (more clustered, repeated use of local space), whereas males -especially subadults - show more diffused space use, consistent with exploratory movements. From the perspective of wild boar management in ASF context, it may be useful to know that rare long-range movements (rather than median displacement), which could drive frontier of ASF spread, are displayed disproportionately by young males and some adult males during mating.

Increase in population density results in a clear pattern of decrease across movement and space use metrics. Intensity of space use increases at very high densities, indicating more clustered movements in constrained space. Population density can reflect habitat productivity and it is possible that what we observe here as the influence of density is in fact the effect of rich habitat (see section Ecological factors below), which can reduce the need for large home ranges due to abundant food resources. Contraction of movement at high population densities does not necessarily imply lower transmission risk as there may be a high contact opportunity, either with other individuals or infected carcasses, where population density is high. Instead, high densities may imply more localised spread potential and potentially stronger within-area persistence.

Ecological factors

Broad biogeographical regions did not yield strong, consistent separation in movement parameters, suggesting that the concept of "ecoregion" per se is too coarse to capture local productivity, hunting pressure, and landscape configuration effects that operate at finer scales.

Forest structure provided clearer behavioural signals: highest forest cover (>75%) was associated with smaller ranges and reduced travel, while highest values of movement metrics were observed at intermediate levels of forest cover (25-75%). Activity becomes less nocturnal as forest cover increases. Similar patterns were observed with increasing share of broad-leaved tree species, which is a proxy for the quality of wild boar habitat. Forested areas usually provide resources (food, shelter) which increase foraging opportunities and reduce perceived risk, allowing more daytime movement and shorter commutes. Conversely, open or mixed mosaics of forest-agricultural landscape can force longer commuting between foraging and resting patches. However, movement rates and space use tended to be reduced at high levels of forest fragmentation, suggesting that intermediate levels of forest cover and fragmentation promote the highest movement rates and widest ranging. Thus, field-woodland mosaic landscapes can pose higher risk for spatial transmission due to increased wild boar movements compared to continuously forested areas.

Anthropogenic factors

Disturbance from drive hunts had a clear anthropogenic influence on movement. Median home range increased from 2.01 km² (no hunting) to 2.19 km² (individual hunting) and 2.71 km² (drive hunts), with mean values increasing from 4.20 ± 9.43 to 4.89 ± 8.83 to 6.29 ± 16.61 km². Core area medians similarly expanded (0.41 → 0.50 → 0.57 km²), with the highest variability under drive hunts. Similar increase was observed in movement rates, with daily distance traveled and maximum displacement rising by 15% and 12% (median values) between no hunting and drive hunting periods, respectively. Nocturnality increased during time windows of 14 days, corresponding to times of the year when drive hunts were carried out, which could be explained by disturbance avoidance and higher movement rates. Repeated collective hunts induce escape movements, shifts in resting sites, and broader ranging (Sodeikat et al. 2003, Scillitani et al. 2009, Olejarz et al. 2024), effects consistent with disturbance ecology and the "risk allocation" hypothesis (Lima & Bednekoff 1999). Importantly, the maximum-displacement–time relationship (0–60 day windows) showed little change across hunting regimes, suggesting that hunting does not systematically generate longer net displacement over multi-week scales. In ASF control context, drive hunting periods represent a risk of animal dispersion and range expansion outside of their typical centers of activity.

Wild boar space use responded non-linearly to the level of landscape anthropization: median home range were smaller at low and high HFI (2.22 and 2.38 km²) than at intermediate HFI (3.03 km²), while distance travelled increased with HFI (median 44 → 51 → 54 km) without a corresponding increase in maximum displacement (median 0.92 → 1.11 → 0.96 km). Animals are least nocturnal at low HFI (median diurnality -0.49) and more nocturnal at intermediate/high HFI (-0.7/-0.64). Intensity of space use was markedly higher at high levels of anthropization, indicating constrained movements in human-dominated landscapes. The combination of more travel, smaller net displacement, and smaller ranges in human-dominated landscape suggests constrained and clustered movement (more tortuous routes, commute between patches of resources) compared to more natural forest-field mosaic. These results are also consistent with the influence of afforestation, where the highest movement and space use metrics were recorded at intermediate levels of afforestation.

4.2. Wild boar social contacts pattern

Temporal factors

As expected, the key difference between within- and between-group contacts was the intensity of contacts. Over 14 day-periods, within-group contact counts were high (often 100–250 contacts per dyad) with no strong seasonal trend, indicating stable cohesion of family groups. Between-group contacts were an order of magnitude lower (medians 1–5 contacts) but showed more pronounced seasonality, with higher medians (5–10) and occasional maxima of ~60–80 during late mating (January) and farrowing (Feb–Apr), then reduced medians (≤3) in summer and minima in autumn (maxima rarely >25). Winter mating can promote brief inter-group encounters driven by male movements (REF), while late winter–spring may increase overlap around key and scarce resources or refuge areas. Epidemiologically, the seasonal "spikes" in between-group contacts are disproportionately important because they represent high risk periods of increased transmission opportunities through direct contact across otherwise weakly connected social groups and potentially faster spread within a population.

Demographic factors

Dyad-based summaries show that within-group contacts were only weakly stratified by sex and age, which was expected under matrilineal group living where females maintain strong local cohesion (Podgórski et al. 2014a,b). In contrast, between-group contacts showed stronger demographic patterning: younger males and mixed dyads (most likely driven by outgroup males) tended to show higher values and variability, while the lowest values were observed among adult females, again consistent with the matrilineal social structure of the species. Young males in transitional life stages (i.e. dispersing from natal groups) can thus act as social bridges in the population, linking groups, and potentially enhance disease transmission through direct contacts.

Increasing density reduced within-group contact medians. However, the highest density class was represented by only 3 dyads, so this result should be interpreted with caution. Between-group contacts peaked at intermediate densities 3-7 ind./km² compared to either very low (< 3 ind./km^2) or very high densities (> 7 ind./km^2) (Appendix H). Evidence for density–contact relationships in mammals remains mixed and may depend on species-specific social structures and the range of densities studied (Ramsey et al. 2002; Sanchez & Hudgens 2015; Vander Wal et al. 2012, Podgórski et al. 2026). It is possible that contact rates scale non-linearly with population densities in wild boar owing to strong social structuring in this species (Podgórski et al. 2018). At higher densities, frequency of fission-fusion events between groups may increase, while stable dyadic associations within groups may decrease. From a practical perspective of disease management, the data shows increased risk of inter-group transmission at intermediate density levels. It also challenges common assumptions of more frequent contacts at higher population densities.

Ecological factors

Forest cover, composition and fragmentation had limited effects on within-group contacts but modulated between-group contacts. Levels of within-group contacts remained broadly stable across gradients of forest cover, proportion of broad-leaved tree species, and forest fragmentation classes. Between-group contacts showed higher averages, variability and maxima at intermediate levels of forest cover (25-75%), broad-leaved shares (25-50%) and fragmentation (Appendix H). Interestingly, this pattern aligns with elevated movement and space use metrics at intermediate levels of landscape structure which suggests that heterogeneous, edge-dense landscapes can increase both movements and inter-group encounters at shared foraging patches and habitat corridors. The absence of strong within-group effects suggests that social organisation is resilient to habitat variation, while inter-group contacts are more sensitive to habitat structure.

