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Final Report

Analysis of black stork flight behaviour under different weather and land-use conditions with special consideration of existing wind turbines in the Vogelsberg SPA

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Cover image: Drone photo of the Hallo wind farm taken from a westerly direction

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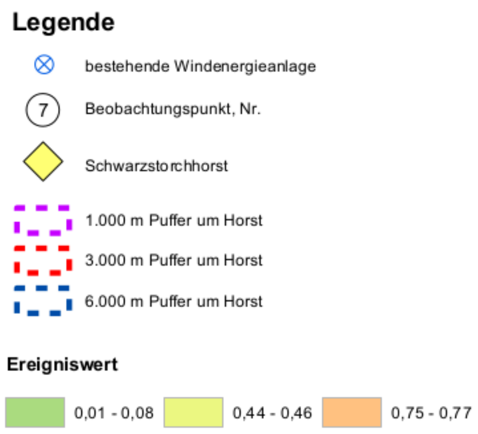
Map 1	
 …	**Map key** Existing wind turbines Observation point, No. Black stork nesting site 1000 m buffer around nesting site 3000 m buffer around nesting site 6000 m buffer around nesting site **Event value** [in numbers replace commas by decimal points, e.g. 0,01 > 0.01]
Map 2	
Legende **Ergebnis** **Nahrungshabitate** Potentielle Nahrungshabitate Genutzte Nahrungshabitate	**Map key** **Results** **Feeding habitats** Potential feeding habitats Utilised feeding habitats
Grundlagen **Natura 2000-Gebiete** Vogelschutzgebiet 5421-401 "Vogelsberg" FFH-Gebiet, Nr. •FFH-Gebiet 5522-301 "In der Kiesel bei Hintersteinau" •FFH-Gebiet 5522-303 "Talauen bei Freiensteinau und Gewässerabschnitt der Salz" •FFH- Gebiet 5522-304 "Vogelsbergteiche und Lüderaue bei Grebenhain" •FFH-Gebiet 5622-310 "Steinaubachtal und Ürzeller Wasser" •FFH-Gebiet 5523-302 "Zuflüsse der Fliede" •FFH-Gebiet 5423-304 "Lüder mit Zuflüssen" •FFH-Gebiet 5622-307 "Kaupe und Lochwiese b ei Ürzell"	Baseline information Natura 2000 sites SPA 5421-401 "Vogelsberg" SAC, No. •SAC 5522-301 "In der Kiesel bei Hintersteinau" •SAC 5522-303 "Talauen bei Freiensteinau und Gewässerabschnitt der Salz" •SAC 5522-304 "Vogelsbergteiche und Lüderaue bei Grebenhain" •SAC 5622-310 "Steinaubachtal und Ürzeller Wasser" •SAC 5523-302 "Zuflüsse der Fliede" •SAC 5423-304 "Lüder mit Zuflüssen" •SAC 5622-307 "Kaupe und Lochwiese bei Ürzell"

•FFH-Gebiet 5622-304 "Weiherskopf/Hohestein"	•SAC 5622-304 "Weiherskopf/Hohestein"
Fließgewässer Fließgewässer 04.211 Kleine bis mittlere Mittelgebirgsbä che	**Watercourses** Watercourses 04.211 Small to medium sized streams of low mountain ranges
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226 Seggensümpfe 227 Strukturreiche Grünlandkomplexe 341 Schilfröhricht 342 Komplexe Verlandungszonen	226 Sedge swamps 227 Structurally rich grassland complexes 341 Phragmites reedbed 342 Complex sedimentation zones
Datenbestand HLNUG Amphibien Fische, Rundmäuler, Krebse und Muscheln Reptilien Fließgewässer mit Nachweisen der Bachforelle (Fischmonitoring im Zuge der Umsetzung der EG-Wasserrahmenrichtlinie)	**HLNUG data** Amphibia Fish, cyclostomata, crustaceans, bivalves Reptiles Watercourses with records of river trout (fish monitoring as part of the implementation of the EU Water Framework Directive)
Sichtbeobachtungen nahrungssuchender Schwarzstorch am Boden (NABU 2016) Flugbeobachtungen in geringer Höhe (NABU 2016) Sichtbeobachtungen Dritter (2016) Beobachtungsnachweise an neugeschaffenen Kleingewässern Neuschaffung von Kleingewässern/Gewässeraufweitungen (Ausgleichsmaßnahme Windpark "Hallo") Neuschaffung von Kleingewässern/Gewässeraufweitungen (Ausgleichsmaßnahme Windpark "Hallo") im 200m Umkreis zu Bereichen mit mittlerer bis sehr hoher Raumnutzung	**Sightings** Black stork on the ground in search of food (NABU 2016) Observations of low altitude flight (NABU 2016) Third-party sightings (2016) Recorded observations at newly created small waterbodies Creation of small waterbodies/widened stream beds (mitigation measure for Hallo wind farm) Creation of small waterbodies/widened stream beds (mitigation measure for Hallo wind farm) within a 200 m radius of areas with medium to very high spatial use
Flugbewegungen 2016 (eigene Erfassung) Nahrungssuche Kat. 0 (0m – 25m) Nahrungssuche Kat. 1 (25m – 50m) Nahrungssuche Kat. 2 (50m – 80m) Nahrungssuche Kat. 3 (50m – 190m) Nahrungssuche (mehrere Höhenkategorien)	**Flight movements in 2016 (own survey)** Searching for food, Cat. 0 (0–25 m) Searching for food, Cat. 1 (25–50 m) Searching for food, Cat. 2 (50–80 m) Searching for food, Cat. 3 (50–190 m) Searching for food (multiple altitude categories)
Schwarzstorch 2016 Schwarzstorchhorst 1.000 m Radius 3.000 m Radius 6.000 m Radius	**Black stork 2016** Black stork nesting site 1000 m radius 3000 m radius 6000 m radius
Bestehende Windenergieanlagen bestehende Windenergieanlagen Störungszone 300m um bestehende WEA	**Existing wind turbines** existing wind turbines 300 m disturbance zone around existing WTs

Map 3	
Ergebnis **Nahrungshabitate** Potentielle Nahrungshabitate, Nr. Genutzte Nahrungshabitate, Nr. **Nahungshabitate im 200m Umkreis von Bereichen mittlerer – hoher Raumnutzung**	**Results** **Feeding habitats** Potential feeding habitats, No. Utilised feeding habitats, No. **Feeding habitats within a 200 m radius of areas with medium to very high spatial use**
Gewichtete Schwerpunkträume **Ereigniswerte** sehr gering (0,01 – 0,31) gering (0,32 – 0,43) mittel (0,44 – 0,56) leicht erhöht (0,57 – 0,74) hoch (0,75 – 1,18) sehr hoch (1,18 – 4,96)	**Weighted focal areas** **Event values** very low (0.01–0.31) low (0.32–0.43) medium (0.44–0.56) slightly elevated (0.57–0.74) high (0.75–1.18) very high (1.18–4.96)
Grundlagen **Bestehende Windenergieanlagen** bestehende Windenergieanlagen Störungszone 300m um bestehende WEA	**Baseline information** **Existing wind turbines** existing wind turbines 300 m disturbance zone around existing WTs
Schwarzstorch 2016 Schwarzstorchhorst 1.000 m Radius 3.000 m Radius 6.000 m Radius	**Black stork 2016** Black stork nesting site 1000 m radius 3000 m radius 6000 m radius

Summary

The overall objective of this research project was to improve the state of knowledge on flight behaviour in black storks under different weather and land-use conditions. In addition, the aim was to analyse flight behaviour in spatial proximity to wind turbines (WTs), as there are as yet no published studies on this issue in Germany.

The project area chosen for this study is the Vogelsberg natural landscape unit at Freiensteinau. Within this natural landscape unit, the black stork has a centre of distribution as well as a nesting site that has been in use for several years and has given rise to successful hatches (Atzenstein nesting site). The project area is also particularly suited to addressing the questions motivating this study because two wind farms are located in spatial proximity to the regularly used Atzenstein nesting site. Other successful nesting sites of black stork pairs are situated approximately 6.6 km and 11 km away from these wind farms.

Flight behaviour was categorised by direct observation of observable flight movements with respect to flight altitude (vertical observation) and species-specific behaviours. The impact of weather and land use was assessed by statistical analysis.

For the purposes of analysing flight behaviour in the vicinity of WTs, a radius of 250 m around the turbines was defined as a danger zone. When the birds entered this zone, their flight movements were described in detail (vertical and horizontal observation), taking into account weather data and the rotor tip speed.

In accordance with the questions motivating this research project, the analyses took into account the impact of topography and land-use types on flight behaviour. A further assessment approach involved the identification of potential and utilised feeding habitats offering a good food supply in a 6 km radius around the Atzenstein nesting site.

The study commenced in late March 2016 and was undertaken jointly by the Büro für ökologische Fachplanungen (BöFa) and gutschker-dongus partner consultancies. The first meeting of the project-accompanying advisory council took place on 12 April 2016 in Ulrichstein. The closing meeting was held on 22 November 2017 in Wiesbaden.

The project remit involved the assessment of not only the own research data from the Freiensteinau project area and the data provided by the NABU-Hessen conservation NGO but also the findings of previous black stork studies. The latter had also been conducted in spatial proximity to existing wind farms and were thus able to contribute technical data to the issues addressed by the present black stork study. Specifically, these are the studies on the Alpenrod wind farm in the Westerwald, the Rabenau wind farm in the Gießen administrative district, and the Wohnste wind farm in the northern German lowlands. With respect to the Rabenau study, it should be noted that its context is similar to that found in the Freiensteinau project area. Black storks were already breeding in the vicinity of the site later chosen for the wind farm development.

The study on the Moskau-Kreuzstein wind farm was included with a view to a more detailed consideration of the impact of topography and land use on flight movements. At the time the study was undertaken, wind farms had not yet been developed in proximity to the study area.

A spatial behaviour analysis had already been conducted in 2015 in the vicinity of the neighbouring planned Hintersteinau wind farm. The subject of the study had been the same black stork nesting site

at the Atzenstein hill; therefore the study was taken into consideration as a comparison to the 2016 assessment.

In order to compare spatial behaviour as determined by direct observation with actual spatial behaviour as determined by telemetry, the present study also evaluated the telemetry study of a black stork fitted with a transmitter in France. Similar to the research at the Alpenrod wind farm, this study also covers the Westerwald natural landscape unit.

However, at the time of publication of the present black stork report, the data of the telemetry study had not yet been released. Therefore, the information regarding this study will be re-added to this report following the release of the data and an updated version of the report will then be published.

Quality assurance for the present black stork study with regard to its methodology and implementation was provided by the ARSU GmbH and Planungsgruppe Grün GmbH consultancies.

Observation points, flight movements, flight altitude categories

Flight movements in the Freiensteinau project area were recorded in the period from 1 April to 11 August 2016 on 40 recording days, with observers working in pairs at observation points and a total recording effort of 640 hours.

