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GPS Tracking Reveals the White-Tailed Eagle *Haliaeetus albicilla* as an Ambassador for the Natura 2000 Network

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Abstract: The Natura 2000 network of protected areas is the backbone of species conservation in the European Union. We investigated whether Austrian-hatched white-tailed eagles (*Haliaeetus albicilla*) make particular use of this multinational network during their natal dispersal, and what habitats were of importance to the eagles. We analyzed the utilization distribution of 907,466 GPS locations from 38 dispersing white-tailed eagles using a dynamic Brownian Bridge Movement Model. Eagles ranged over a huge area of central-eastern Europe. Natura 2000 sites overlapped with 67% of the resulting 50% isopleth; i.e., a high probability of utilization of Natura 2000 areas by white-tailed eagles was found. White-tailed eagles used wetlands, waterbodies, and deciduous forests adjacent to wet habitats disproportionately often. Coniferous forests and settlements were avoided. Anthropogenically caused mortalities hardly occurred within Natura 2000 sites. Our study suggests that the Natura 2000 network is a crucial tool for conserving the white-tailed eagle. This top predator is an ambassador for the Natura 2000 idea during all life stages, and should continue to be a conservation priority of the network.

Keywords: Natura 2000; SPA; conservation; dispersal; satellite telemetry; habitat use; utilization distribution; mortality

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1. Introduction

Natura 2000 is the largest coordinated, multinational network of protected areas in the world and a key conservation tool in the European Union (EU) [1]. It stretches across all 27 EU countries, and covers 18% of the EU's area. Its aim is to ensure the long-term survival of the EU's most valuable and threatened species and habitats. The Natura 2000 network consists of Special Areas of Conservation for the protection of selected non-avian species and habitats designated under the Habitats Directive (92/43/EEC; hereinafter: Fauna–Flora-Habitat Directive, FFH), and Special Protection Areas (SPAs), which aim to conserve a variety of resident and migratory bird species considered rare and/or threatened and designated under the Birds Directive (2009/147/EC, https://environment.ec.europa.eu/topics/nature-and-biodiversity/natura-2000) (accessed on 1 November 2023). For species listed in Annex I of the Birds Directive, member states must identify the location and extent of areas that might qualify as SPAs.

The white-tailed eagle (*Haliaeetus albicilla*) is one of 193 taxa listed in Annex I (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0147) (accessed on 1 November 2023). Although the European population of the white-tailed eagle has, in recent decades, recovered from a critically low level [2], this has occurred only after centuries-long declines due to shooting and trapping, loss and degradation of habitats, deliberate and accidental (e.g., lead) poisoning, the effects of pesticides and pollutants, and disturbance, collision, and electrocution [3–6]. As a large raptor, the white-tailed eagle could possibly

contribute to the achievement of broader biodiversity goals [7,8], especially within the context of a reserve network, like Natura 2000 [9]. Indeed, a white-tailed eagle presence might be used to overcome the difficulty of testing the effectiveness of Natura 2000, and help justify the protected status of some areas [10].

In Austria, about 70 breeding pairs of white-tailed eagles existed in 2023 (R. Probst et al., in prep.). While nesting pairs are known to be sedentary, juvenile, immature, and non-breeding, floating adults [11] move over large parts of central and eastern Europe in the course of their natal dispersion [12], which typically lasts several years in this delayed-maturity species [13]. Several studies have examined the process of natal dispersal in white-tailed eagles, and have recorded details such as timing [14], distances travelled [15,16], habitat use [17], degree of fidelity to the natal area upon recruitment [18], and the potential of human–wildlife conflicts associated with wind energy [19]. White-tailed eagles begin their dispersal from July to October of their hatch year [12] and breed in their fourth calendar year at the earliest [20]. In between, extensive movements can be undertaken; it is not known that certain individuals spend a significant period of time in their natal territory.

As the Natura 2000 concept claims to offer a "safe haven" to Europe's most valuable and endangered species, we examined whether dispersing white-tailed eagles make particular use of this network of protected areas. We postulated that Natura 2000 areas that included eagle-preferred habitats (e.g., low-lying wetlands, wet forests, etc.) would be used disproportionately because of food availability and the low potential for disturbance. We analyzed the temporal–spatial overlap between our extensive data from Global Positioning System (GPS) tracking of dispersing Austrian-hatched white-tailed eagles and the network [21,22].

2. Materials and Methods

2.1. White-Tailed Eagle Tracking Data

We used tracking data from 38 dispersing individuals, tagged as nestlings from 2015 to 2022 in eastern Austria as part of the WWF (World Wide Fund for Nature) White-tailed Eagle Project [12]. We fitted the eagles with 30 to 50 g solar-powered tracking devices (tag manufacturers: Ecotone or Ornitela). All transmitters were $\leq$3% of the eagles' mass [23,24]. Tracking technology varied between transmitters and changed (improved) over time. Also, data collection was reliant on the solar charging of the tags. These factors resulted in variations in the rate at which data were collected. Thus, "gaps" in the data occurred that, in most cases, spanned a few seconds to several days, though in a few cases extended to a number of weeks. The high temporal variation in data collection rates was accounted for by the method we used for estimating the spatial use of the individuals (see Section 2.3).