Anthropogenic factors

While the report indicates that drive hunting is associated with increased movement, the contact data was not stratified by hunting modality in a substantial way. Drive hunts can reduce within-group contacts and temporarily disrupt group cohesion (Podgórski et al. 2026). However, this effect was not observed here, possibly due to different (wider) dataset, different association index used, and no modelling which would account for confounding factors. Between-group contacts could be expected under drive hunts due to increasing spatial mixing. However, this pattern was observed neither here nor by Podgórski et al. 2026. Given that interactions between groups can play a particularly important role in pathogen transmission (Drewe 2010; VanderWaal et al. 2016), our results do not indicate that hunting disturbance facilitates the spread of directly transmissible diseases. However, elevated movements and increased ranging during drive hunting periods, which our data shows, can still pose a risk of ASF transmission into new areas.

Contact distributions overlapped broadly between classes of landscape anthropization both within- and between-groups (Appendix G, H), suggesting no strong effect of anthropization on overall contact rates in contrast to configuration of the natural habitat, e.g. forest cover.

4.3. Wild boar - pig farms contacts patterns

Temporal factors

Wild boar – pig farm contacts showed some temporal variation across the year. The number of contacts between wild boar and pig farms did not exceed a median of 10 contacts per boar/farm dyad across all 14-day periods but was strongly right-skewed (Fig. 18), with occasional high values (up to 131). The widest spread, highest extremes and averages were observed during the farrowing season (Feb-Apr) and summer (May-Aug) (Appendix I). Peaks of contact intensity concentrated in March–April and late August–early September, consistent with crop phenology, foraging-driven movements, and movement along edges. For ASF prevention, these patterns recommend seasonally intensified biosecurity measures and farm-perimeter surveillance during peak-risk time windows.

Demographic factors

Males generally showed higher farm contacts than females (Appendix I)). Adult males showed the highest frequency of contacts with pig farms of all sex/age classes. This could be, at least partly, explained by their high movement rates and wide ranging. Alternatively, high contact frequency with the farms could be driven by seeking mating opportunities, particularly around backyard and open-air holdings. Regardless of the mechanisms, risk mitigation should be focused on adult males' movements and presence.

Pig farm-wild boar contact frequency increased at high densities of wild boar population: low and medium densities (<5 individuals/km²) showed medians of 4 and 3 contacts/14 days, whereas high density (5–7 ind./km²) showed a median of 6 and roughly doubled mean contacts (12 vs 6), with the highest variability and maxima up to 131. This indicates that "tail risk" (i.e. rare high-contact windows) becomes more likely as local wild boar abundance rises, reinforcing the management value of population reduction, as well as reducing availability of food waste attracting wild boar, around high-consequence holdings.

Ecological factors

Wild boar-pig farm contacts peaked at intermediate forest contexts: at 50-75% forest cover, at 25–50% broad-leaved cover, and two medium forest fragmentation classes (Appendix I). These results point toward the potential effect of landscape structure, where mixed mosaics with edges and corridors connecting habitat patches facilitate movement between shelter and food (forest, crops), increasing the probability of wild boar coming into contact with the farm perimeter. The results are also in line with greater movement metrics and exploration potential at intermediate habitat structure. It is also plausible that pig farms are more accessible to wild boar, and thus more frequently visited, if they are embedded in the mosaic of woodlands and crop fields as compared to more open (which wild boar is less likely to roam through) or closed, i.e. forested landscapes (where pig holdings are unlikely to be located). While wild boar-pig farm contacts may simply be a by-product of a farm location in a certain habitat, farm biosecurity should be spatially prioritised not only by wild boar density but also by landscape configuration.

Anthropogenic factors

Hunting modality showed limited systematic impact on farm contacts with contact rates broadly similar across hunting regimes, suggesting that wild boar-farm proximity is driven more by landscape structure and population density than by short-term hunting disturbance. However, another explanation could be that hunting activity is restricted in the perimeter of the pig farms either by land and farm owners or by authorities, effectively discouraging hunters from performing hunts (particularly driven) in the farm vicinity. Nonetheless, because movement increases under drive hunts, disturbance could still shift where contacts occur (e.g., displacement into farmland edges) without markedly shifting the median count, another reason to interpret "no strong effect" cautiously and to move toward multivariable modelling.

Contact between wild boar and pig farms were twice as high at low anthropization levels, compared to intermediate and high Human Footprint Index (Appendix I). Again, it is plausible that farms located in rural areas with low HFI are more accessible to wild boar, while access to farms in human-dominated landscapes may be restricted by infrastructure. Regardless, farms within rural, more natural landscapes may be at higher risk of exposure to wild boar.

4.4. Temporal analysis of maximum displacement distance

The temporal analysis of maximum displacement distance shows only a limited increase in net spatial displacement with increasing observation window (from median of 0.6 km across 5 days to 1.1 km within across 60 days). Moreover, influencing factors analysed showed limited modulating effect on the maximum displacement distance across temporal observation windows. This highlights the sedentary nature of wild spatial behavior across various ecological conditions. However, in contrast to the stable medians, the upper tails of the distributions expanded with time. Upper values of the interquartile range varied between 3 km (in 0-10 days period) and 4 km (in 0-60 days periods). These patterns indicate that longer monitoring periods increase the likelihood of capturing infrequent larger displacement events while typical spatial displacement remains limited. These events likely correspond to dispersal movements, mating-related excursions of males, or disturbance-driven displacement, and they occurred in only a small proportion of individuals (Fig.

6). Extreme values of >10 km (with a maximum of 66km) were rare. Yet, these infrequent movements indicate a risk of long-distance movements by some individuals. Our results are consistent with a recent analysis based on a similar EUROBOAR dataset (Wielgus et al. 2025) which showed that probability of wild boar leaving an area with a radius of 1km varied from ~30% at 5 day window to ~75% at 50 days, while area with a radius 5km had a very low probability (<5%) of being left from throughout the 50 days' time window.

From a behavioural perspective, these findings confirm strong site fidelity in wild boar (Podgóski et al. 2014a), with most individuals remaining spatially constrained despite extensive cumulative movement, i.e. daily distance travelled. From an epidemiological viewpoint, the displacement distributions observed here suggest that most transmission occurs locally, but a small fraction of events enables longer-distance spread. This is consistent with spatial transmission kernels described for ASF, where most transmission events occur within 1.5 km, with some rare events at longer distances (Pepin et al. 2021). From a modelling perspective, this pattern supports the use of short-distance kernels (on the order of 1–2 km) to represent dominant local transmission processes, including within- and between-group spread and environmental contamination around carcasses.

5. Recommendations

Main highlights of this report are:

- **Wild boar spatial behaviour was predominantly sedentary**: median net displacement over 14-day windows was ~1 km, indicating strong site fidelity despite substantial cumulative travel distances, confirming strong site fidelity across most ecological contexts.
- **Movement and contact patterns were highly heterogeneous and right-skewed**, with a small proportion of individuals/time windows showing disproportionately high movement rates and contact intensity, representing “tail risk” for wider ASF spread.
- **Seasonal patterns were detected**, with the largest ranges, highest movement rates, and increased nocturnality during autumn-winter, highest between-group contacts during winter-spring, and highest wild boar-pig farm contacts in spring and late summer
- **Sex and age structured key risk-relevant behaviours**: males used larger areas and travelled more than females, showed greater inter-group connectivity, and more frequent contacts with pig farms. Elevated movement and between-group contact variability was most pronounced in subadult males, while interactions with pig farms were most frequent among adult males.
- **Landscape structure modulated movement and contact opportunities**, with intermediate forest cover and forest–agricultural mosaic landscapes associated with higher movement rates, inter-group contacts, and wild boar–pig farm interactions
- **Drive hunting was associated with increased ranging and movement and a shift towards greater nocturnality**, elevating the risk of short-term spatial displacement, even though it does not systematically increase long-term net displacement or direct contact rates.
- **Wild boar–pig farm contacts were generally infrequent but episodically high**, with peaks in March–April and late August–early September and higher contact frequency in adult males, at intermediate forest cover and fragmentation, and high wild boar density, supporting seasonally and spatially targeted biosecurity prioritisation.