At the outset of the study, a total of 12 observation points for recording were available for selection. These were largely reduced to 3 observation points (No. 5b, No. 7 and No. 9) based on visibility analyses, field visits with the quality-assuring consultancies, and photo visualisation. These three observation points were best suited to the various requirements of a black stork spatial behaviour analysis, such as visibility into the nesting site location in the forest and the wind farm respectively, and good surveyability of flight movements in both near- and long-distance ranges.

The survey in the undulating study area was undertaken by recorders who had been calibrated by means of flying drones. A total of 121 flight movements were recorded which could be subdivided into 303 flight events. Five different flight altitude categories were distinguished in this context (0–25 m; 25–50 m, 50–80 m, 80–190 m, > 190 m).

A total of 29% of the recorded flights were in the 80–190 m category (rotor height, altitude category 3) which is a critical height for collisions with modern WTs. This percentage constituted the largest proportion of flight movements in the five altitude categories.

It should be noted in this context that altitude category 3 comprises a 90 m span in altitude while the lower altitude categories cover smaller spans. As a result, it was to be expected that a greater number of flight movements would be recorded in altitude category 3.

Moreover, given the topography and the presence of trees and shrubs it was not always possible to observe the black storks' flights close to the ground. It is therefore possible that flights in the low altitude categories are underrepresented. However, a relatively high number of flight movements took place in the danger zone of modern WT. The other evaluated studies on wind farms, i.e. the Alpenrod, Moskau-Kreuzstein and Wohnste studies, have also shown that during the breeding period black storks regularly fly at altitudes that are critical with respect to wind turbines. The proportion of flight movements visually recorded at critical altitudes as part of the above studies varies from 8% to 32%.

Flight behaviour in the vicinity of wind turbines

In the course of the present study conducted in 2016, on ten out of 121 flights (8.3%) black storks approached WTs to a degree that brought them into the danger zone (250 m radius around the WT; horizontal view). Flythroughs through wind farms were not observed during the present study. At the times the flights in the danger zone of the WTs occurred, weather conditions were always favourable (no precipitation, no high wind speeds, optimum visibility). Overall, the black storks observed were seen to fly horizontally and at times very closely around either the entire wind farm or individual turbines. The WTs were in operation at the times the flights were recorded, with rotors aligned parallel, but also sometimes perpendicular, to the direction of flight.

NABU-Hessen recorded a flythrough through the wind farm by two black storks at a critical altitude. However, the birds had chosen a sufficiently wide corridor between turbines and weather conditions were also favourable at that time.

The study on the Alpenrod wind farm (spatial behaviour analysis and monitoring) recorded flights in the danger zone at a similar proportion to that observed in the project area. Out of a total of 105 recorded flights, eight (7.6%) took place in the turbines' danger zone.

The Rabenau wind farm study painted a picture that is more or less similar: Out of a total of 50 flights, 3 (6%) took place in the danger zone. As part of that study, in May 2016 a black stork was observed to clearly engage in a horizontal manoeuvre to avoid entering the wind farm.

Looking at the combined results of the reviewed studies on black storks breeding near wind farms at Freiensteinau, Alpenrod, Hintersteinau, Rabenau and Wohnste respectively, a total of 27 (6.7%) out of 406 flights were observed in the turbines' danger zone (horizontal view). Out of these, only 12 flights can be described as conflictual given that they took place at the turbines' critical altitude in the rotor area (vertical view). These 12 flights constitute 45% of the risky flights (or 3% of total flights). Given this low proportion of conflictual flights, it would appear that the species takes a "precautionary approach" to WTs. The birds flew around the wind farms or traversed them if there was a sufficiently wide corridor.

Overall, it can be seen that despite the in part only short distances between nesting sites and the nearest wind turbine (550 m to 1300 m) only a very small proportion of total flights must be regarded as conflictual. In all those instances the storks managed to fly around the wind farms or fly through them if there was a sufficiently wide corridor; no collisions were observed. Moreover, none of the adult birds went missing in the course of the surveys, which means that there were no collisions during the study period.

Impact of weather conditions on black stork flight altitude

The present study could not infer a statistically supported model that would explain the probability of the occurrence of flights in the altitude category covering the rotor blades. Following a correlation assessment of the available weather parameters, the following parameters were used for further statistical analysis: wind speed, nacelle alignment (wind direction), visibility, temperature, sunshine duration, precipitation and air pressure.

Further parameters were discarded due to their correlation with other parameters. However, in the course of statistical analysis it became apparent that sunshine duration was often statistically significant.

Despite the unfavourable R-squared values of the respective underlying binomial Generalised Linear Models (GLM) this may point towards sunshine duration having a certain impact on black stork flight altitudes. Further more comprehensive studies, especially studies using telemetry data, could provide further insights in this respect.

In conclusion it can be said that thermals are highly likely to influence black stork flight altitudes. However, this is a conclusion that could not be drawn with certainty as part of the present study. Thermals probably play a role in particular for long-distance flights.

Land use, feeding habitats and topography

With respect to flight movements, no particular preference could be detected for land-use types. Compared to arable land or grassland, the different forest types were used significantly more frequently relative to the proportion of land area under forest cover around the nesting site, although open countryside constitutes a significantly higher proportion of land use.

For the birds studied it was shown that independent of the land cover present in a black stork pair's home range, flight movements traversed all landscape elements contained therein. Therefore the determining factors were the land-use type in which the nesting site and the feeding habitats sought out by the birds were located and the land-use types they had to fly over on their way between the nesting site and feeding habitats. It is therefore reasonable to conclude that land use in itself had no discernible impact on the spatial distribution of the black storks' flight activity.

In the other reviewed black stork studies, the birds showed a slight bias towards watercourses, and floodplains in particular, which are essential feeding habitats or lead towards such habitats; flight activity was slightly higher in such areas and the birds used them as flight corridors. It is likely therefore that black storks use distinctive valleys for orientation and that more frequently valleys also serve as flight corridors – as long as they lead towards the birds' essential feeding habitats.

In addition, it could be shown that black storks generally fly over peaks in German low mountain ranges.

The present study found a changeover, in terms of flights towards feeding habitats, from those located north of the nesting site (predominantly ponds) in the springtime to feeding habitats located to the south (predominantly semi-natural watercourses and alluvial floodplains) in the summertime. The greater abundance of amphibians in feeding habitats located in the northern to north-western section of the study area may explain the preferential use of these areas in the springtime (cf. Section 4.6).

This behaviour is evidence of a certain flexibility of the species when it comes to utilising hunting habitats in the vicinity of the nesting site, as long as the area contains an appropriate range of suitable hunting areas.

With reference to flight behaviour we can conclude that while valleys can serve as guides, flights take place above all landscape elements. In addition, it is important for black storks to have available a complex network of feeding habitats free of disturbances which can be utilised flexibly in the course of the year.

Flight activity, phenology, spatial behaviour and distances

In the Freiensteinau project area a total of approximately 0.19 flights per hour of observation or 1.52 flights per recording unit (8 hours) were recorded (121 plausible flights, two observers).

Taking into account the other reviewed studies on black storks, it was found that for studies undertaken in the vicinity of breeding territories at a distance of up to 3 km to the nesting site, generally using two recorders working synchronously and 18 days of observations at eight hours each per recorder, a number of approximately 0.17 flights of black storks is realistic. This equates to an average of approximately 1.4 flights per recording unit (cf. Table 51).

The studies reviewed show that approximately 79–98% of visually recorded flights from the nesting site covered a radius of up to 3000 m. Between 2% and 21% of flights covered distances of up to 6000 m from the nesting site (cf. Table 54). It should be noted, however, that the studies reviewed focused on a potential area of conflict and did not constitute full-coverage spatial behaviour analyses of entire territories.

<u>Conclusions</u>

The overall review of the black stork study conducted and the existing studies evaluated here shows that there have been several successful breeding attempts by black storks within a radius of 3000 m of existing wind turbines (WTs).

In Freiensteinau it was found that on 10 flights out of a total of 121 the birds entered the danger zone around the turbines. Of these, five flights were at a critical altitude. These risky flights all took place under conditions of good visibility and low to moderate winds.

Moreover, it could be shown that the black storks studied flew to within a few metres of active wind turbines, actively flew around, over or under the turbine area and, in individual cases, traversed wind farms if the situation was "manageable". Where weather conditions were favourable, the birds passed around the periphery of the installations or flew between turbines if there was a sufficiently wide corridor. It would appear that the adult birds studied only approached the wind farm if the risk was calculable.

Weather conditions do not significantly influence flight altitude in the danger zone. However, thermals probably play a role in flight altitude, especially when it comes to long-distance flights.

Land use does not impact on the spatial distribution of flight activity. However, the black storks observed were seen to evade active WTs, at times flying only very closely around them.

Overall it can be said that despite the in part only short distances between nesting sites and the nearest wind turbine (between 550 m and 1300 m) only a very small proportion of total flights must be regarded as conflictual. In all these instances the storks flew around the wind farms or through them if there was a sufficiently wide corridor; no collisions were observed. Moreover, none of the adult birds went missing in the course of the surveys, which means that there were no collisions during the study period.

In general it can be said that these conclusions were drawn based on observations of a small number of black storks and should therefore not be generalised. For this reason, it would be important to conduct further investigations (telemetry of birds breeding in the vicinity of WTs) and especially studies using new GPS transponders which record altitude data at the same time. This would allow for more profound statements on altitudes and spatial behaviour as well as on the utilisation of feeding habitats and primary home ranges.

Moreover, telemetry studies should be conducted over a period of at least 3 to 5 years focusing on several black stork specimens in different breeding areas so as to allow for assessments of a broader range of comparative data as well as of long-term data.

1 Introduction

The subject of this black stork study is the investigation of black stork flight behaviour in the vicinity of existing wind turbines (WTs) in the Vogelsberg SPA (DE 5421-401) and adjacent areas.

The study serves to extend the knowledge on black stork flight behaviour where WTs are located near nest sites. This study does not undertake an assessment of the findings with regard to the species' sensitivity to WTs.

The study's objective is to generate knowledge on black stork flight altitude in relation to weather conditions, land use and activity range during the species' main phase of activity (courtship, breeding and rearing periods) and to characterise in greater detail the black storks' flight behaviour in the vicinity of existing WTs.

No conclusions are drawn on the behaviour of juveniles, given the small number of available observations. A contribution in this regard was made by the supplementary assessment of the Rabenau wind farm study. That study was able to take account of juvenile storks, as it covered a sufficiently long observation period up to the end of August at which point juvenile storks had already begun to fly.

There are as yet no reliable published studies of black stork flight movements during the main phase of activity in the breeding area in the vicinity of WTs. Data on weather parameters, land use and topography which may potentially influence spatial behaviour are similarly lacking. Given the knowledge gaps with regard to the species' behaviour in the vicinity of WTs it is essential to build knowledge on the species' flight behaviour in order to ensure that wind energy expansion is compatible.

The study's focus is on the detailed recording of flight movements in the area of the Hallo and Auf der Haid wind farms, with regard to the nearby occupied nesting site in the Atzenstein forest (northeast of Freiensteinau).