2.2. Data Analysis

Spatial analyses were performed in R Studio [25], using R 4.02 [26]. Movement patterns were analyzed using the packages *move* [27], *adehabitat* [28], and *ggplot2* [29]. Dynamic Brownian Bridge Movement Models (dBBMMs, [30]) were calculated with the package *move* [27], and estimation of time spent in SPAs was performed by the package *recurse* [31]. Maps were generated in QGIS [32]. All spatial calculations and visualizations were done in the ETRS89-extended/LAEA Europe Projection (EPSG-Code 3035 [33]). Dispersal [14] commenced when the young eagle left the nest site and remained >5 km away for $\geq$10 days [34]. End of dispersal—achieved by only one bird in the study—was identified manually by expert opinion that considered movement patterns and displacement [12].

2.3. Utility Distribution

To determine the utilization distribution (UD), we calculated dynamic Brownian Bridge Movement Models (dBBMMs, [30]). We used a resolution of 1000 m, set margin size to 15, window size to 31, and time step to 12 s. DBBMMs calculate the occurrence probability of an animal in space and time as a function of the difference between two localizations using Brownian motion [35,36]. They quantify the utilization distribution

of an animal based on its movement path, and account for temporal autocorrelation and high data volumes. DBBMMs work well with GPS data with high temporal variation, and, therefore, describe the spatial use of animals more accurately. The isopleths of the UD were mapped at the 50%, 75%, 90% 95%, 99%, and 100% levels.

2.4. Natura 2000 and Land Cover Data

Analyses of habitat within the UD used the Copernicus Global Land Service (land cover 100 m, collection 3, 2019, [37]), which identifies 23 land cover types for EU countries of continental Europe. We aggregated and summarized all land cover types that comprised ≤1% of the area of the eagles' 50% UD, and combined "herbaceous wetland" and "permanent water bodies" into "Wetland & Waterbodies". A total of 11 classes remained, which were used for the analyses. Spatial data about the Natura 2000 network were obtained from the European Environmental Agency (https://www.eea.europa.eu/) (accessed on 12 November 2023).

2.5. Statistical Analyses

We calculated the number of pixels (100 m) of each habitat type within the utilization distributions (UDs), Natura 2000 areas, and Special Protection Areas (SPAs), then applied a chi-square test to determine whether the observed distribution of birds across these habitats differed significantly from what would be expected by chance. A chi-square test is suitable for categorical data, such as the presence or absence of birds in various habitats.

It is important to note that the *p*-value in a chi-square test is highly sensitive to sample size. In cases with large datasets, like ours, even minor differences can result in statistically significant *p*-values. To provide a more nuanced interpretation of our findings, we also calculated odds ratios along with their corresponding confidence intervals. Odds ratios offer insight into the strength and direction of the associations between bird presence and habitat types. Values > 1.0 suggest a higher likelihood of birds using a specific land cover type within the areas of interest (i.e., UD Total, UD Natura 2000, or UD SPA).

Additionally, we applied a Bonferroni correction, which is crucial in studies like ours, where multiple hypotheses are being tested simultaneously, as it reduces the risk of Type I errors (false positives). By adjusting our significance threshold accordingly, we ensured that our results are robust and not merely artifacts of multiple comparisons.

3. Results

3.1. Utilization Distribution

During 2015–2022, 907,466 locations of dispersing white-tailed eagles were collected. Within the borders of the EU, 904,129 fixes (99.63%) were located. On average, eagles were tracked for 615 ± 480 (min. 20, max. 1588) days. Eagles ranged over a large area of central-eastern Europe (Figure 1). The extent to which eagles wandered during dispersal varied greatly.

3.2. Utilization of Natura 2000 Protected Sites

Areas used more by eagles (i.e., lower % isopleths) overlapped more with protected areas than areas used less by eagles (i.e., higher % isopleths). Natura 2000 sites, SPAs, and FFHs overlapped with 67%, 63%, and 46% of 50% isopleths, respectively (Table 1). This relationship was significant (Spearman's ρ: r = −1.00, $p < 0.001$) in all three types of protected areas. However, the relationship was less pronounced in FFHs (sites not focused on bird conservation). Further, some Natura 2000 sites were—most probably due to spatial proximity to natal sites and habitat composition—more important than others. The median number of SPAs visited by individual white-tailed eagles was 19.5 (min. 1, max. 56) SPAs. This corresponds to an average of 39.44 ± 21.78 (min. < 1, max. 97.85) % of the days for which telemetry data are available.