Main recommendations:

- **Move from descriptive patterns to inference via statistical modelling.** The report explicitly presents patterns from raw data; next steps should apply hierarchical or mixed-effects modelling to isolate temporal, demographic, ecological, and anthropogenic effects while controlling confounders in order to deliver policy-grade inference beyond descriptive gradients.
- **Strengthen pig farm metadata.** Collect farm-level biosecurity and production system descriptors to convert proximity into an exposure/risk estimate.
- **Continue and broaden data collection.** Maintain and expand the EUROBOAR harmonised pipeline and continue data collection to reduce geographic and demographic gaps, strengthen representativeness, and improve transferability of inference and recommendations across Europe.
- **Operationalise seasonality.** Align surveillance and biosecurity reinforcement with periods of elevated movement, between-group connectivity and pig farm interactions.

- **Prioritise mitigation and surveillance around bridging and mobile cohorts** (especially subadult/adult males) during winter-spring when inter-group mixing and movement potential increase.
- **Integrate landscape configuration into farm-risk zoning,** enhanced fencing, perimeter management, and monitoring. Prioritise farms embedded in forest-fields mosaics, where typical contact levels and extremes are higher.

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Appendix A – Values of the home range size (km²) by influencing factors.

Factor	Class/Level	N.ind	Mean ± SD	Median	Range
Overall		692	5.24 ± 11.85	2.43	0.12-485.98
Hunting type	No hunting	380	4.2 ± 9.43	2.01	0.13 - 305.06
	Individual hunting	258	4.89 ± 8.83	2.19	0.12 - 91.02
	Drive hunts	280	6.29 ± 16.61	2.71	0.17 - 485.98
Biogeographical region	Alpine	8	5.45 ± 10.09	2.97	0.17 - 73.93
	Atlantic	20	5.79 ± 7.01	3.73	0.24 - 42.44
	Black Sea	3	4.52 ± 10.27	2.24	0.41 - 62.73
	Boreal	76	6.39 ± 12.18	2.69	0.13 - 254.12
	Continental	486	5.18 ± 12.26	2.47	0.12 - 485.98
	Mediterranean	75	4.08 ± 10.62	1.47	0.13 - 235.65
	Pannonian	24	3.32 ± 5.29	2.26	0.26 - 91.02
Forest fragmentation (ratio between the perimeter and area of forest patches)	Very low (< 40)	157	6.75 ± 11.08	3.29	0.13 - 120.18
	Low (40-65)	234	4.36 ± 9.25	2.15	0.12 - 254.12
	High (65-80)	219	4.75 ± 13.62	2.23	0.13 - 485.98
	Very high (> 80)	82	6.06 ± 15.28	2.08	0.13 - 305.06
% forest cover	Very low (0-25%)	125	5.98 ± 14.49	2.19	0.13 - 305.06
	Low (25-50%)	312	5.21 ± 8.51	2.84	0.15 - 120.18
	High (50-75%)	202	5.51 ± 14.61	2.24	0.13 - 485.98
	Very high (75%-100%)	53	2.54 ± 3.84	1.45	0.12 - 50.6

Home range size (km²) by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Range
% forest cover (broad-leaved species)	Very low (0-25%)	463	5.66 ± 13.37	2.48	0.13 - 485.98
	Low (25-50%)	208	4.46 ± 7.74	2.42	0.20 - 120.18
	High (50-75%)	21	3.15 ± 6.3	1.49	0.12 - 62.73
Wild boar density (individuals/km)	Very low (< 3 ind./km2)	102	6.5 ± 10.57	3.08	0.12 - 107.96
	Low (3 - 5 ind./km2)	329	5.54 ± 10.7	2.63	0.13 - 305.06
	High (5 - 7 ind./km2)	235	4.21 ± 9.48	1.98	0.15 - 254.12
	Very high (> 7 ind./km2)	26	5.59 ± 33.29	1.51	0.26 - 485.98
Human Footprint Index (0 to 100)	Low (< 35)	477	5.02 ± 12.29	2.22	0.12 - 485.98
	Intermediate (35 - 60)	188	6.03 ± 10.95	3.03	0.13 - 235.65
	High (> 60)	27	3.93 ± 5.19	2.38	0.18 - 42.44
Sex	Male	244	7.17 ± 12.35	3.39	0.12 - 235.65
	Female	448	4.3 ± 11.48	2.09	0.13 - 485.98
Age classes	0-12 months	107	7.74 ± 11.71	4.03	0.13 - 132.77
	12-24 months	193	4.88 ± 9.08	2.56	0.15 - 235.65
	>24 months	392	4.91 ± 12.72	2.15	0.12 - 485.98
Females age classes	0-12 months	52	5.28 ± 7.63	2.95	0.21 - 61.14
	12-24 months	103	3.97 ± 5.51	2.33	0.15 - 52.24
	>24 months	293	4.29 ± 12.93	1.95	0.13 - 485.98
Males age classes	0-12 months	55	9.63 ± 13.78	4.89	0.13 - 132.77
	12-24 months	90	5.97 ± 11.98	2.90	0.17 - 235.65
	>24 months	99	6.93 ± 11.8	3.13	0.12 - 120.18

Home range size (km²) by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Range
Season	Mating	432	6.54 ± 16.1	2.76	0.12 - 485.98
	Farrowing	389	4.82 ± 11.29	2.05	0.13 - 305.06
	Summer	507	4.26 ± 8.72	2.12	0.13 - 235.65
	Autumn	409	5.38 ± 8.54	2.92	0.13 - 120.18
Females during season	Mating	283	5.55 ± 17.1	2.44	0.15 - 485.98
	Farrowing	254	3.86 ± 11.72	1.79	0.13 - 305.06
	Summer	333	3.26 ± 5.34	1.83	0.14 - 77.13
	Autumn	274	4.64 ± 6.94	2.62	0.13 - 91.02
Males during season	Mating	149	8.61 ± 13.56	4.03	0.12 - 132.77
	Farrowing	135	6.61 ± 10.22	2.88	0.14 - 73.93
	Summer	174	6.31 ± 12.88	3.04	0.13 - 235.65
	Autumn	135	7.06 ± 11.21	3.79	0.23 - 120.18

Appendix B – Values of the Core area (km²) by influencing factors.