The project remit involved the assessment of not only the own research data from the Freiensteinau project area but also the findings of other studies on black storks in spatial proximity to wind farms (Rabenau, Alpenrod, Hintersteinau, Wohnste) and supplementary data provided by the NABU-Hessen conservation NGO.

The present study is accompanied by external quality assurance for methodology and study implementation. The aim is to ensure a high level of transparency, plausibility, comprehensibility and technical reliability in terms of both its approach and its findings.

Concurrent with the commencement of the study a project advisory council was established consisting of representatives of conservation associations, wind energy associations, competent authorities, technical experts and representatives of the scientific community. The advisory council serves to ensure a high level of transparency with regard to project implementation vis-a-vis third parties and to contribute the widest possible range of expert knowledge.

2 Black stork

2.1 Occurrence and population development

In contrast to the white stork, the black stork is a shy occupant of relatively undisturbed habitats and, in central Europe, it breeds almost exclusively in woodlands. While the species had been close to extirpation in Germany, black stork populations have increased significantly in recent decades and have re-colonised large parts of their original range. At the turn of the 20th century, only between 10 and 25 breeding pairs were left in Germany (JANSSEN et al. 2004); the current population in Germany is estimated to be in the order of 650–750 breeding pairs (GEDEON et al. 2015).

The current centres of distribution in Germany are in the low mountain ranges at altitudes of between 250 and 600 m as well as in the larger forested areas of the regional states of Lower Saxony, Brandenburg and Saxony-Anhalt. Core regions include the Harz mountain range, Solling, north Hessian mountain region, Rothaar Mountains, Westerwald low mountain range, Vogelsberg, Rhön Mountains, Thuringian Forest, Franconian Forest, Fichtel Mountains, Upper Palatine Forest, Saxon Highlands, Ore Mountain Range, and Elbe Sandstone Mountains (JANSSEN et al. 2004).

The black stork is not currently on the nationwide German Red List of Endangered Bird Species (GRÜNEBERG et. al 2015); in the regional state of Hesse it continues to be listed as an endangered species (KREUZIGER et al. 2014). The black stork is strictly protected under the German Federal Ordinance on the Conservation of Species (Bundesartenschutzverordnung) and it is an Annex I species under the EU Birds Directive. The assessment of the conservation status of breeding bird species in Hesse (VSW 2014) considers the black stork conservation status to be unfavourable/insufficient; this assessment gave rise to the development of a species action plan with a view to achieving a favourable conservation status (VSW 2012).

Different estimates of the Hessian black stork population have been published. Kreuziger et al. (2014) gives a figure of 60 to 80 breeding pairs in this regional state. The breeding bird atlas for Hesse (HGON 2010) projected a total population of 100 to 120 territory pairs. However, these values would appear to be too high as they do not take account of secondary nest sites. The ornithological centre for the regional states Hesse, Rheinland Palatinate and Saarland (Staatliche Vogelschutzwarte für Hessen, Rheinland-Pfalz und das Saarland) estimates that there are between 50 and 60 breeding pairs in Hesse, approximately one third of which suffer breeding failure (pers. comm. Hormann 2017). While the species' centre of distribution is in the low mountain ranges of northern and eastern Hesse, black storks are also increasingly settling in the Taunus mountain range with its high forest cover. At between 16 and 21 breeding pairs, the Vogelsberg natural landscape unit had the highest density of black storks (HGON 2010). At present, these numbers for the Vogelsberg natural landscape unit are much lower; it is estimated that only nine breeding pairs are present (pers. comm. Hormann 2016).

2.2 Breeding habitat, home range and distance flights

Black storks breed in relatively undisturbed mature forests and predominantly search for food in streams and other watercourses. When selecting their breeding site, lack of disturbance is a primary factor and of greater importance than forest size (JANSSEN et al. 2004).

Large old trees with strong limbs are preferred for nest establishment, with the tree canopy offering the nest site protection from strong solar radiation. In Germany, these conditions are best met by old oaks, beeches or pine trees. The large birds must be able to fly freely up to the nest tree, which is why it should be located in the vicinity of a forest ride or sizeable gap in the forest canopy (JANSSEN et al. 2004).

Nest sites may be used for decades, in some cases for up to 40 years. However, such long periods of use are hardly to be expected in the central European landscapes that are subject to intensive anthropogenic use. Black storks are able to utilise the nest sites of birds of prey as a base for their own nest; evidence is available for the utilisation of the nests of common buzzards, northern goshawks, white-tailed eagles, ospreys, lesser spotted eagles and of the Buteo buteo vulpinus subspecies of the common buzzard (JANSSEN et al. 2004).

The black stork is a species with large spatial requirements; various and, in part, highly divergent figures are given in the literature. FLADE (1994), for example, states a spatial requirement during the breeding period of 100 km2. SCHRÖDER & BURMEISTER 1974, as cited in JANSSEN et al. 2004, give an average home range of 100–150 km². Analysed telemetry data that calculate the entire range using MCP (Minimum Convex Polygon) and thus also include localisation points for which there are only a small number of instances of "presence", provide significantly larger black stork range estimates. For two black stork pairs breeding in France, satellite telemetry resulted in home range sizes of 51,125 ha (=511 km2) and 87,433 ha (874 km2) respectively during the rearing period (JIGUET & VILLARUBIAS 2004). The analysis of the two female black storks' home ranges showed extreme range size deviations of 172,020 ha (1720 km2) during the rearing period and 44,000 ha (440 km2) during the post-fledgling period (JIGUET & VILLARUBIAS 2004).

Differences in the figures for flight distances between nest sites and feeding habitats are less pronounced. SACKL (1993) describes the home range radius of a black stork pair in Styria (Austria) as having a maximum extent of 7.3 km, with 76% of the feeding habitats having been located within a 3 km radius. Other figures for distance flights in the literature range from 10 to 20 km (different authors in JANSSEN et al. 2004). The "Heligoland Paper" (Helgoländer Papier) also notes that black storks covered distances of more than 20 km to reach their feeding habitats (LAG VSW 2015). As part of his long-term investigations, ROHDE (2009) found that a majority of the regular feeding flights covered distances of more than 5–7 km from the nest site. According to SÜDBECK et al. (2005) black storks cover a range of up to 16 km around the nest site for feeding purposes.

JADOUL (2000) states that during the breeding period 89% of the storks' locations (mostly feeding habitats) lay within a 20 km radius, and 55% within a 10 km radius. A possible explanation for these results may be the distribution and quality of feeding habitats. It is plausible for energetic reasons that the birds give preference to utilising feeding habitats located closer to the nest site. However, where these habitats do not offer sufficient feed it is reasonable to expect the birds to extend their feeding range to such an extent that it meets the feed requirements of both the adult birds and the offspring of the black stork breeding pair concerned (cf. GARNIEL 2014).

2.3 Feeding ecology of black storks

Preferred feeding habitats, especially in the low mountain ranges, are forest streams or tree-lined streams as well as ponds located in stream valleys. Black storks feed primarily on fish as well as on amphibians and aquatic invertebrates, while small mammals and reptiles are more rarely caught (JANSSEN et al. 2004).

The most frequently consumed prey is the brown trout (Salmo trutta), a typical representative of relatively cool, oxygen-rich, fast flowing watercourses with gravel beds and representative of many other prey species of rhithral streams preferred by the black stork, such as the loach (Barbatula barbatula), European bullhead (Cottus gobio), Eurasian minnow (Phoxinus phoxinus), brook lamprey (Lampetra planeri), river lamprey (Lampetra fluviatilis) and sea lamprey (Petromyzon marinus) (GNOR 2015).

Black stork foraging is closely tied to certain habitats. While there is a range of potential prey, black storks prefer organisms caught in humid or aquatic habitats. The species' main food groups include fish (small fish up to 25 cm in length), amphibians and (mostly aquatic) invertebrates (i.a. beetles, butterflies, grasshoppers) (JANSSEN et al. 2004).

Surveys undertaken by SACKL (1993) in Western Styria and the Waldviertel in Austria have shown that the main feeding habitats of the black stork included semi-natural streams and riverbanks (43%), wet grassland mown for livestock bedding and other cut meadows in the vicinity of forests and streams (25%), and fishponds (14%).

The publication by STRAZDS (2004) on black storks in Latvia notes a stronger affinity to different types of watercourses, assigning to them a share of 64.16%. At 16.32%, meadows, pastures and fens are of lesser importance, as are fishponds and other ponds which represented 14.56% of all utilised feeding habitats.

Watercourses that are lined by patchy vegetation structures offer sufficient cover to the black stork and increase the watercourse's species diversity, as even in warm weather their temperature tends to fluctuate less than watercourses devoid of vegetation; moreover, the roots provide cover for fish. Especially the leaf litter produced by alder trees growing along streams provides a basic food source for a range of organisms. Alder trees are thus of importance to the streams' biocoenoses and therefore determine their quality as feeding habitat for the black stork (cf. JANSSEN et al. 2004). Streams in the low mountain ranges, which tend to be characterised by predominantly gravelly or rocky beds, dynamic channel development and special channel structures such as longitudinal or cross-sectional banks and a still relatively fast flow, are important habitats and spawning grounds for fish species inhabiting streams, e.g. trout, as well as for invertebrates.

However, the density of the watercourse network alone does not give any indication of a watercourse's suitability as a feeding habitat. In contrast, watercourse quality is of major significance. "Structural watercourse quality" provides a measure of the degree of naturalness of watercourses and their floodplains. In analyses of the distribution of black stork occurrences in Hesse and the watercourses' structural quality it became "evident with high significance that the focal areas of black stork populations correlate with the presence of natural or semi-natural watercourses (structural quality grades 1-3)" (VSW 2012). Watercourses of this level of structural quality are particularly frequent at higher altitude areas located far from settlements and in areas with a high proportion of forest cover (after VSW 2012).

However, where a detailed analysis is undertaken within areas hosting black stork breeding ranges, the distribution network of watercourses that offer rich food sources, and small fish in particular, in the vicinity of the nest site is relevant (DIEHL 1999, JANSSEN 1999) (see Section 3.2.5).

2.4 Annual rhythms

In central Europe, black storks arrive at the nest site predominantly between mid-March and mid-April. The partners normally arrive separately at the nest site, with the male generally arriving ahead of the female. However, pairs have also been observed to arrive together (JANSSEN et al. 2004).

In western central Europe, and therefore also in Hesse, eggs are mostly laid between late March and mid-April. There are between three and five eggs in a clutch and these are incubated for approximately 35 to 36 days. At night only the females incubate the eggs while the partners take turns during the day (JANSSEN et al. 2004). During the first 3 to 4 weeks of their life the chicks are constantly watched by an adult. The adult bird keeping watch tends to fly off immediately as the feed-bearing partner arrives. The frequency of daily feedings is dependent on the age and number of young and varies from two to twelve, and in some cases up to 14 feedings. The juvenile storks start flying between 63 and 71 days of age and continue to return to the nest site for feedings and overnight roosting for up to another 14 days (BAUER & BAUMANN 2005). Cases of significantly longer periods of nest attachment by juvenile storks following their first flights have been observed (JANSSEN et al. 2004). Migration to the African wintering grounds commences from late August at the earliest.