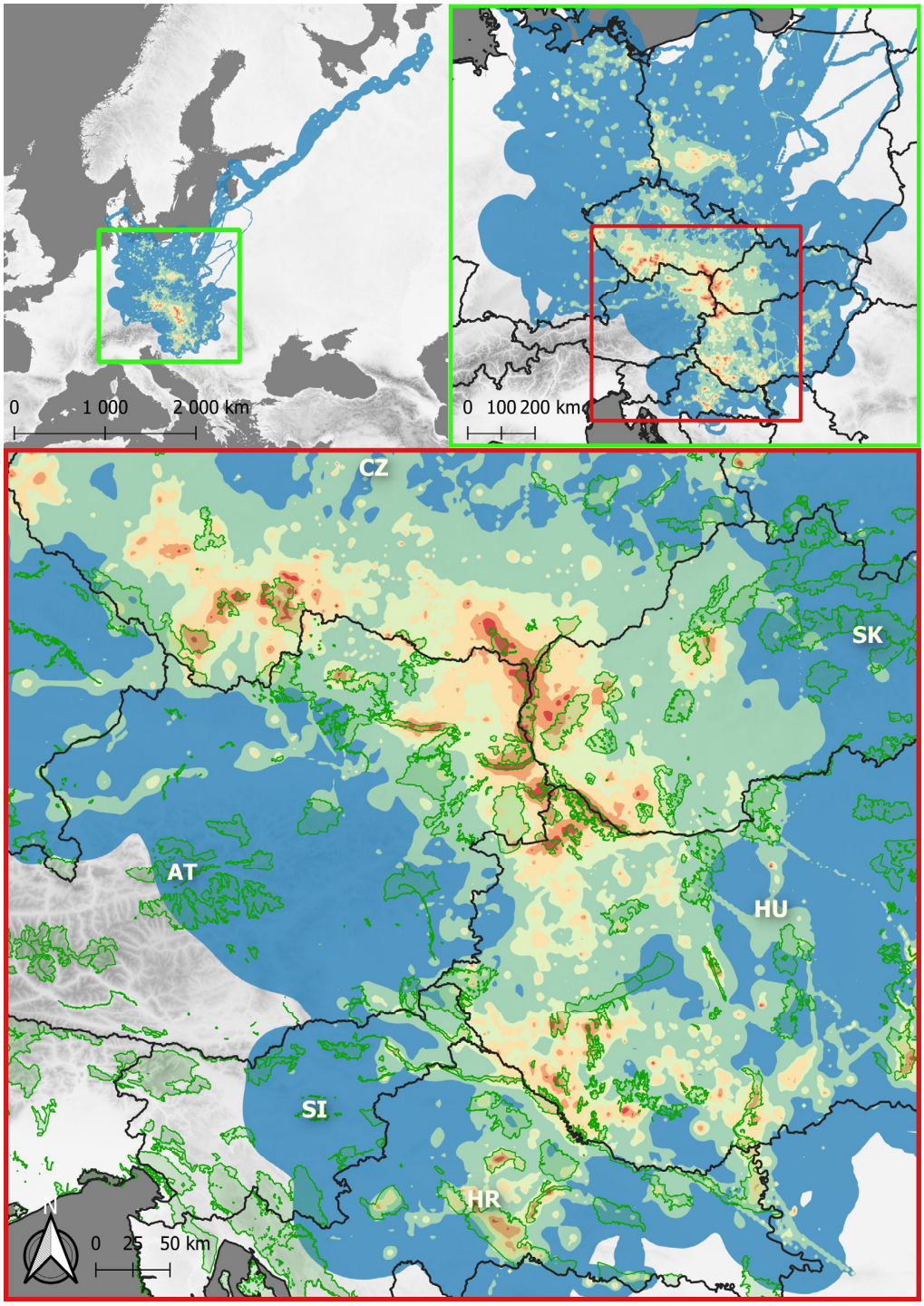

Figure 1. Dynamic Brownian Bridge Movement Model (dBBMM) of the range of 38 dispersing white-tailed eagles hatched in Austria during 2015–2022. The green box shows ranging across central Europe. The red box shows ranging zoomed to the border areas of Austria (AT), Croatia (HR), the Czech Republic (CZ), Slovakia (SK), Hungary (HU), and Slovenia (SI). UD: 50%; 75%; 90%; 95%; 99%; 100% isopleth. Green polygons: Special Protection Areas of Natura 2000 network.

Table 1. Utilization of Natura 2000 sites by 38 dispersing white-tailed eagles hatched in Austria. UD: Utilization distribution calculated by a dynamic Brownian Bridge Movement Model; SPA: Special Protected Area, FFH: areas protected under Fauna–Flora-Habitat Directive, and *N*: number of protected sites within the UD category.