Factor	Class/Level	N	Mean ± SD	Median	Range
Overall		692	1.43 ± 4.57	0.50	0.06-239.26
Hunting type	No hunting	380	1.09 ± 3.09	0.41	0.06 - 82.39
	Individual hunting	258	1.42 ± 3.24	0.50	0.06 - 43.97
	Drive hunts	280	1.74 ± 6.89	0.57	0.06 - 239.26
Biogeographical region	Alpine	8	1.44 ± 2.25	0.56	0.06 - 10.25
	Atlantic	20	1.83 ± 2.83	0.91	0.06 - 16.80
	Black Sea	3	1.07 ± 2.92	0.49	0.16 - 17.94
	Boreal	76	1.86 ± 4.81	0.57	0.06 - 84.91
	Continental	486	1.4 ± 4.79	0.51	0.06 - 239.26
	Mediterranean	75	1.02 ± 3.5	0.36	0.06 - 80.7
	Pannonian	24	0.79 ± 0.9	0.49	0.06 - 6.70
Forest fragmentation (ratio between the perimeter and area of forest patches)	Very low (< 40)	157	1.87 ± 4.41	0.67	0.06 - 76.44
	Low (40-65)	234	1.17 ± 3.23	0.45	0.06 - 84.91
	High (65-80)	219	1.33 ± 5.86	0.46	0.06 - 239.26
	Very high (> 80)	82	1.57 ± 4.29	0.46	0.06 - 82.39
% forest cover	Very low (0-25%)	125	1.65 ± 5.22	0.44	0.06 - 84.49
	Low (25-50%)	312	1.30 ± 2.81	0.59	0.06 - 51.65
	High (50-75%)	202	1.63 ± 6.11	0.50	0.06 - 239.26
	Very high (75%-100%)	53	0.71 ± 1.38	0.33	0.06 - 19.10

Core area size (km²) by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Range
% forest cover (broad-leaved species)	Very low (0-25%)	463	1.59 ± 5.26	0.50	0.06 - 239.26
	Low (25-50%)	208	1.11 ± 2.56	0.52	0.06 - 51.65
	High (50-75%)	21	0.84 ± 2.03	0.38	0.06 - 19.10
Wild boar density (individuals/km)	Very low (< 3 ind./km^2)	102	1.89 ± 4.50	0.63	0.06 - 76.44
	Low (3 - 5 ind./km^2)	329	1.47 ± 3.62	0.54	0.06 - 84.49
	High (5 - 7 ind./km^2)	235	1.10 ± 3.24	0.42	0.06 - 84.91
	Very high (> 7 ind./km^2)	26	1.90 ± 14.87	0.35	0.06 - 239.26
Human Footprint Index (0 to 100)	Low (< 35)	477	1.38 ± 4.80	0.48	0.06 - 239.26
	Intermediate (35 - 60)	188	1.63 ± 4.04	0.59	0.06 - 84.49
	High (> 60)	27	1.01 ± 1.87	0.47	0.07 - 16.80
Sex	Male	244	1.98 ± 4.81	0.67	0.06 - 84.49
	Female	448	1.16 ± 4.42	0.44	0.06 - 239.26
Age classes	0-12 months	107	2.24 ± 4.63	0.88	0.06 - 84.49
	12-24 months	193	1.24 ± 3.11	0.51	0.06 - 80.70
	>24 months	392	1.35 ± 4.98	0.46	0.06 - 239.26
Females age classes	0-12 months	52	1.55 ± 2.53	0.68	0.06 - 19.15

	12-24 months	103	1.01 ± 1.90	0.50	0.06 - 21.29
	>24 months	293	1.16 ± 5.02	0.41	0.06 - 239.26

Core area size (km^{2}) by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Range
Males age classes	0-12 months	55	2.77 ± 5.69	1.05	0.06 - 84.49
	12-24 months	90	1.52 ± 4.12	0.52	0.06 - 80.70
	>24 months	99	1.97 ± 4.81	0.65	0.06 - 55.98
Season	Mating	432	1.84 ± 6.67	0.58	0.06 - 239.26
	Farrowing	389	1.35 ± 3.81	0.44	0.06 - 82.39
	Summer	507	1.15 ± 3.16	0.45	0.06 - 80.70
	Autumn	409	1.38 ± 2.93	0.60	0.06 - 51.65
Females during season	Mating	283	1.57 ± 7.19	0.51	0.06 - 239.26
	Farrowing	254	1.03 ± 3.49	0.37	0.06 - 82.39
Females during season - *continued*	Summer	333	0.86 ± 1.66	0.41	0.06 - 23.25
	Autumn	274	1.19 ± 2.25	0.54	0.06 - 27.21
Males during season	Mating	149	2.39 ± 5.39	0.84	0.06 - 84.49
	Farrowing	135	1.93 ± 4.29	0.58	0.06 - 48.37
	Summer	174	1.74 ± 4.91	0.57	0.06 - 80.70

	Autumn	135	1.81 ± 4.05	0.72	0.06 - 51.65

Appendix C – Values of the distance travelled (km) by influencing factors.

Factor	Class/Level	N	Mean ± SD	Median	Range
Overall		692	48.98 ± 21.45	46.17	4.02-195.56
Hunting type	No hunting	380	46.61 ± 21.15	43.46	5.22 - 195.56
	Individual hunting	258	48.23 ± 19.77	45.59	4.02 - 139.65
	Drive hunts	280	53.44 ± 22.66	50.48	9.06 - 178.52
Biogeographical region	Alpine	8	40.46 ± 21.91	38.31	4.51 - 114.85
	Atlantic	20	53.87 ± 25.7	54.85	8.27 - 142.30
	Black Sea	3	42.9 ± 17.77	42.39	17.3 - 89.43
	Boreal	76	52.74 ± 20.36	48.92	5.53 - 154.16
	Continental	486	48.3 ± 21.56	45.31	4.02 - 195.56
	Mediterranean	75	47.12 ± 23.55	42.94	5.16 - 178.52
	Pannonian	24	47.84 ± 16.37	46.73	12.95 - 121
Forest fragmentation (ratio between the perimeter and area of forest patches)	Very low (< 40)	157	55.28 ± 23.19	52.04	5.53 - 149.59
	Low (40-65)	234	45.01 ± 19.33	43.23	4.02 - 178.52
	High (65-80)	219	48.25 ± 20.45	45.39	5.22 - 173.48
	Very high (> 80)	82	49.17 ± 23.32	46.11	6.39 - 195.56

Distance travelled (km) by influencing factors - continued					
Factor	**Class/Level**	**N**	**Mean ± SD**	**Median**	**Range**
% forest cover	Very low (0-25%)	125	50.09 ± 23.13	46.96	6.39 - 195.56
	Low (25-50%)	312	51.54 ± 22.16	49.29	4.51 - 178.52
	High (50-75%)	202	47.25 ± 19.95	44.27	4.02 - 154.16
	Very high (75%-100%)	53	40.36 ± 16.62	37.80	7.70 - 110.61
% forest cover (broad-leaved species)	Very low (0-25%)	463	49.48 ± 21.28	46.72	4.02 - 195.56
	Low (25-50%)	208	49.15 ± 21.85	46.25	5.16 - 178.52
	High (50-75%)	21	35.12 ± 15.98	31.41	7.70 - 90.81
Wild boar density (individuals/km)	Very low (< 3 ind./km^2)	102	52.09 ± 21.03	49.31	5.53 - 139.65
	Low (3 - 5 ind./km^2)	329	51.23 ± 21.86	49.25	4.02 - 195.56
	High (5 - 7 ind./km^2)	235	45.18 ± 20.73	42.00	5.16 - 178.52
	Very high (> 7 ind./km^2)	26	44.76 ± 19.48	42.20	7.05 - 145.28
Human Footprint Index (0 to 100)	Low (< 35)	477	47.39 ± 21.12	44.28	4.02 - 195.56
	Intermediate (35 - 60)	188	53 ± 21.92	51.47	5.22 - 173.48
	High (> 60)	27	55.83 ± 20.03	54.32	17.15 - 142.3
Sex	Male	244	52.39 ± 23.13	49.63	4.51 - 178.52
	Female	448	47.32 ± 20.37	44.65	4.02 - 195.56