2.5 Flight behaviour

Black storks measure 0.9 to 1 m in length and weigh between 2400 and 3000 g; their wingspan measures between 1.5 and 1.9 m. Given their body size, black storks, similar to other stork species, excel at soaring (GRÖBEL & HORMANN 2014).

Soaring allows the black stork to cover great distances in passive flight without expending much energy after using thermals – under beneficial weather conditions – to climb to higher altitudes by flying a spiraling path within these columns of rising air (thermaling flight). Soaring plays a particularly important role during migration but persistent thermal soaring is also used to cover distances between breeding and feeding habitats in a highly energy-efficient manner. During the breeding season, thermal soaring is one of the most frequently used forms of distance flight at 64% (JANSSEN et al. 2004).

Figure 1 (JADOUL 1998) demonstrates the principle of thermal soaring. The black storks utilise thermal columns for thermaling flight in order to reach high altitudes after which they soar passively over great distances that can be extended by repeated circular upward flights.

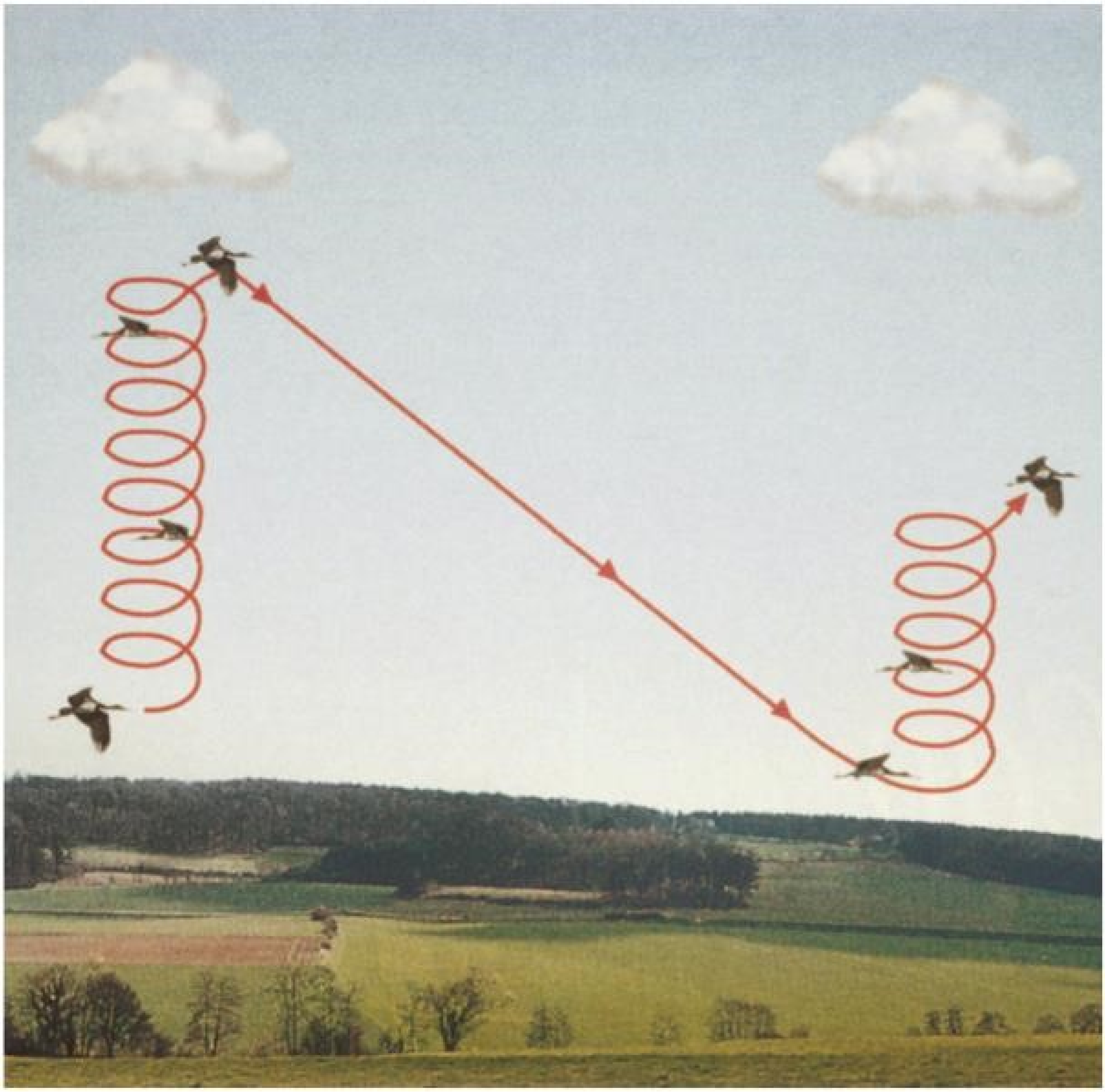

Figure 1: Depiction of flight behaviour consisting of thermaling flight and thermal soaring (after JADOUL 1998)

Thermaling flight allows black storks to gain altitude. Depending on weather conditions the black storks may repeatedly spiral upwards in thermals on their way to the feeding habitat. The spiralling upward flight primarily commences on the forest edge, followed by distance flight (ROHDE 2009) which is used to directly approach the feeding habitats.

Distance flights are targeted and mostly straight-line flights. These may be soaring flights, passive flight following thermaling flight, rowing flights, active flight involving wing beats, or a combination of soaring and rowing flight. The combination of soaring and rowing flight is the black storks' most frequent flight pattern. With this flight pattern the black storks reach an average speed of 15.4 m/s, with speeds ranging from 8 to 20 m/s. Their rowing flight speed is roughly similar at an average speed of 16 m/s (BRUDERER & BOLDT 2001).

Territorial behavioural patterns primarily involve courtship flights which, with reference to the individual bird, may also be termed territorial flights. The range of aerial courtship displays is remarkably diverse (SACKL 1993). As soon as the black storks arrive in their breeding grounds they conduct extensive territorial flights. The altitudes reached as part of different forms of flight in territorial flights range from up to 200 m for low altitude circular flights and between 400 and 1500 m for upward circular flight and soaring. As part of these territorial flights the birds display their white undertail-coverts ("flagging"), thus signalling their territorial claim. Territorial flights are undertaken under optimum weather conditions and primarily between 10:30 and 11:30 as well as between 13:00 and 14:00 hours. The breeding pairs' synchronous courtship flights can be observed in thermal updraughts from late morning to afternoon. Courtship flights may be observed into August/September. In addition to the flights signalling territorial claims, the birds also undertake other territorial flights especially in defence against rivals competing for their nest site. This involves, for example, threatening gestures (flagging, dangling shanks) that are used to entice outsider storks to leave the territory (JANSSEN et al. 2004).

Direct final approaches to and departures from the nest site tend to take place below the forest canopy. Despite its large size, the black stork is well able to navigate tree limbs and trunks. Where available, logging trails are used for the approach to the nest site (VSW 2012).

Flight movements for foraging purposes are similar to the approach to the nest site for which the storks need to, for example, navigate between trees. The black stork directly approaches its (mostly undisturbed) feeding habitats. On approach it descends and lowers its speed and conducts slowly soaring and in part meandering flight movements while lowering its head and searching for food. Black storks often make their final approach to the ground in open and accessible areas. Circling flight movements above the feeding habitats, similar to thermaling flight, have also been observed.

3 Materials and methods

3.1 Study area

The Atzenstein nest site is located approximately 1300 m away from the nearest wind turbine (WT) as part of the Hallo wind farm.

The following descriptions of the study area refer to the area within a 6 km radius around the Atzenstein black stork nest site.

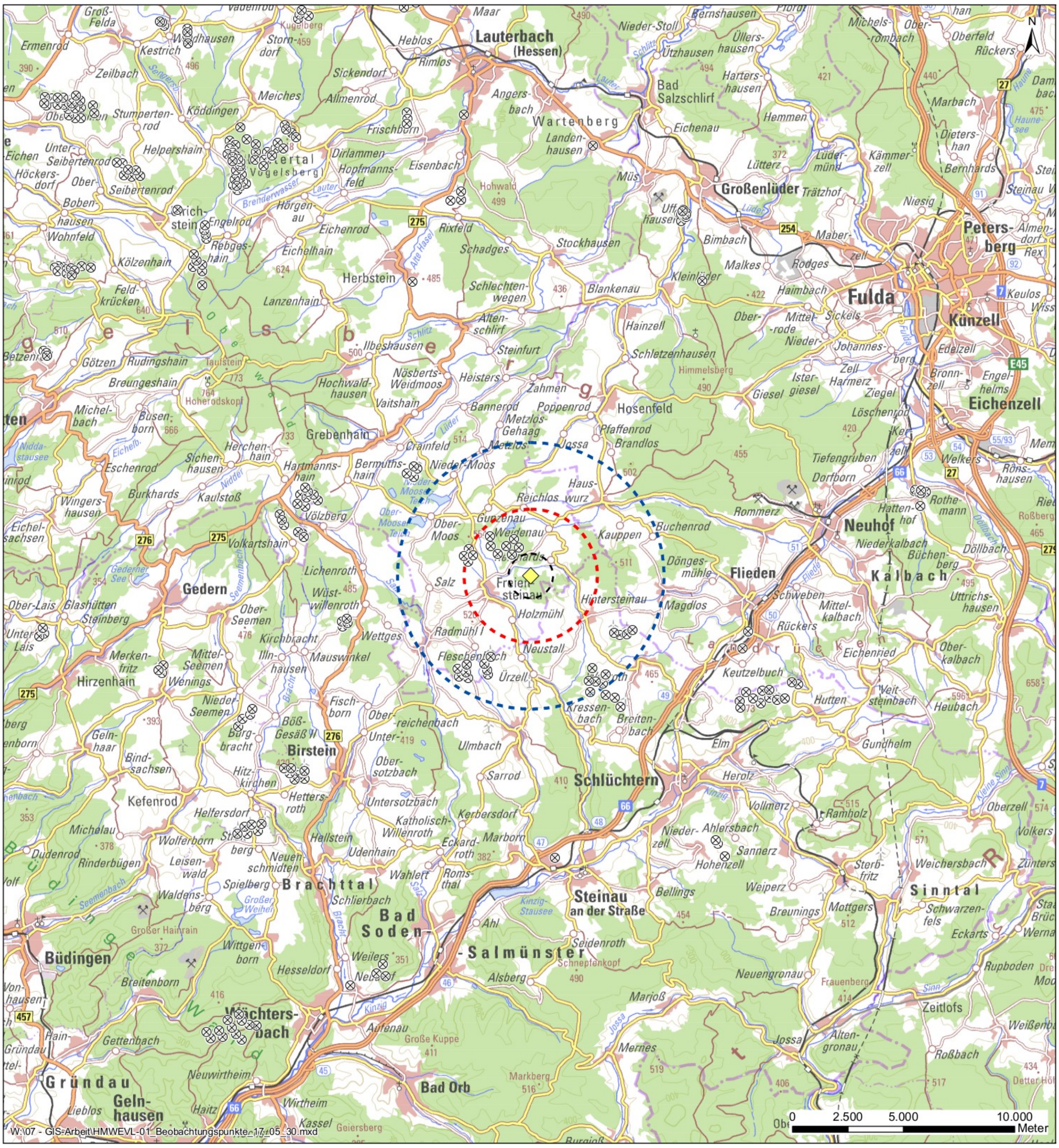

Figure 2: Location of the study area (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Location, physiographic unit

The study area is located on the south-eastern border of the Middle Hesse region, in the Freiensteinau municipality as part of the Vogelsberg district. Towards the south and east, the study area reaches into the Southern Hesse and Northern Hesse regions respectively. In the south of the study area, the Steinau an der Straße municipality (Main-Kinzig district) directly borders the Freiensteinau municipality. In the eastern part, Freiensteinau is bordered by the Flieden, Neuhof and Hosenfeld municipalities (Fulda district).