UD	UD km²	Natura 2000 km²	Natura 2000 (%)	*N* Natura 2000	SPA km²	SPA (%)	*N* SPA	FFH km²	FFH (%)	*N* FFH
50	1511.75	1011.25	67	132	958.39	63	42	694.40	46	95
75	8736.76	4007.22	46	352	3593.08	41	94	2558.31	29	266
90	34,910.50	11,219.63	32	786	9330.37	27	181	7642.40	22	620
95	73,010.58	19,490.57	27	1254	15,567.74	21	250	13,186.28	18	1025
99	228,276.92	50,288.81	22	2846	38,060.01	17	443	33,453.07	14	2455
100	1,049,229.59	177,079.49	17	8116	136,947.16	13	1019	110,085.44	10	7265

3.3. Utilization of Land Cover Types

The use of 11 land cover types within the different UD levels is shown in Table 2. We considered the 100% UD class to encompass all habitats available to eagles (both within protected areas and across the wider landscape). Compared to the other UD classes (50–99%), significant differences existing in the use of each of the 11 different habitat types within the three areas being considered (UD Total, Natura 2000, and SPA) were almost universal (158 of 165 Bonferroni-corrected p-values < 0.001). We approximated the scale of differences in the utilization of land cover types using odds ratios. Pairwise comparisons between the 100% UD and the 50% UD within the UD Total, UD Natura 2000, and UD SPA showed that dispersing white-tailed eagles used the habitats "wetland and waterbodies" (UD Total: 1.92, Natura 2000: 2.14, SPA: 1.33), "closed forest, deciduous, broad leaf" (UD Total: 3.42, Natura 2000: 2.39, SPA: 1.63) and "open forest, deciduous, broad leaf" (UD Total: 2.48, Natura 2000: 2.28, SPA: 1.49) disproportionately often. In contrast, the land cover types "urban/build up" (UD Total: 0.37, Natura 2000: 0.96, SPA: 1.41), "closed forest, evergreen, needle-leaved forest" (UD Total: 0.40, Natura 2000: 0.26, SPA: 0.87) and "closed forest, mixed" (UD Total: 0.66, Natura 2000: 0.93, SPA: 0.87) were (mostly) used at below-average frequency in the 50% UD according to the odds ratios in all three categories.

A between-categories analysis of individual land cover types, using all six UD distributions probabilities (50–100%), showed the utilization of "wetlands and waterbodies" to be significantly higher in Natura 2000 areas (5.42–10.92%; $t = -4.62$, $p = 0.006$) and in SPAs (5.81–11.35%; $t = -4.9$, $p = 0.004$) than in the UD Total (4.86–8.92%). The same applied to "closed forest, deciduous", where utilization in Natura 2000 protected areas (18.08–34.58%; $t = -11.03$, $p < 0.001$) and SPAs (15.18–34.01%; $t = -9.1$, $p < 0.001$) was significantly higher than in the entire UD (9.51–26.42%). Also, the habitat class "open forest, deciduous" was more intensively utilized within the Natura 2000 network (0.62–1.40%; $t = -9.91$, $p < 0.001$) than in SPAs (0.52–1.41%; $t = -4.10$, $p = 0.009$) and in the UD Total (0.45–1.12%).

Eagles avoided "urban/build up" habitats in protected areas. While there was a utilization of 1.5–4.65% in the UD Total, this was reduced to 0.52–0.71% in Natura 2000 areas ($t = 6.55$, $p = 0.001$) and to 0.52–0.88% in SPAs ($t = 6.57$, $p = 0.001$). In the "closed forest, evergreen, needle-leafed" class, the use of UD Total (7.54–17.0%) differed neither from Natura 2000 sites (5.93–19.26%; $t = -2.45$, $p = 0.058$), nor from SPAs (5.79–19.91%; $t = -2.31$, $p = 0.069$). For the land cover type "closed forest, mixed" there was a significant difference between UD Total (4.80–9.86%) and UD Natura 2000 sites (6.87–9.42%; $t = -3.67$, $p = 0.014$), but no statistical difference between UD Total and UD SPAs (6.12–8.03%; $t = -1.46$, $p = 0.205$).

Table 2. Utilization of land cover types by 38 dispersing white-tailed eagles hatched in Austria. UD: Utilization distribution (50%, 75%, 90%, 95%, 99%, and 100% isopleths) was calculated by a dynamic Brownian Bridge Movement Model. Utilization is given for the entire area used by eagles (Total), for Natura 2000 sites and SPAs.