Distance travelled (km) by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Range
Age classes	0-12 months	107	52.02 ± 23.21	50.68	6.39 - 173.48
	12-24 months	193	49.46 ± 20.87	47.51	4.02 - 144.93
	>24 months	392	48.24 ± 21.27	45.01	5.22 - 195.56
Females age classes	0-12 months	52	46.14 ± 18.16	45.61	8.27 - 92.79
	12-24 months	103	47.59 ± 20.39	45.10	4.02 - 130.06
	>24 months	293	47.37 ± 20.59	44.48	5.53 - 195.56
Males age classes	0-12 months	55	56.54 ± 25.56	53.31	6.39 - 173.48
	12-24 months	90	51.72 ± 21.23	50.55	4.51 - 144.93
	>24 months	99	51.05 ± 23.12	46.79	5.22 - 178.52
Season	Mating	432	51.1 ± 22.5	48.10	6.50 - 177.43
	Farrowing	389	43.38 ± 20.42	40.05	4.51 - 195.56
	Summer	507	46.48 ± 18.97	44.10	4.02 - 144.93
	Autumn	409	56.57 ± 22.61	55.45	5.16 - 142.30
Females during season	Mating	283	48.72 ± 20.34	46.43	7.51 - 154.16
	Farrowing	254	40.38 ± 17.22	38.38	5.53 - 195.56
	Summer	333	45.20 ± 18.58	43.10	4.02 - 123.36

	Autumn	274	56.28 ± 23.02	55.22	5.16 - 139.65

Distance travelled (km) by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Range
Males during season	Mating	149	56.05 ± 25.74	51.95	6.50 - 177.43
	Farrowing	135	48.96 ± 24.37	43.63	4.51 - 178.52
	Summer	174	49.05 ± 19.48	47.03	5.22 - 144.93
	Autumn	135	57.25 ± 21.67	56.02	8.18 - 142.30

Appendix D – Values of the Maximum displacement distance by influencing factors.

Factor	Class/Level	N	Mean ± SD	Median	Maximum
Overall		692	1.59 ± 2.30	0.97	66.62
Hunting type	No hunting	380	1.45 ± 1.97	0.86	30.21
	Individual hunting	258	1.64 ± 2.53	0.97	23.27
	Drive hunts	280	1.68 ± 2.73	0.98	66.62
Biogeographical region	Alpine	8	1.56 ± 1.55	1.05	7.68
	Atlantic	20	1.69 ± 1.59	1.26	12.01
	Black Sea	3	1.82 ± 3.86	0.69	17.60
	Boreal	76	1.7 ± 2.5	1.01	34.74
	Continental	486	1.61 ± 2.32	0.99	66.62
	Mediterranean	75	1.39 ± 1.99	0.75	30.38
	Pannonian	24	1.24 ± 1.29	0.92	14.99
Forest fragmentation (ratio between the perimeter and area of forest patches)	Very low (< 40)	157	1.86 ± 2.36	1.17	26.08
	Low (40-65)	234	1.46 ± 2.18	0.88	34.74
	High (65-80)	219	1.43 ± 2.21	0.94	66.62
	Very high (> 80)	82	1.95 ± 2.72	1.02	18.39

Maximum displacement distance by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
% forest cover	Very low (0-25%)	125	1.81 ± 2.46	0.99	30.38
	Low (25-50%)	312	1.57 ± 1.91	1.06	30.21
	High (50-75%)	202	1.63 ± 2.72	0.97	66.62
	Very high (75%-100%)	53	1.08 ± 1.52	0.67	20.82
% forest cover (broad-leaved species)	Very low (0-25%)	463	1.68 ± 2.54	1.00	66.62
	Low (25-50%)	208	1.4 ± 1.54	0.97	18.28
	High (50-75%)	21	1.45 ± 2.52	0.76	20.82
Wild boar density (individuals/km)	Very low (< 3 ind./km^2)	102	1.79 ± 2.39	1.12	26.08
	Low (3 - 5 ind./km^2)	329	1.74 ± 2.28	1.06	21.48
	High (5 - 7 ind./km^2)	235	1.35 ± 1.91	0.86	34.74
	Very high (> 7 ind./km^2)	26	1.33 ± 4.41	0.72	66.62
Human Footprint Index (0 to 100)	Low (< 35)	477	1.57 ± 2.38	0.92	66.62
	Intermediate (35 - 60)	188	1.69 ± 2.1	1.11	30.38
	High (> 60)	27	1.34 ± 1.36	0.96	12.01
Sex	Male	244	1.95 ± 2.49	1.24	30.38
	Female	448	1.42 ± 2.17	0.86	66.62

Maximum displacement distance by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
Age classes	0-12 months	107	2.11 ± 2.51	1.33	21.22
	12-24 months	193	1.61 ± 2.18	1.01	30.38
	>24 months	392	1.49 ± 2.28	0.90	66.62
Females age classes	0-12 months	52	1.66 ± 1.9	1.05	14.31
	12-24 months	103	1.44 ± 1.95	0.95	21.48
	>24 months	293	1.39 ± 2.25	0.82	66.62
Males age classes	0-12 months	55	2.46 ± 2.85	1.57	21.22
	12-24 months	90	1.83 ± 2.41	1.15	30.38
	>24 months	99	1.81 ± 2.35	1.18	30.21
Season	Mating	432	1.76 ± 2.69	1.04	66.62
	Farrowing	389	1.55 ± 2.18	0.93	21.48
	Summer	507	1.48 ± 2.08	0.89	30.38
	Autumn	409	1.59 ± 2.05	1.02	30.21
Females during season	Mating	283	1.63 ± 2.79	0.93	66.62
	Farrowing	254	1.35 ± 2.09	0.84	21.48
	Summer	333	1.28 ± 1.83	0.79	23.27
	Autumn	274	1.4 ± 1.59	0.94	18.38

Maximum displacement distance by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
Males during season	Mating	149	2.02 ± 2.45	1.29	23.44
	Farrowing	135	1.91 ± 2.32	1.18	20.54
	Summer	174	1.87 ± 2.48	1.22	30.38
	Autumn	135	2.04 ± 2.8	1.34	30.21

Appendix E – Values of the diurnality index by influencing factors.