The study area comprises the geological-volcanic unit formed by the basaltic Vogelsberg mountain range which, based on its altitudinal zonation, is divided into two main natural landscape units, i.e. the Lower Vogelsberg (350) and the Upper Vogelsberg (351) centrally overlying the former.

The study area includes terrain altitudes of between 260 and 550 m a.s.l. The WTs in the two wind farms Hallo and Auf der Haid are located at altitudes of 495–500 and 510–515 m a.s.l. respectively.

Hallo wind farm and Auf der Haid wind farm

The Hallo wind farm was put into service in September 2014, consisting of seven Enercon E-101 WTs with a hub height of 135 m. Nine wind turbines were originally planned, seven of which were granted permission. WTs H2 and H9 were not approved. The neighbouring Auf der Haid wind farm was repowered in 2014 with four Enercon E-101 WTs with a hub height of 135 m. For this type of WT (Enercon 101) the rotor-free area below the rotor tip is 80 m (cf. Figure 15).

Originally this wind farm consisted of four smaller WTs with lower hub heights of 58 m and 65 m respectively and a 44 m rotor diameter. These older installations in the Auf der Haid wind farm had been approved in 1997 (three WTs) and 1999 (one WT).

Preliminary investigations

A species conservation regulatory technical report (*Artenschutzrechtlicher Fachbeitrag*, KARL 2012) is available for the approval process for the Hallo wind farm development. The species conservation regulatory technical report is based on population survey data from 2011 and on field protocols prepared by biologist Dipl.-Biol. Frank W. Hennig who conducted the survey on four observation days in 2011. Other information taken into consideration includes data from the approval documents for the Auf der Haid wind farm by BFF, Korn & Stübing (March 2010, in KARL 2012) and data by M. Jäger of NABU (German Federation for Nature Conservation, 2010 and 2011).

Figure 3 shows an overview map of the results of the survey conducted by the consultancy firm KARL (2012) for the Hallo wind farm development. The survey data are depicted with reference to the main flight routes while lesser frequented routes were not taken into account (KARL 2012). The depictions of flight movements constitute interpretations of the data as analysed.

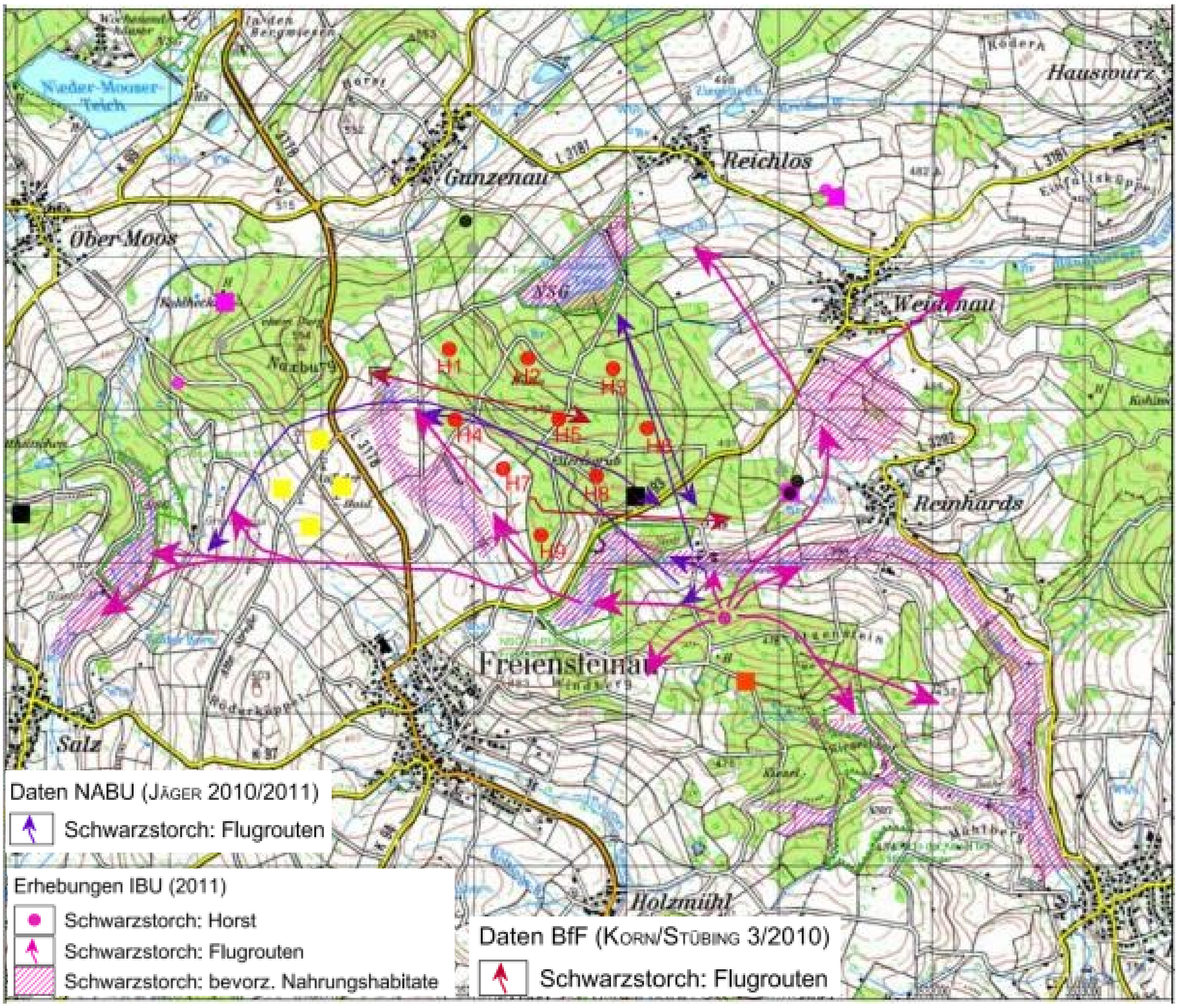

Figure 3: Black stork flight movements prior to the development of the Hallo wind farm (after Karl 2012)

Daten NABU …	Data by NABU (Jäger 2010/2011) Black Stork: flight routes
Erhebungen IBU…	Surveys by IBU (2011) Black stork: nest site Black stork: flight routes Black stork: pref. feeding habitats
Daten BfF…	Data by BfF (Korn/Stübing 3/2010) Black stork: flight routes

Flight movements in 2011 after Karl (2012)

Out of the eight flight movements observed between late June and late July, one on 20.07.2011 traverses the southern wind farm in the area of WTs H7 and H9.

30.06.2011 (two flight movements)

15:06 hrs: One stork departs the nest site in a south-easterly direction over the Atzenstein, long flight movement.

17:46 hrs: One stork departs the nest site in an easterly direction over the Steinaubachtal and Reinhards in the direction of the Kohlwald mountain, long flight movement.

09.07.2011 (two flight movements)

09:18 hrs: Short flight movement east of the forest at Hallo in the area of the K 93 towards Hainbach west of Weidenau.

14:08 hrs: Long flight movement east of the forest at Hallo commencing at the Reinhard water tower and continuing in a north-easterly direction to the Hängsberger Wasser river.

10.07.2011 (two flight movements)

08:15 hrs: Short flight movement over grassland north of the Atzenstein in an easterly direction towards the Steinaubach stream.

11:17 hrs: Short flight movement in the Steinaubachtal, flying in an easterly direction towards Reinhards.

20.07.2011 (two flight movements)

20:00 hrs: Two departures from the forest hosting the nest site. One of these flights takes a north-westerly direction above the planned WT H9 and WT H7. The other flight movement takes a south-westerly direction towards the Ürzeller Wasser stream east of Freiensteinau.

Information on flight altitudes

According to KARL (2012), flight altitudes were consistently below 50 m.

Flight movements recorded in 2010/2011 by M. Jäger of NABU, nest attendant and local representative of the VSW (ornithological centre)

Four flight routes (inward and outward flights) are shown in the area of the planned wind farm. A further flight route is used in the Stollmühle area. The flight routes lead to feeding habitats and traverse the forest area at Hallo. Listed feeding habitats include the upper reaches of the Steinaubach stream (southeast of Naxburg), the Reichlos pond, and an area of wet grassland near Salz.

Flight movements recorded in 2010 by BFF, Korn & Stübing in (KARL 2012)

Two flight routes are shown in the Hallo forest area leading towards the standing water and upper reaches of the Steinaubach stream (southeast of Naxburg) and towards the southern edge of the forest in the Hallo forest area.

With regard to the flight routes observed in 2011 the expert report concludes the following:

"The data indicate that the storks fly westwards, more or less in a straight line, to reach the upper reaches of the Salz river. The storks also use the stream between the Hallo and the L 3178 state road for foraging; to this end the storks fly along the upper slopes and close to the forest edge. The Steinaubachtal valley can be approached directly from the nest site. From this valley the storks also fly to the area between Reinhards and Weidenau and towards the Reichlos pond, which means that according to our own observations the storks fly around the Hallo forest area. Judging from the data made available by JÄGER and BFF however, there are also flight routes that lead over the forest area and through the centre of the planned wind farm." (KARL 2012, translated from German original quote).

The expert report notes the following feeding habitats:

- Entire Steinaubachtal valley up to Hintersteinau
- Reichlos pond
- Area between Reinhards and Weidenau
- Area of wet grassland north of Salz (including the Bruchwiesen nature reserve)
- Valley forest meadows at the Kieselkopf hill

The preliminary study conducted with respect to the Hallo wind farm does not meet current standards for spatial behaviour analyses. However, the observed flight routes are an important reference point, allowing for the information to be compared to current spatial behaviour as described in Chapter 6.

3.2 Land use

The study area is characterised by a patchwork of smaller contiguous forest areas dispersed in an otherwise open landscape with a hilly and in part plateau-like landform and terraced terrains with a richly structured bocage landscape. Semi-natural alluvial systems with springs, small alder woodlands, swamps, wet fallows, wet grassland, ponds and fens traverse the study area in the form of a linear network and also include some larger sites within the otherwise intensively used agricultural landscape.