Land Cover Types	**UD Total (%)**						**UD Natura 2000 (%)**						**UD SPA (%)**					
	100	**99**	**95**	**90**	**75**	**50**	**100**	**99**	**95**	**90**	**75**	**50**	**100**	**99**	**95**	**90**	**75**	**50**
Others	6.27	1.64	1.22	1.23	1.20	1.26	13.29	3.75	2.38	2.07	1.77	1.42	15.55	4.35	2.60	2.21	1.80	1.38
Wetland and waterbodies	4.86	2.54	3.39	4.05	6.31	8.92	5.42	6.70	8.84	8.99	10.43	10.92	5.81	7.59	9.91	9.83	11.14	11.35
Herbaceous vegetation	2.31	1.54	1.26	1.25	1.33	1.38	2.91	2.20	1.69	1.35	1.21	1.40	3.12	2.31	1.81	1.39	1.16	1.33
Cropland	37.02	47.68	50.01	48.26	46.69	35.87	22.60	26.61	26.27	25.02	28.08	26.06	24.17	29.07	28.20	26.64	29.52	26.94
Urban/built up	4.19	4.65	4.37	3.53	2.85	1.59	0.54	0.71	0.83	0.66	0.60	0.52	0.52	0.74	0.88	0.66	0.61	0.52
Closed forest, evergreen, needle-leafed	17.10	14.54	12.43	11.81	9.43	7.54	19.26	17.29	16.25	14.84	10.80	5.93	19.91	17.75	16.18	14.44	10.33	5.79
Closed forest, deciduous, broad-leafed	9.51	12.25	14.00	16.35	17.95	26.42	18.08	25.48	27.41	30.30	29.36	34.58	15.18	22.64	25.42	29.14	28.39	34.01
Closed forest, mixed	9.86	6.24	4.80	4.86	5.15	6.74	9.42	8.08	6.87	7.05	7.37	8.05	8.03	7.04	6.12	6.35	6.96	7.88
Open forest, deciduous, broad-leafed	0.45	0.71	0.80	0.86	0.90	1.12	0.62	0.94	1.05	1.17	1.26	1.40	0.52	0.78	0.91	1.10	1.19	1.41
Open forest, mixed	1.91	1.78	1.47	1.47	1.49	1.59	1.77	1.63	1.58	1.66	1.77	1.66	1.55	1.54	1.49	1.57	1.68	1.58
Open forest, unknown	6.52	6.41	6.26	6.33	6.70	7.57	6.10	6.62	6.83	6.90	7.36	8.07	5.64	6.19	6.48	6.68	7.20	7.83

3.4. Mortality

Of 38 white-tailed eagles that survived past their initial dispersal from their natal sites, 10 (26.3%) died. Five more birds disappeared for unknown reasons, and a further five lost their tags, and in two cases, the tags malfunctioned. Most eagles died soon after becoming independent, at an estimated age of 1.5 ± 1.15 (min. 0.4, max. 3.2) years, or 0.99 ± 1.09 (min. 20 days, max. 2.8 years) years after initial dispersal. Of the ten birds that died, four (40.0%) died in their first calendar year, four (40%) died in their second calendar year, and two (20.0%) died in their third calendar year.

Seven (70.0%) deaths were caused by anthropogenic factors (e.g., collision, electrocution, poisoning (including lead poisoning), and shooting), two (20.0%) were due to natural causes, and the cause of one (10.0%) was unclear. All but one (85.7%) of the human-caused losses, a lead poisoning, occurred outside Natura 2000 sites (Figure 2). Although descriptively striking, the difference in mortality inside and outside protected areas is not statistically significant due to the small sample size (Fisher's Exact Test: $p = 0.083$).