Factor	Class/Level	N	Mean ± SD	Median	Range
Overall		692	-0.48 ± 0.33	-0.57	-0.98-0.89
Hunting type	No hunting	380	-0.43 ± 0.36	-0.52	-0.94 - 0.89
	Individual hunting	258	-0.46 ± 0.35	-0.56	-0.97 - 0.78
	Drive hunts	280	-0.51 ± 0.28	-0.57	-0.97 - 0.64
Biogeographical region	Alpine	8	-0.29 ± 0.24	-0.30	-0.71 - 0.38
	Atlantic	20	-0.58 ± 0.19	-0.62	-0.9 - 0.02
	Black Sea	3	-0.09 ± 0.3	-0.11	-0.56 - 0.43
	Boreal	76	-0.35 ± 0.31	-0.41	-0.9 - 0.75
	Continental	486	-0.53 ± 0.31	-0.62	-0.98 - 0.89
	Mediterranean	75	-0.41 ± 0.37	-0.53	-0.95 - 0.8
	Pannonian	24	-0.43 ± 0.35	-0.49	-0.96 - 0.64
Forest fragmentation (ratio between the perimeter and area of forest patches)	Very low (< 40)	157	-0.51 ± 0.28	-0.56	-0.97 - 0.75
	Low (40-65)	234	-0.42 ± 0.34	-0.50	-0.98 - 0.89
	High (65-80)	219	-0.54 ± 0.31	-0.64	-0.97 - 0.81
	Very high (> 80)	82	-0.45 ± 0.39	-0.57	-0.96 - 0.8

Diurnality index by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
% forest cover	Very low (0-25%)	125	-0.53 ± 0.34	-0.64	-0.97 - 0.8
	Low (25-50%)	312	-0.59 ± 0.26	-0.65	-0.98 - 0.8
	High (50-75%)	202	-0.37 ± 0.32	-0.43	-0.95 - 0.75
	Very high (75%-100%)	53	-0.31 ± 0.39	-0.40	-0.91 - 0.89
% forest cover (broad-leaved species)	Very low (0-25%)	463	-0.49 ± 0.31	-0.57	-0.97 - 0.8
	Low (25-50%)	208	-0.49 ± 0.32	-0.57	-0.98 - 0.81
	High (50-75%)	21	-0.15 ± 0.46	-0.22	-0.91 - 0.89
Wild boar density (individuals/km)	Very low (< 3 ind./km^2)	102	-0.42 ± 0.33	-0.49	-0.96 - 0.89
	Low (3 - 5 ind./km^2)	329	-0.56 ± 0.3	-0.65	-0.97 - 0.8
	High (5 - 7 ind./km^2)	235	-0.42 ± 0.34	-0.50	-0.98 - 0.81
	Very high (> 7 ind./km^2)	26	-0.51 ± 0.22	-0.56	-0.85 - 0.31
Human Footprint Index (0 to 100)	Low (< 35)	477	-0.42 ± 0.34	-0.49	-0.98 - 0.89
	Intermediate (35 - 60)	188	-0.66 ± 0.2	-0.70	-0.97 - 0.59
	High (> 60)	27	-0.62 ± 0.15	-0.64	-0.88 - -0.08

Diurnality index by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
Sex	Male	244	-0.57 ± 0.28	-0.64	-0.97 - 0.87
	Female	448	-0.44 ± 0.34	-0.52	-0.98 - 0.89
Age classes	0-12 months	107	-0.62 ± 0.22	-0.68	-0.96 - 0.37
	12-24 months	193	-0.55 ± 0.3	-0.63	-0.98 - 0.8
	>24 months	392	-0.43 ± 0.34	-0.51	-0.97 - 0.89
Females age classes	0-12 months	52	-0.6 ± 0.24	-0.67	-0.96 - 0.37
	12-24 months	103	-0.53 ± 0.3	-0.60	-0.98 - 0.8
	>24 months	293	-0.4 ± 0.35	-0.47	-0.97 - 0.89
Males age classes	0-12 months	55	-0.64 ± 0.21	-0.69	-0.93 - 0.24
	12-24 months	90	-0.58 ± 0.28	-0.66	-0.97 - 0.79
	>24 months	99	-0.53 ± 0.3	-0.61	-0.95 - 0.87
Season	Mating	432	-0.49 ± 0.3	-0.55	-0.97 - 0.72
	Farrowing	389	-0.44 ± 0.34	-0.51	-0.97 - 0.89
	Summer	507	-0.45 ± 0.34	-0.55	-0.98 - 0.81

	Autumn	409	-0.59 ± 0.29	-0.67	-0.97 - 0.8

Diurnality index by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
Females during season	Mating	283	-0.47 ± 0.3	-0.51	-0.97 - 0.72
	Farrowing	254	-0.4 ± 0.34	-0.47	-0.97 - 0.89
	Summer	333	-0.37 ± 0.37	-0.47	-0.98 - 0.81
	Autumn	274	-0.56 ± 0.31	-0.65	-0.96 - 0.8
Males during season	Mating	149	-0.53 ± 0.31	-0.62	-0.95 - 0.64
	Farrowing	135	-0.5 ± 0.33	-0.58	-0.95 - 0.87
	Summer	174	-0.6 ± 0.23	-0.65	-0.95 - 0.43
	Autumn	135	-0.65 ± 0.23	-0.72	-0.97 - 0.57

Appendix F – Values of the intensity of space use by influencing factors.

Factor	Class/Level	N	Mean ± SD	Median	Range
Overall		692	24.65 ± 9.59	23.48	3.88-77.2
Hunting type	No hunting	380	25.55 ± 9.98	24.55	3.88 - 77.2
	Individual hunting	258	25.44 ± 9.83	24.21	4.61 - 68.24
	Drive hunts	280	24.68 ± 9.19	23.64	5.37 - 74.99
Biogeographical region	Alpine	8	20.9 ± 11.71	16.96	6.67 - 55.42
	Atlantic	20	23.53 ± 10.27	21.84	5.67 - 53.38
	Black Sea	3	23.66 ± 9.44	21.97	7.72 - 47.47
	Boreal	76	24.5 ± 8.87	23.91	4.64 - 74.99
	Continental	486	24.23 ± 9.56	22.89	3.88 - 77.2
	Mediterranean	75	28.44 ± 10.88	27.64	4.38 - 65.88
	Pannonian	24	25.46 ± 8.05	25.00	9.01 - 54.3
Forest fragmentation (ratio between the perimeter and area of forest patches)	Very low (< 40)	157	24.12 ± 9.59	23.01	4.64 - 77.2
	Low (40-65)	234	24.07 ± 9.37	22.86	4.38 - 74.99
	High (65-80)	219	25.4 ± 9.38	24.38	3.88 - 68.24
	Very high (> 80)	82	25.74 ± 10.82	24.03	5.52 - 74.38

Intensity of space use by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
% forest cover	Very low (0-25%)	125	26.36 ± 11.53	24.56	5.52 - 74.38
	Low (25-50%)	312	24.31 ± 9.29	23.09	3.88 - 77.2
	High (50-75%)	202	23.79 ± 8.66	23.02	4.61 - 74.99
	Very high (75%-100%)	53	26.44 ± 9.69	25.18	5.07 - 65.05
% forest cover (broad-leaved species)	Very low (0-25%)	463	24.73 ± 9.88	23.61	3.88 - 74.99
	Low (25-50%)	208	24.72 ± 9.03	23.50	5.45 - 77.2
	High (50-75%)	21	22.06 ± 7.83	20.96	5.07 - 47.47
Wild boar density (individuals/km)	Very low (< 3 ind./km^2)	102	23.27 ± 8.79	22.40	4.64 - 74.1
	Low (3 - 5 ind./km^2)	329	24.89 ± 9.83	23.74	3.88 - 74.38
	High (5 - 7 ind./km^2)	235	24.77 ± 9.63	23.35	4.38 - 77.2
	Very high (> 7 ind./km^2)	26	28.01 ± 9.42	28.09	6.48 - 56.94
Human Footprint Index (0 to 100)	Low (< 35)	477	24.45 ± 9.39	23.33	4.61 - 77.2
	Intermediate (35 - 60)	188	24.75 ± 9.79	23.48	3.88 - 68.24
	High (> 60)	27	29.18 ± 12.01	27.13	6.77 - 74.1