As a result of the predominantly intensive agricultural management, structurally rich forest areas have largely retreated to the hilltops and upland plateaus.

The watercourses in the study area had been used to power mills in the past, including the centrally located Steinaubach stream. The larger storage ponds in the areas around Ober-Moos and Reichlos were used for fish production in the past (NOWAK & SCHULZ 2004).

The full-coverage land-use data of the digital landscape model (DLM) were used for the land-use analysis with regard to flight behaviour.

Given that the black stork is considered a character bird species of "intact stream ecosystems with a healthy fish population" (JANSSEN & KOCK 1996, NOTTORF 1988, SACKL 1993, HAUFF 1993, STRAZDS et al. 1993, KLAUS et al. 1993) and successful breeding is only "made possible by the presence of a certain density of intact streams in the riverine landscape " (JANSSEN & KOCK 1996, BOCK et al. 1993), the analysis must take additional quality parameters into account.

Therefore, in addition to the data on semi-natural watercourse structures (see Section 3.2.2), data on aquatic or humid habitats of alluvial plains and marshlands (see Section 3.2.4) as well as data on the food supply (populations of fish, amphibians and reptiles) were included in the analysis.

Additionally, the results of the monitoring for the purposes of establishing new small waterbodies/widened stream beds (PLANUNGSGRUPPE GRÜN 2016b) were taken into account.

3.2.1 Natura 2000 sites

The following Natura 2000 sites are located in the study area (see Figure 4, Figure 5); these are of varying relevance to the black stork study.

1. SPA 5421-401 "Vogelsberg"
2. SAC 5522-301 "In der Kiesel bei Hintersteinau"
3. SAC 5522-303 "Talauen bei Freiensteinau und Gewässerabschnitt der Salz"
4. SAC 5522-304 "Vogelsbergteiche und Lüderaue bei Grebenhain"
5. SAC 5622-310 "Steinaubachtal und Ürzeller Wasser"

6. SAC 5523-302 "Zuflüsse der Fliede"
7. SAC 5423-304 "Lüder mit Zuflüssen"
8. SAC 5622-307 "Kaupe und Lochwiese bei Ürzell"
9. SAC 5622-304 "Weiherskopf/Hohestein"

Of relevance to the analysis of potential feeding habitats are the SACs that host extensive alluvial systems including watercourses, standing waters and aquatic or humid habitats (sites 3-7). Sites hosting small-scale humid habitats structures for the species are also of significance (Sites 2, 8, 9). Moreover, the Vogelsberg SPA 5421-401 is of relevance to the analysis; however, this SPA does not fully cover the entire study area but is limited to its north-western section (see Figure 4).

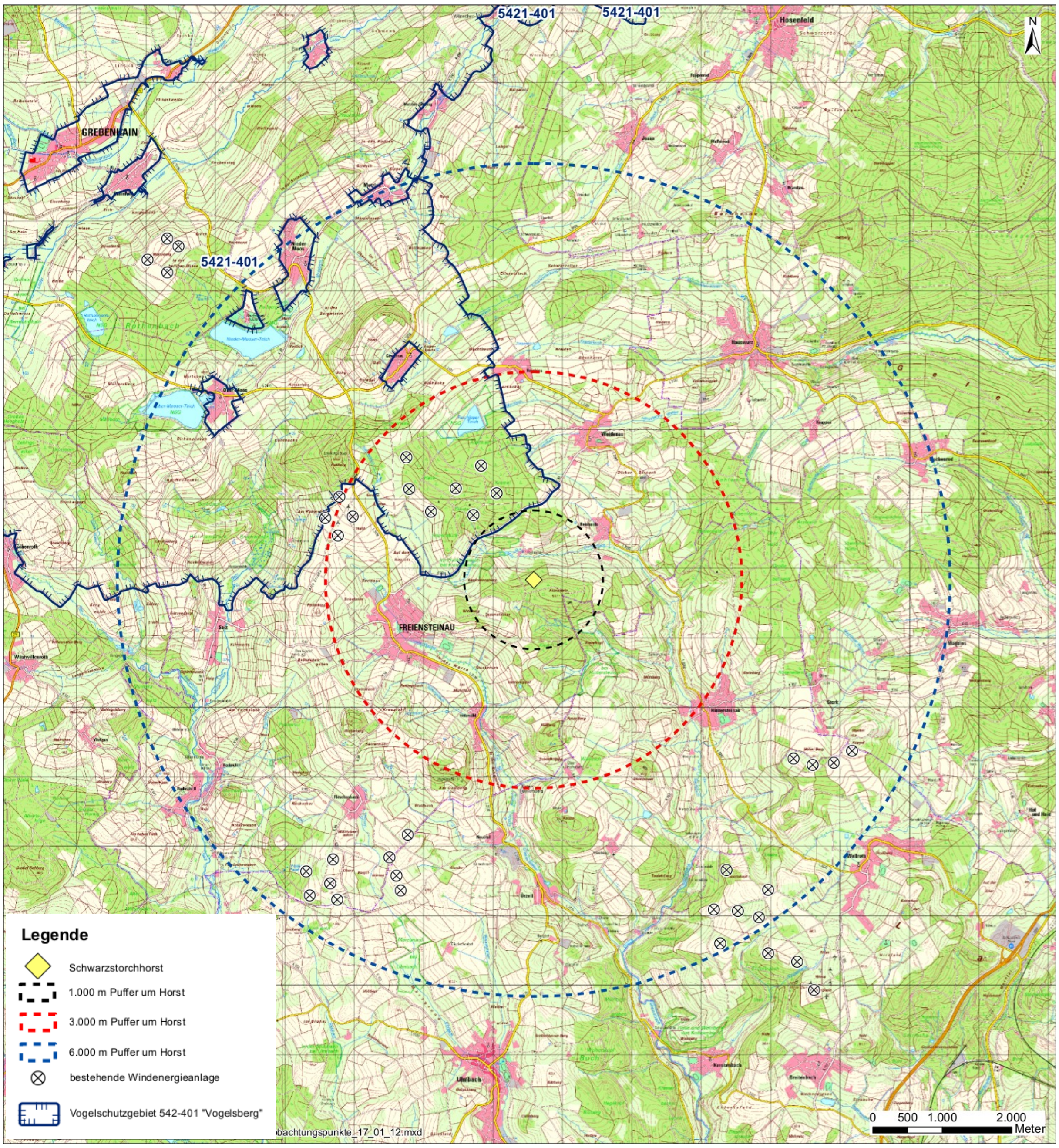

Figure 4: Vogelsberg SPA 5421-401 and its location within the study area (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key
Schwarzstorchhorst	Black stork nest site
1.000 m Puffer um Horst	1000 m buffer around nest site
3.000 m Puffer um Horst	3000 m buffer around nest site
6.000 m Puffer um Horst	6000 m buffer around nest site
Bestehende…	Existing wind turbine
Vogelschutz…	SPA 5421-401 Vogelsberg

Figure 5: SACs within the study area which contain habitat structures for the black stork (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

3.2.2 Watercourses

Semi-natural watercourses are among the most important food sources for the black stork. A decisive factor for a watercourse's degree of naturalness and its associated richness as a food source, i.e. its abundance of small fish, cyclostomata and aquatic invertebrates (benthic macroinvertebrate fauna), is a varied and porous interstitial with a high diversity of substrates (stones, coarse gravel, granular gravel, sand, silt) (JANSSEN 1999). This structural diversity benefits both the species diversity and abundance of benthic macroinvertebrates and fish (JANSSEN 1988).

Potentially very well suited feeding habitats for the black stork were considered to be structural quality grades 1-3, i.e. all recorded watercourse segments the streambed structure of which is unaltered, as well as any significantly or strongly altered segments classified as structural quality grades 4 and 5 insofar as they are segments that are located between semi-natural segments. Figure 6 shows the watercourses for which a GESIS (information system for structural watercourse quality) assessment on streambed structure is available.

Given that data on structural watercourse quality in the study area are only available for watercourses more than 1 m in width and given that the black stork also frequents narrower streams rich in small fish in both forests and open habitats, the semi-natural watercourse segments included in the statewide Hessian habitat inventory as recorded in 2006 were also taken into account. The segments thus documented represent smaller streams of the low mountain ranges that display high structural diversity and a diversity of substrates (see Figure 7).

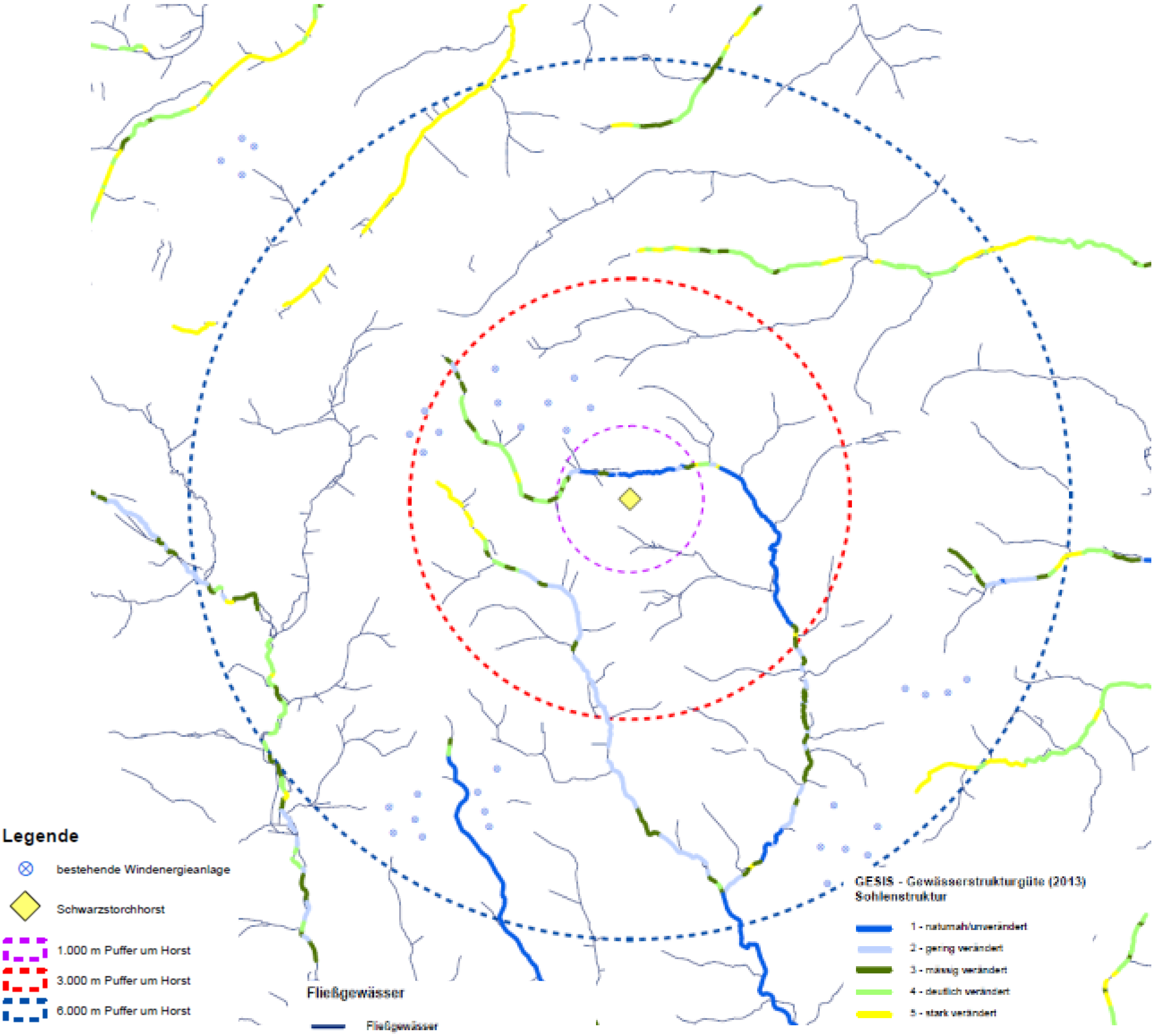

Figure 6: Overview of structural watercourse quality with regard to streambed structure in the study area, GESIS 2013