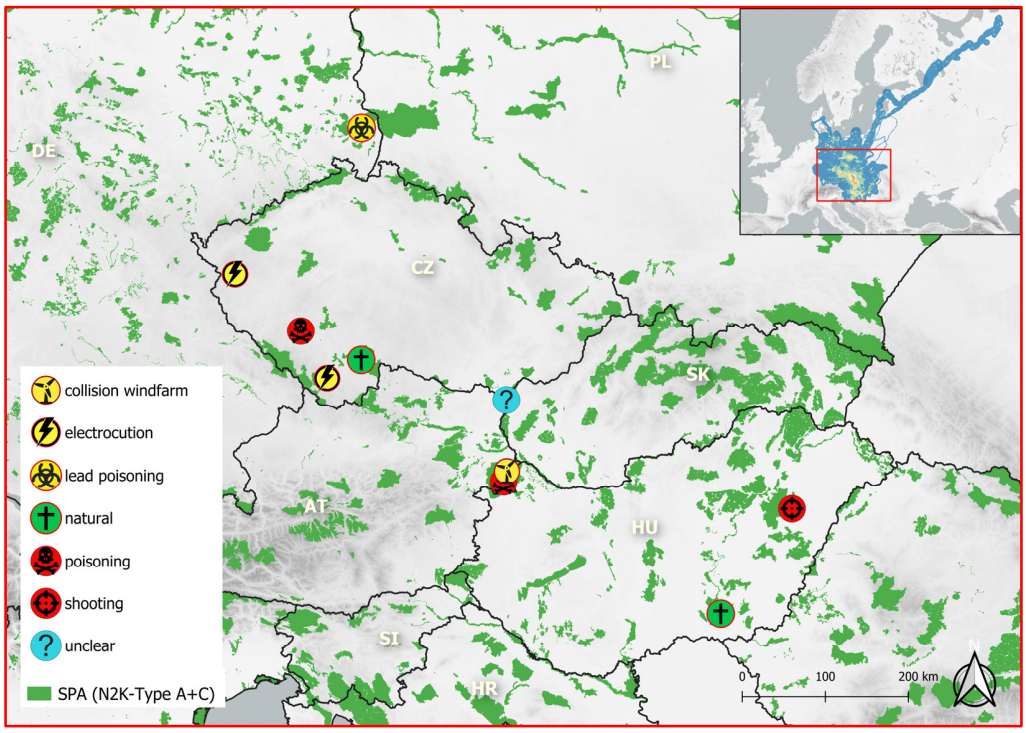

Figure 2. Location of SPAs (green) and distribution of losses during dispersal of 10 Austria-hatched white-tailed eagles. Anthropogenic losses were primarily outside protected areas. The red box locates the area in which mortalities occurred. Austria (AT), Croatia (HR), the Czech Republic (CZ), Slovakia (SK), Hungary (HU), and Slovenia (SI).

4. Discussion

Natura 2000 protected areas offer a wide range of provisioning, regulating, and socio-cultural ecosystem services [38]. However, they are primarily designated based on ecological and biogeographical criteria to meet specific conservation objectives. A recent multi-taxonomic assessment across European biogeographic regions shows that the Natura 2000 network is effective in limiting biodiversity loss [10]. Yet, against a backdrop of persistent, continent-wide declines in biodiversity, there are calls for improvements to the network, including data-improved red list assessments, increased focus on those sites with the highest conservation value, species-specific conservation plans, augmented population monitoring, and substantial financial resource allocation for research, implementation, and education [39,40].

By using dBBMMs to analyze GPS telemetry data, we measured, in a relatively unbiased way, the selection of protected areas by white-tailed eagles in our study area [11,41]. We assume that the use of areas by white-tailed eagles is mainly determined by habitat quality and food availability, and in some cases, perhaps, intra-specific competition [15,42]. In addition, we assume that dispersal is non-directional, although geography (e.g., mountain barriers or river courses) may affect movement, and genetically influenced predisposition of directional movement cannot be ruled out [43,44].

In Austria, 38.8% of the white-tailed eagle population breeds in Natura 2000 areas, 34.4% of which are in SPAs, and an equal proportion in FFH areas (WWF Austria data, 1999–2023). Of the tracked eagles, 81% were hatched in Natura 2000 areas. In the course of their years of dispersal, these eagles visited large parts of central and eastern Europe, conspicuously avoiding alpine areas. These results from our eastern Austrian study area are similar to those from other central European telemetry studies, which have shown that non-breeding white-tailed eagles range over huge areas and avoid high elevations [15].

Areas qualify as Natura 2000 sites because they help achieve EU biodiversity goals, including providing important habitats for species of conservation concern, like the white-tailed eagle [4,45]. Mostly, the relevance of protected areas to white-tailed eagle conservation has focused on their importance to breeding eagles [4,46], and little attention has been paid to their importance to dispersing eagles (but see, e.g., [47]).

Our results show that during dispersal, tracked eagles used the Natura 2000 network disproportionately more than non-protected areas. Despite this clear finding, we were unable to find other studies that evaluated specifically the use of Natura 2000 sites by dispersing white-tailed eagles. What published information exists on the dispersal of other *Haliaeetus* eagles, including the well-studied bald eagle (*H. leucocephalus*), is typically mechanistic and reports aspects like the distance and direction of dispersal (e.g., [48–50]). Also, as with the white-tailed eagle, the importance of protected areas to bald eagles, especially when populations were at low levels during much of the 20th century, focused mostly on breeding (e.g., [51]).

Despite differences in ecological requirements, the breeding distribution of the greater spotted eagle (*Clanga clanga*) overlaps with that of the white-tailed eagle in many places, including eastern Europe [52]. The ecology of the two eagle species also overlaps in that they both typically nest in and frequent forested areas near wetlands, lakes, and rivers, and such habitats serve as stop-overs during migration and as wintering areas [53]. Keeping in mind those similarities between the two species, it is striking that nine out of twelve European wintering sites used by tracked greater spotted eagles were located in SPAs or national parks [54]. Two of the three remaining wintering ranges were in FFH areas, and only one site was under no formal protection.

The regions visited by white-tailed eagles were characterized by a high proportion of deciduous forests and permanent waterbodies, consistent with those regions having lowland wetlands, and nearby forest areas. White-tailed eagles typically forage over lowland wetland habitats, and forest areas are used by the eagles to rest and roost. In contrast, human settlements and coniferous forests were avoided by eagles. Levels of human disturbance in urban areas are often too high for non-habituated eagles [55,56]. Coniferous forests are more usually found at higher altitudes in central Europe, and visits by our tracked eagles to the European Alps were extremely rare (Figure 1). Relative to the total area used by tracked eagles, wetlands and deciduous forests in Natura 2000 sites and SPAs were used more, and areas of human settlement coniferous forest were used less. A number of the variables we examined that might relate to the eagles' use of an area were not independent of one another (e.g., altitude and conifer distribution, altitude and waterbody occurrence, etc.). It was beyond the scope of this study to untangle the effects of these variables, though doing so might shed light on why eagles prefer some locations over others.