Intensity of space use by influencing factors - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
Sex	Male	244	22.67 ± 8.85	21.57	3.88 - 72.84
	Female	448	25.62 ± 9.79	24.50	4.64 - 77.2
Age classes	0-12 months	107	21.49 ± 8.78	20.18	4.61 - 65.67
	12-24 months	193	24.84 ± 9.79	23.60	3.88 - 74.1
	>24 months	392	25.16 ± 9.55	24.02	4.64 - 77.2
Females age classes	0-12 months	52	23.01 ± 10.14	21.63	5.67 - 59.91
	12-24 months	103	25.15 ± 9.78	23.70	6.03 - 74.1
	>24 months	293	26.02 ± 9.72	24.99	4.64 - 77.2
Males age classes	0-12 months	55	20.31 ± 7.37	19.64	4.61 - 65.67
	12-24 months	90	24.47 ± 9.8	23.53	3.88 - 72.84
	>24 months	99	22.41 ± 8.44	21.17	5.07 - 59.88
Season	Mating	432	23.58 ± 9.02	22.62	4.61 - 68.24
	Farrowing	389	23.06 ± 9	22.00	4.64 - 77.2
	Summer	507	25.49 ± 9.74	24.37	5.07 - 74.1
	Autumn	409	26.67 ± 10.36	25.37	3.88 - 74.99

Intensity of space use by influencing factors - continued					
Factor	**Class/Level**	**N**	**Mean ± SD**	**Median**	**Maximum**
Females during season	Mating	283	24.32 ± 9.06	23.44	5.37 - 68.24
	Farrowing	254	23.44 ± 8.96	22.27	4.64 - 77.2
	Summer	333	26.79 ± 9.92	25.83	5.36 - 74.1
	Autumn	274	27.91 ± 10.75	26.31	5.02 - 74.99
Males during season	Mating	149	22.04 ± 8.76	20.62	4.61 - 65.67
	Farrowing	135	22.35 ± 9.05	21.44	5.45 - 59.88
	Summer	174	22.85 ± 8.78	21.81	5.07 - 72.84
	Autumn	135	23.83 ± 8.78	22.91	3.88 - 72.76

Appendix G – Values of contact rates within groups

Factor	Class/Level	N	Mean ± SD	Median	Range
Overall		124	162.06 ± 91.16	169	1 -347
Hunting type	No hunting	65	152.29 ± 90.52	162	1 - 331
	Individual hunting	59	170.22 ± 84.47	182	1 - 330
	Drive hunts	28	163.38 ± 94.20	171	1 - 302
Biogeographical region	Boreal	3	183.9 ± 109.51	245	2 - 298
	Continental	119	160.16 ± 90.15	166	1 - 347
	Pannonian	2	233.38 ± 76.38	259	2 - 303
Forest fragmentation (ratio between the perimeter and area of forest patches)	Very low (< 40)	41	173.33 ± 88.61	183	1 - 331
	Low (40-65)	40	158.67 ± 89.66	166	1 - 347
	High (65-80)	34	157.96 ± 93.31	162	1 - 334
	Very high (> 80)	9	145.8 ± 99.52	157	1 - 317
% forest cover	Very low (0-25%)	11	196.44 ± 102.84	222	1 - 334
	Low (25-50%)	86	156.59 ± 88.72	163	1 - 347
	High (50-75%)	25	173.48 ± 93.84	198	1 - 330
	Very high (75%-100%)	2	145.86 ± 78.94	148	6 - 234

Values of contact rates within groups - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
% forest cover (broad-leaved species)	Very low (0-25%)	58	151.89 ± 88.94	162	1 - 330
	Low (25-50%)	36	173.87 ± 88.00	182	1 - 331
Wild boar density (individuals/km2)	Very low (< 3 ind./km^2)	8	190.00 ± 100.23	229	2 - 302
	Low (3 - 5 ind./km^2)	94	164.99 ± 90.10	171	1 - 334
	High (5 - 7 ind./km^2)	19	153.76 ± 90.90	155	1 - 347
	Very high (> 7 ind./km^2)	3	87.50 ± 83.86	58	2 - 234
Human Footprint Index (0 to 100)	Low (< 35)	88	165.04 ± 90.18	173	1 - 347
	Intermediate (35 - 60)	36	154.76 ± 93.23	158	1 - 334
Sex	Male	35	154.57 ± 87.68	156	1 - 330
	Female	89	164.41 ± 92.13	172	1 - 347
Age classes	0-12 months	37	162.71 ± 86.34	169	1 - 330
	12-24 months	49	166.69 ± 93.12	174	1 - 347
	>24 months	38	154.40 ± 92.73	161	1 - 334
Females age classes	0-12 months	17	156.01 ± 86.35	165	2 - 311
	12-24 months	36	173.27 ± 92.31	184	1 - 347
	>24 months	36	155.47 ± 93.12	161	1 - 334

Values of contact rates within groups - continued

Factor	Class/Level	N	Mean ± SD	Median	Range
Males age classes	0-12 months	20	166.59 ± 86.27	171	1 - 330
	12-24 months	13	113.02 ± 82.26	103	2 - 263
	>24 months	2	108.11 ± 60.69	92	44 - 211
Season	Mating	71	160.37 ± 95.28	163	1 - 347
	Farrowing	60	171.34 ± 103.15	188	1 - 332
	Summer	77	162.26 ± 85.57	172	1 - 333
	Autumn	41	154.60 ± 81.83	162	1 - 327
Females during season	Mating	51	167.17 ± 95.02	170	1 - 347
	Farrowing	42	156.68 ± 106.50	158	1 - 332
	Summer	59	166.76 ± 86.97	180	1 - 333
	Autumn	33	160.13 ± 84.84	169	1 - 327
Males during season	Mating	20	141.15 ± 93.78	129	1 - 330
	Farrowing	18	204.90 ± 86.78	230	22 - 328
	Summer	18	146.01 ± 78.51	157	2 - 291
	Autumn	8	127.88 ± 59.47	117	2 - 243

Appendix H – Values of contact rates between groups

Factor	Class/Level	N	Mean ± SD	Median	Range
Overall		245	18.72 ± 39.85	4	1 -307
Hunting type	No hunting	125	14.64 ± 31.05	3	1 - 240
	Individual hunting	95	18.21 ± 39.53	3	1 - 307
	Drive hunts	76	9.35 ± 18.95	3	1 - 197
Biogeographical region	Alpine	2	6.50 ± 2.12	6	5 - 8
	Atlantic	3	6.67 ± 8.96	2	1 - 17
	Black Sea	1	2.00 ± 1.41	1	1 - 4
	Boreal	36	11.41 ± 24.83	3	1 - 197
	Continental	186	20.93 ± 42.86	4	1 - 307
	Mediterranean	13	4.94 ± 5.81	2	1 - 35
	Pannonian	4	3.88 ± 3.71	2	1 - 12
Forest fragmentation (ratio between the perimeter and area of forest patches)	Very low (< 40)	64	9.04 ± 16.86	2	1 - 108
	Low (40-65)	76	28.94 ± 52.84	7	1 - 268
	High (65-80)	86	15.93 ± 33.29	3	1 - 307
	Very high (> 80)	19	18.52 ± 46.93	3	1 - 229