	Map key
Bestehende…	Existing wind turbine
Schwarzstorchhorst	Black stork nest site
1.000 Puffer um Horst	1000 m buffer around nest site
3.000 Puffer um Horst	3000 m buffer around nest site
6.000 Puffer um Horst	6000 m buffer around nest site
Fließgewässer	Watercourse
GESIS …	GESIS – Structural watercourse quality (2013) Streambed structure
1…	1 – semi-natural/unaltered
2…	2 – insignificantly altered
3…	3 – moderately altered
4…	4 – significantly altered
5…	5 – strongly altered

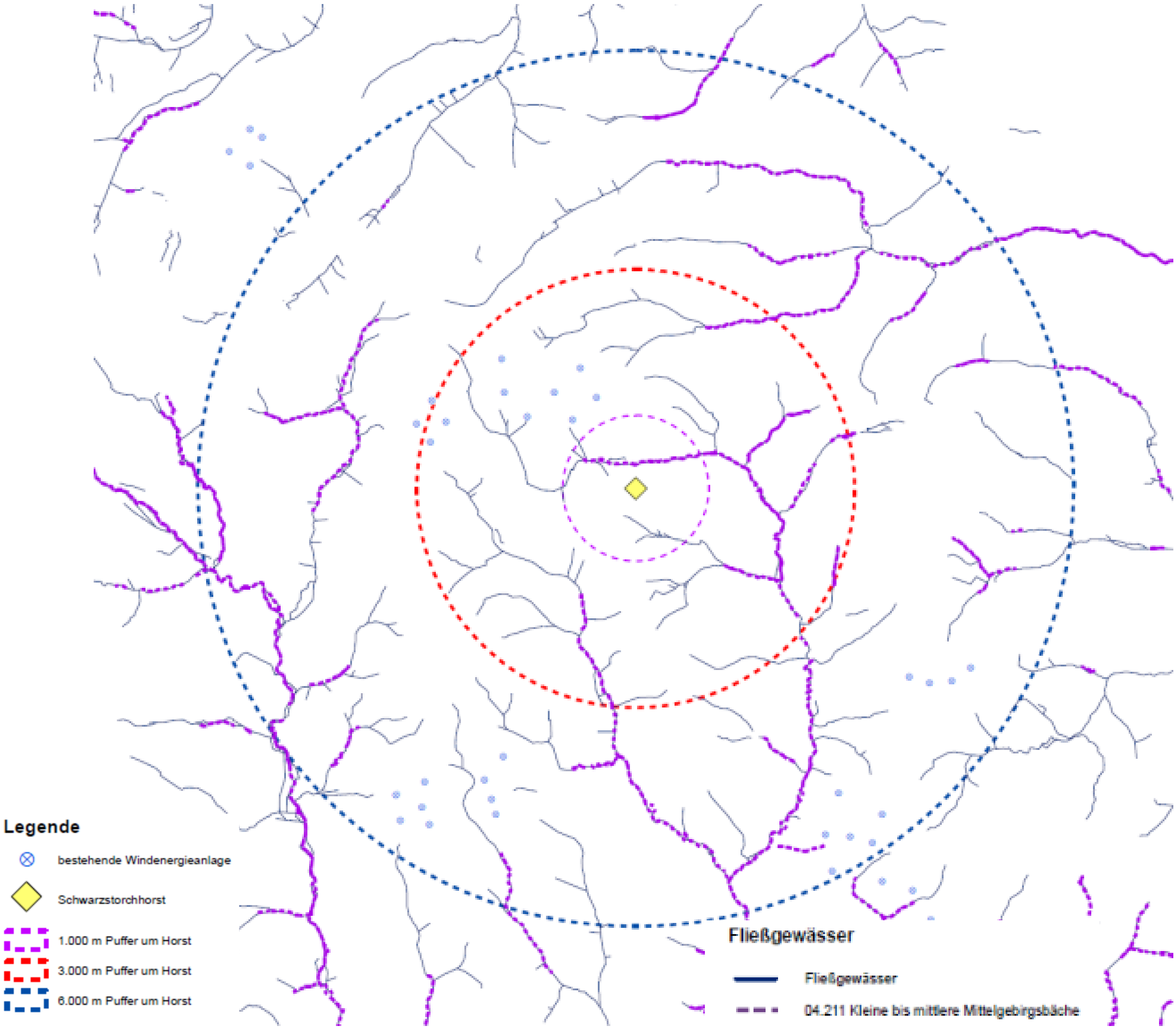

Figure 7: Overview of semi-natural small to medium sized streams of low mountain ranges in the study area, Hessian habitat inventory, recording year 2006

04.211 ...	04.211 Small to medium sized streams of low mountain ranges

The population density of aquatic organisms is critical with a view to the assessment of the watercourses' suitability as black stork feeding habitats. Therefore the data made available on fish, cyclostomata, crustaceans, bivalves were analysed (see Section 3.2.5).

Based on the general assumption that semi-natural watercourse segments with a varied and porous interstitial provide a mosaic of micro-habitats for a range of different aquatic invertebrates, no further analysis was conducted with respect to this faunal group.

3.2.3 Standing waters

Standing waters are among the other important feeding habitats for the black stork (JANSSEN et al. 2004). Existing DLM data, habitat maps of the Natura 2000 sites, and data of the statewide Hessian habitat inventory were included in the assessment. The following categories were used for the assessment of potential feeding habitats.

Table 1: Relevant habitat types for standing waters in the SPA

Code	Type
321	Man-made ponds, natural ponds
322	Flooded extraction pits and larger flooded quarries
323	Impounding reservoir
324	Natural alluvial waters

Table 2: Relevant biotope types for standing waters, within and outside of SACs

Code	Type
04.410	Impounding reservoirs
04.420	Man-made ponds
04.440	Pools
04.430	Flooded extraction pits and quarries

Key criteria for the potential suitability of standing waters are relatively undisturbed locations, the presence of shallow and accessible shorelines and the provision of sufficient cover and protection by riparian woody vegetation growing along waterbody margins (VSW 2012, JANSSEN et al. 2004).

The data made available on fish, amphibians and reptiles (see Section 3.2.5) were analysed for the purpose of assessing the quality of the standing waters as food sources.

3.2.4 Aquatic and humid habitats of alluvial areas and marshlands

According to the literature review (see Section 2.3) the black stork, in order to expand its feeding habitat, seeks out aquatic and humid habitats of alluvial and marshy areas in the forest as well as structured open landscapes occurring in the vicinity of the watercourses and ponds of alluvial plains. The distribution of aquatic biocoenoses in the study area was determined using the baseline data compilation for the Natura 2000 sites and the statewide Hessian habitat inventory. The following categories were taken into account:

Table 3: Relevant habitat types in the SPA

Code	Type
162-165	Humid forest
225	Wet grassland, extensively used
226	Sedge swamps
227	Structurally rich grassland complexes
341	Phragmites reed bed
342	Complex sedimentation zones

Table 4: Relevant biotope types, within and outside of the SAC

Code	Type
01.173	Alluvial forests along small streams
01.174	Carr and marshy forests

02.200	Woodlands of humid to wet sites
04.211	Small to medium sized streams of low mountain ranges
05.110	Reeds
05.130	Humid fallow and perennial tall herb communities
05.140	Tall sedge swamps
05.210/05.220	Small sedge swamps
06.210	Grassland of humid to wet sites
06.220	Grassland of periodically humid sites

3.2.5 Food supply in the study area

Whether or not a potential feeding habitat is utilised by the black stork is critically dependent on the actual availability of a food supply.

A comprehensive data set held by the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG) for the study area was evaluated with respect to a range of different faunal groups of aquatic or humid habitats in order to determine the presence or otherwise of the required faunal food supply described in Section 2.3. The distribution data were obtained from a number of different expert reports (AGAR 2007, AGAR 2008, AGAR 2009, BPG 1993, BIOPLAN MARBURG GBR 2009, BIOPLAN MARBURG GBR 2014, BIOPLAN MARBURG GBR 2015, DEMUTH-BIRKERT et al. 2000, FENA 2005, FENA 2006, FENA 2008, DÜMPELMANN 2004, FORSCHUNGSSTATION KÜNANZHAUS 2013, GIMPEL 2005, HEIMES 1990, HLUG 2019-2013, PNL 2012, PNL 2007, HGON 2005, JEDICKE 1999, JEDICKE 1992, JEDICKE & ECKSTEIN 2000, JUNGBLUTH & SCHMIDT 1972, JUNGBLUTH 1974, NICOLAY 2002, NICOLAY 2008, NICOLAY 2013, NZH 2000, ECODAT 2004, REGIERUNGSPRÄSIDIUM GIEßEN 2013, REGIERUNGSPRÄSIDIUM KASSEL 2013, PNL 2000, SCHWEVERS 1990, SCHWEVERS 1991, SCHWEVERS 2002, SONNTAG 1985, STEINER 2005a, STEINER 2005b, STEINER & ZITZMANN 2006a, STEINER & ZITZMANN 2006b, STEINER & ZITZMANN 2006c, UIH INGENIEUR- UND PLANUNGSBÜRO 2007, WAGU GMBH 2007).

The following faunal groups were analysed:

Amphibians:

Alpine newt (*Triturus alpestris*), common toad (*Bufo bufo*), European tree frog (*Hyla arborea*), palmate newt (*Triturus helveticus*), fire salamander (*Salamandra salamandra)*, yellow-bellied toad (*Bombina variegata*), common frog (*Rana temporaria*), pool frog (*Rana lessonae*), natterjack toad (*Bufo calamita*), northern crested newt (*Triturus cristatus*), marsh frog (*Rana ridibunda*), smooth newt (*Triturus vulgaris*), common water frog (*Rana kl. esculenta*).