We assume that protected areas provide not only ideal habitats and available food, but that human disturbance is minimized by visitor control measures. Although there

were areas of deciduous forest and wetland outside protected areas used, we think that such areas in protected areas were preferred by eagles because human disturbance was comparatively low.

Our study demonstrates the importance of the Natura 2000 network to dispersing white-tailed eagles and suggests that the network is a crucial tool for conserving this top predator, especially taking into account the network's documented importance to their breeding. Beyond their importance as foraging, resting, and roosting sites, our study suggests Natura 2000 protected areas are also "safe havens" for dispersing eagles. Only one of the tagged eagles that had been killed by a human-related cause was found in a Natura 2000 area. However, even in that case, the lead poisoning was suspected to have initially taken place outside the protected zone. Although our sample of mortality events is small, the pattern of causes is in line with mortality information for adult white-tailed eagles from Austria, where persecution (31.17%) is followed by collision with wind turbines (28.57%) as the most frequent causes of death (n = 77; R. Probst et al., in prep.). Persecution of raptors is a crime in the EU, though many challenges exist to enforcing laws that protect raptors, and nature in general. Also, while wind energy is seen as an important tool in mitigating the effects of climate change (including effects on nature and protected species), turbines are a threat to eagles and other birds. Wise and sensitive spatial planning of windfarms and the associated infrastructure, including keeping core use areas free from energy development, will be the key to the long-term protection of white-tailed eagles and other sensitive raptor species. White-tailed eagle collisions with wind turbines in Centrope and the Carpathian Basin are concentrated in eastern Austria [57,58], where most turbines are located. In future years, collision threats are expected to increase because more wind power developments are being considered. As the additional mortality of individuals of different ages and breeding status can have a disproportional impact on bird populations, including white-tailed eagles [59], comprehensive protection will be achieved only if those core areas include not only important current and potential breeding areas/habitats, but also important areas for dispersing immature and floating non-breeders.

Although obvious, it is worth remembering that much of the network's strength comes from the coherence of the individual sites in delivering EU-wide conservation benefits. For many other protected species, large proportions of the populations are not so closely tied to protected area networks [60,61]. However, the white-tailed eagle remains an ambassador for the Natura 2000 idea, and thus, its conservation, during all life stages, should continue to be a priority of the network. We have included a list of the most important Natura 2000 areas in central and eastern Europe for our tracked white-tailed eagles during dispersal in Appendix A.

As a priority, conservation efforts in Natura 2000 sites and management plans should be tailored to this top predator [62]. Improvements to conservation measures, such as the enlargement of core areas or restoration of river and wetland ecosystems, should be considered and implemented where possible. Corridors between Natura 2000 sites for dispersing white-tailed eagles should be developed or improved, not least in light of the increased expansion of green infrastructure such as wind power developments.

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Appendix A

Table A1. List of Natura 2000 sites intersecting with the highest utility distribution class (50% isopleth of the UD). Only areas with a minimum intersection area of 1 km^2 are shown.

Site Code	Site Name	Country	Site Type	50% UD Area [km^2]	Natura 2000 Site Area [km^2]	Ratio of Areas: 50% UD to Natura 2000 Site
AT1202V00	March-Thaya-Auen	AT	A	119.5	148.3	81%
SKCHVU016	Zahorske Pomoravie	SK	A	98.7	321.8	31%
HUFH30005	Hanság	HU	C	72.1	135.5	53%
CZ0311033	Třeboňsko	CZ	A	71.1	473.6	15%
AT1204000	Donau-Auen östlich von Wien	AT	B	69.0	95.2	73%
AT1204V00	Donau-Auen östlich von Wien	AT	A	68.8	91.0	76%
AT1202000	March-Thaya-Auen	AT	B	63.7	88.8	72%
SKCHVU007	Dunajske luhy	SK	A	61.1	176.5	35%
HUFH30004	Szigetköz	HU	C	59.7	171.8	35%
CZ0624119	Soutok-Podluží	CZ	B	58.8	97.2	61%
CZ0621027	Soutok-Tvrdonicko	CZ	A	58.2	95.8	61%
CZ0621029	Pálava	CZ	A	57.6	85.4	67%
AT1125129	Parndorfer Platte-Heideboden	AT	A	46.5	89.8	52%
SKUEV0090	Dunajske luhy	SK	B	42.0	45.4	92%
AT1216000	Tullnerfelder Donau-Auen	AT	B	36.4	175.3	21%
AT1216V00	Tullnerfelder Donau-Auen	AT	A	36.4	177.6	21%
CZ0624100	Milovický les	CZ	B	24.4	24.4	100%
CZ0311036	Hlubocké obory	CZ	A	23.1	33.2	70%
CZ0314126	Hlubocké obory	CZ	B	22.6	32.6	69%
HUDD10008	Belső-Somogy	HU	A	21.5	333.3	6%
HUDD20063	Szentai-erdő	HU	B	18.1	195.3	9%
HUBF30003	Kis-Balaton	HU	C	15.3	133.4	11%