Values of contact rates between groups - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
% forest cover	Very low (0-25%)	43	10.6 ± 18.41	3	1 - 144
	Low (25-50%)	130	22.46 ± 45.38	4	1 - 307
	High (50-75%)	60	15.23 ± 36.6	3	1 - 268
	Very high (75%-100%)	12	15.3 ± 23.79	5	1 - 110
% forest cover (broad-leaved species)	Very low (0-25%)	169	16.27 ± 35.96	3	1 - 307
	Low (25-50%)	75	22.94 ± 45.45	5	1 - 268
	High (50-75%)	1	2 ± 1.41	1	1 - 4
Wild boar density (individuals/km 2)	Very low (< 3 ind./km^2)	28	5.88 ± 10.87	2	1 - 75
	Low (3 - 5 ind./km^2)	152	16.21 ± 35.31	3	1 - 307
	High (5 - 7 ind./km^2)	55	27.61 ± 51.15	7	1 - 268
	Very high (> 7 ind./km^2)	10	14.73 ± 26.55	3	1 - 110
Human Footprint Index (0 to 100)	Low (< 35)	157	19.4 ± 41.23	4	1 - 268
	Intermediate (35 - 60)	86	17.66 ± 37.56	4	1 - 307
	High (> 60)	2	1.5 ± 0.71	1	1 - 2

Values of contact rates between groups - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
Sex	Male	74	17.78 ± 33.07	5	1 - 248
	Female	171	19.17 ± 42.74	3	1 - 307
Age classes	0-12 months	40	24.16 ± 46.04	5	1 - 248
	12-24 months	77	19.85 ± 43.15	3	1 - 268
	>24 months	128	16.17 ± 34.77	4	1 - 307
Females age classes	0-12 months	21	23.75 ± 50.52	3	1 - 229
	12-24 months	46	25.96 ± 51.67	4	1 - 268
	>24 months	104	14.23 ± 33.70	3	1 - 307
Males age classes	0-12 months	19	24.48 ± 42.37	7	1 - 248
	12-24 months	31	8.61 ± 13.64	3	1 - 84
	>24 months	24	22.67 ± 37.51	9	1 - 215
Season	Mating	126	14.56 ± 31.84	4	1 - 268
	Farrowing	92	25.98 ± 45.50	5	1 - 248
	Summer	141	22.18 ± 47.53	4	1 - 307
	Autumn	98	11.61 ± 22.46	3	1 - 171

Values of contact rates between groups - continued					
Factor	**Class/Level**	**N**	**Mean ± SD**	**Median**	**Maximum**
Females during season	Mating	85	12.79 ± 30.9	3	1 - 268
	Farrowing	69	24.09 ± 42.58	4	1 - 217
	Summer	97	25.57 ± 54.64	4	1 - 307
	Autumn	71	11.92 ± 24.88	3	1 - 171
Males during season	Mating	41	18.22 ± 33.49	6	1 - 210
	Farrowing	23	29.91 ± 51.07	9	1 - 248
	Summer	44	15.43 ± 27.44	4	1 - 231
	Autumn	27	10.88 ± 15.4	4	1 - 86

Appendix I – Values of contact rates between wild boar and pig farms

Factor	Class/Level	N	Mean ± SD	Median	Range
Overall		186	9.52 ± 13.44	4	1-131
Hunting type	No hunting	39	9.31 ± 13.61	4	1 - 100
	Individual hunting	30	8.85 ± 9.01	5	1 - 40
	Drive hunts	41	8.74 ± 11.69	3	1 - 58
Biogeographical region	Atlantic	2	7.60 ± 9.99	3	1 - 25
	Boreal	6	2.87 ± 4.39	1	1 - 18
	Continental	109	9.35 ± 14.06	4	1 - 131
	Mediterranean	4	14.21 ± 13.68	9	1 - 47
	Pannonian	12	10.31 ± 9.8	7	1 - 55
Forest fragmentation (ratio between the perimeter and area of forest patches)	Very low (< 40)	15	4.12 ± 5.05	2	1 - 19
	Low (40-65)	35	9.45 ± 13.40	3	1 - 60
	High (65-80)	66	10.24 ± 13.65	6	1 - 131
	Very high (> 80)	17	5.67 ± 14.36	2	1 - 100

Values of contact rates between wild boar and pig farms - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
% forest cover	Very low (0-25%)	37	5.84 ± 8.35	3	1 - 100
	Low (25-50%)	60	8.10 ± 11.37	3	1 - 60
	High (50-75%)	33	13.73 ± 16.84	9	1 - 131
	Very high (75%-100%)	3	3.85 ± 4.26	2	1 - 16
% forest cover (broad-leaved species)	Very low (0-25%)	81	7.30 ± 10.43	3	1 - 100
	Low (25-50%)	50	12.17 ± 15.90	6	1 - 131
	High (50-75%)	2	4.08 ± 4.36	2	1 - 16
Wild boar density (individuals/km)	Very low (< 3 ind./km^2)	11	5.81 ± 5.43	4	1 - 24
	Low (3 - 5 ind./km^2)	73	6.73 ± 9.33	3	1 - 100
	High (5 - 7 ind./km^2)	49	12.65 ± 16.49	6	1 - 131
Human Footprint Index (0 to 100)	Low (< 35)	75	12.16 ± 16.14	6	1 - 131
	Intermediate (35 - 60)	55	5.67 ± 6.31	3	1 - 38
	High (> 60)	3	6.50 ± 9.33	2	1 - 25
Sex	Male	58	10.87 ± 13.19	5	1 - 100
	Female	75	8.36 ± 13.57	4	1 - 131

Values of contact rates between wild boar and pig farms - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
Age classes	0-12 months	30	4.45 ± 5.22	3	1 - 24
	12-24 months	35	4.91 ± 9.04	2	1 - 100
	>24 months	68	11.95 ± 15	6	1 - 131
Females age classes	0-12 months	11	6.47 ± 7.05	3	1 - 24
	12-24 months	16	4.83 ± 5.98	2	1 - 38
	>24 months	48	9.57 ± 15.39	5	1 - 131
Males age classes	0-12 months	19	3.48 ± 3.74	2	1 - 20
	12-24 months	19	5.00 ± 11.78	2	1 - 100
	>24 months	20	15.2 ± 13.84	12	1 - 60
Season	Mating	68	7.97 ± 9.57	4	1 - 58
	Farrowing	41	13.52 ± 19.97	5	1 - 131
	Summer	75	10.40 ± 15.42	5	1 - 115
	Autumn	75	8.37 ± 10.08	4	1 - 58
Females during season	Mating	40	6.70 ± 8.29	3	1 - 55
	Farrowing	16	10.33 ± 19.10	5	1 - 131

Values of contact rates between wild boar and pig farms - continued

Factor	Class/Level	N	Mean ± SD	Median	Maximum
Females during season - *continued*	Summer	38	10.45 ± 17.90	5	1 - 115
	Autumn	43	7.23 ± 9.59	3	1 - 58
Males during season	Mating	28	9.65 ± 10.86	4	1 - 58
	Farrowing	25	16.32 ± 20.45	5	1 - 100
	Summer	37	10.34 ± 12.28	5	1 - 59
	Autumn	32	9.76 ± 10.54	6	1 - 47