Table A1. *Cont.*

Site Code	Site Name	Country	Site Type	50% UD Area [km^2]	Natura 2000 Site Area [km^2]	Ratio of Areas: 50% UD to Natura 2000 Site
CZ0314023	Třeboňsko-střed	CZ	B	15.3	40.3	38%
CZ0311040	Boletice	CZ	A	14.5	235.6	6%
CZ0314123	Boletice	CZ	B	14.5	203.5	7%
HR1000009	Ribnjaci uz Česmu	HR	A	14.4	231.8	6%
HUFH10004	Mosoni-sík	HU	A	13.0	131.0	10%
CZ0624099	Niva Dyje	CZ	B	12.5	32.5	38%
HUDD20044	Boronka-melléke	HU	B	11.8	114.9	10%
CZ0311037	Českobudějovické rybníky	CZ	A	11.5	63.6	18%
SKUEV0313	Devinske jazero	SK	B	11.2	12.6	89%
SKUEV0125	Gajarske aluvium Moravy	SK	B	11.2	12.4	90%
CZ0621030	Střední nádrž vodního díla Nové Mlýny	CZ	A	10.5	10.5	100%
HUKN10007	Alsó-Tisza-völgy	HU	A	10.4	362.9	3%
PLB240001	Dolina Górnej Wisły	PL	A	10.3	247.7	4%
HR2000416	Lonjsko polje	HR	B	10.2	511.4	2%
HR1000004	Donja Posavina	HR	A	10.2	1210.8	1%
HUKN20031	Alsó-Tisza hullámtér	HU	B	9.5	79.3	12%
HR1000010	Poilovlje s ribnjacima	HR	A	8.8	135.4	7%
DE4552451	Biosphärenreservat Oberlausitzer Heide- und Teichlandschaft	DE	A	7.8	300.4	3%
HUDD10012	Balatoni berkek	HU	A	7.6	86.5	9%
HUDD20031	Fehérvíz	HU	B	6.6	15.5	43%
CZ0624103	Mušovský luh	CZ	B	5.6	5.6	100%
SKUEV0168	Horny les	SK	B	5.6	5.6	100%
CZ0314019	Velký a Malý Tisý	CZ	B	4.9	6.8	73%
SKUEV0163	Rudava	SK	B	4.8	19.6	24%
DE4552302	Oberlausitzer Heide- und Teichlandschaft	DE	B	4.2	137.2	3%
SKCHVU014	Male Karpaty	SK	A	4.2	524.6	1%
SKUEV0276	Kuchynska hornatina	SK	B	4.1	32.8	12%
HUDI10005	Sárvíz völgye	HU	A	4.0	78.7	5%
SKCHVU028	Strazovske vrchy	SK	A	4.0	597.3	1%
HR2000440	Ribnjaci Siščani i Blatnica	HR	B	3.6	7.3	49%
AT1221V00	Truppenübungsplatz Allentsteig	AT	A	3.4	109.2	3%
CZ0621028	Lednické rybníky	CZ	A	3.3	6.9	48%
HR2000437	Ribnjaci Končanica	HR	B	3.2	12.9	25%

Table A1. *Cont.*

Site Code	Site Name	Country	Site Type	50% UD Area [km^2]	Natura 2000 Site Area [km^2]	Ratio of Areas: 50% UD to Natura 2000 Site
CZ0620009	Lednické rybníky	CZ	B	3.1	6.2	50%
DE6336301	US-Truppenübungsplatz Grafenwöhr	DE	B	2.9	192.7	2%
DE6336401	US-Truppenübungsplatz Grafenwöhr	DE	A	2.9	192.5	2%
SKUEV2090	Dunajske luhy	SK	B	2.1	12.2	17%
PLH020041	Ostoja nad Baryczą	PL	B	2.0	821.1	0%
PLB020001	Dolina Baryczy	PL	A	2.0	555.8	0%
DE2347401	Großes Landgrabental	DE	A	1.9	142.0	1%
DE2348301	Galenbecker See	DE	B	1.9	18.6	10%
SKUEV0172	Beznisko	SK	B	1.8	9.2	19%
CZ0313101	Krvavý a Kačležský rybník	CZ	B	1.8	5.6	31%
PLB320003	Dolina Dolnej Odry	PL	A	1.5	615.5	0%
CZ0314124	Blanský les	CZ	B	1.5	222.1	1%
HUDI20009	Budai-hegység	HU	B	1.1	95.2	1%

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