Fish, cyclostomata, crustaceans and bivalves:

European eel (*Anguilla anguilla*), grayling (*Thymallus thymallus*), river trout (*Salmo trutta fario*), brook lamprey (*Lampetra planeri*), European bitterling (*Rhodeus amarus*), thick shelled river mussel (*Unio crassus)*, common chub (*Leuciscus cephalus*), European crayfish (*Astacus astacus*), common minnow (*Phoxinus phoxinus*), duck mussel (*Anodonta anatina*), European perch (*Perca fluviatilis*), swan mussel

(*Anodonta cygnea*), European bullhead (*Cottus gobio*), gudgeon (*Gobio gobio*), common dace (*Leuciscus leuciscus*), northern pike (*Esox lucius*), spinycheek crayfish (*Orconectes limosus*), Eurasian ruffe (*Gymnocephalus cernua*), Atlantic salmon (*Salmo salar*), moderlieschen (*Leucaspius delineatus*), rainbow trout (*Oncorhynchus mykiss*), thick shelled river mussel (*Unio crassus riparius*), common roach (*Rutilus rutilus*), common rudd (*Scardinius erythrophthalmus*), European weather loach (*Misgurnus fossilis*), tench (*Tinca tinca*), stone loach (*Barbatula barbatula*), zander (*Sander lucioperca*).

Reptiles:

Slowworm (*Anguis fragilis*), common European adder (*Vipera berus*), grass snake (*Natrix natrix*), smooth snake (*Coronella austriaca*), viviparous lizard (*Lacerta vivipara*), sand lizard (*Lacerta agilis*).

3.2.6 Creation of small waterbodies/widened stream beds

Numerous habitat enhancement measures for black storks were already carried out in the study area in the years 2012 to 2015; these were mitigation measures for the Hallo wind farm and involved the creation of small water bodies/widened stream beds of a total size of 0.75 ha (PLANUNGSGRUPPE GRÜN 2016b). The aim of these measures was to prevent possible disturbances at the storks' feeding habitats and to steer foraging flights by the black stork pair breeding 1.3 km away from the wind farm at the Atzenstein towards low-conflict landscape zones.

1. Measures taken at the Schwarzellerbach stream

In 2013 and 2014, five small waterbodies/widened stream beds of a total size of 2250 m² were established in the alluvial plain of the Schwarzellerbach stream. In 2014, juvenile moderlieschen (*Leucaspius delineatus*) were introduced. The stream carries water year-round including the dry summer months. According to the consultancy (PLANUNGSGRUPPE GRÜN 2016a) there have been numerous black stork sightings in the alluvial plain. Evidence of a foraging black stork observed on 25.08.2016 by Lars Simpelkamp was included in the consultants' report (PLANUNGSGRUPPE GRÜN 2016a).

2. Measure taken at Kemmete and Weiherwiesen

In 2013, the bed of the Kemmete stream downstream of the Ziegelteich pond was widened in five places, totalling an area of 2200 m². Common toads and common frogs took up residence in the small water bodies in the same year. According to the consultancy (PLANUNGSGRUPPE GRÜN 2016a) there are records of black stork sightings along the stream; however, the exact dates or numbers of individuals sighted are not specified. The stream carries water year-round including the dry summer months (PLANUNGSGRUPPE GRÜN 2016a).

3. Measure taken at the Holzmühler pond

In 2013, a small 650 m² waterbody was created and connectivity established to the Holzmühler pond. The small waterbody carries water to capacity despite dry conditions at the peak of summer (PLANUNGSGRUPPE GRÜN 2016a).

4. Measure taken in Reinhards

In 2013, a 1200 m² waterbody was created southeast of Reinhards at the Steinebach stream. In 2015, the small waterbody was enlarged to a size of 2400 m². In 2016 it carried water even during dry summer conditions, albeit not as much as prior to the enlargement (PLANUNGSGRUPPE GRÜN 2016a). According to the consultancy (PLANUNGSGRUPPE GRÜN 2016a) undetailed records exist of black stork sightings at the small waterbody.

5. Measure taken at Fleschenbach

Along the Wöllbach stream northeast of Fleschenbach four small water bodies were created totalling 1200 m² in size. According to the consultancy (PLANUNGSGRUPPE GRÜN 2016a) a black stork was sighted at the location on 29.04.2015. Three of the four small water bodies carry water year-round including during dry summer conditions (PLANUNGSGRUPPE GRÜN 2016a).

3.3 Selection of observation points

The observation points were selected in such a way that the recorders had a good view of the study area or parts thereof. The selection of observation points is an important basis of the survey's quality, its results and the results' relevance. Therefore, the following criteria were developed specifically for the black stork survey and the individual observation points were to meet as many of these criteria as possible (based on (ROHDE 2009)):

- Low distance to the known nest site – less than 3 km;
- Good visibility at both near- and long-distance ranges – with a view to recording distance flights;
- Very good visibility of the forest hosting the nest site and of existing WTs.

During the course of the surveys, the focus was placed on observations of flight movements in the existing wind farm and its surrounds.

The first step in the selection involved modelling; to this end an elevation model was compiled including all visibility ranges. Twelve potential observation points were identified on this basis (Figure 8). These were ground truthed in the field, photographed (viewshed) and assessed against the criteria given above.

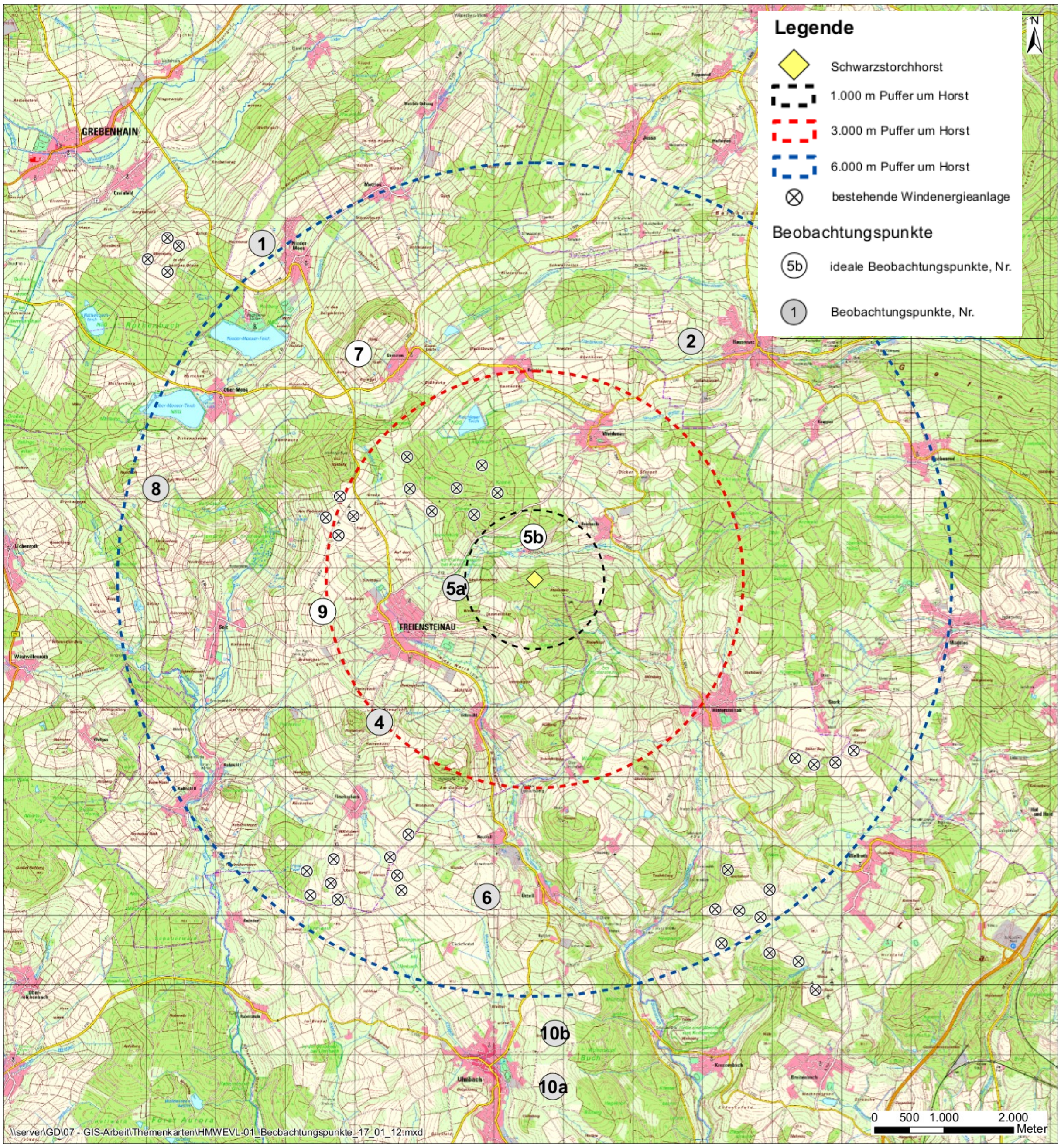

Figure 8: Overview of the observation points (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Beobachtungspunkte	Observation points
Ideale …	Ideal observation points, No.
Beobachtungspunkte…	Observation points, No.

On the initial survey days the observation points selected based on the elevation model were assessed as to their suitability in accordance with the set criteria. Subsequently three observation points were selected which most closely met the set criteria and these were manned primarily on the subsequent survey days: 5b, 7 and 9 (see Figure 9, Figure 10 and Figure 11). All three observation points are characterised by a distance of no more than 4000 m to the Atzenstein nest site and by their spatial proximity to the wind farms. A detailed list of the observation times and observation points is given in Table 12 (see 3.6).

Observation point 5b (Figure 9) was distinguished by its proximity to the forest hosting the Atzenstein nest site and by excellent visibility into this forest. This observation point was therefore particularly suited to observing the activities around the nest site during the rearing period and for recording flight movements in the vicinity of the forest hosting the nest site during inclement weather and at dawn or dusk. Moreover, with regard to flight movements it lent itself well to observing approaches to and departures from the forest hosting the nest site, especially to the north of the nest site.

Figure 9: Observation point 5b, view towards the forest hosting the nest site (facing south)

Observation point 7 offers a view towards the southeast, i.e. towards the two wind farms Hallo and Auf der Haid, as can be seen in Figure 10. Moreover, the Ober-Moos and Nieder-Moos ponds, which are relevant as potential black stork feeding habitats, are located towards the west. This observation point was well suited to observing flight movements (distance flights, thermaling flights and foraging flights) in the northern half of the study area as well as high altitude flights in the entire study area. It also allowed for some of the approaches and departures to and from the forest hosting the nest site to be observed.

Figure 10: Observation point 7, view towards both of the wind farms (facing southeast)

Observation point 9 is characterised by offering good surveyability in both near- and long-distance ranges. It offers spatial proximity to the wind farms located towards the northeast (Auf der Haid and Hallo) and an overview of the forest hosting the Atzenstein nest site. Moreover, this observation point provides a good view towards the forest hosting the Holmenstein nest site which was not occupied during the study period. Distance flights, thermaling flights and foraging flights as well as approaches to and departures from the two forests could be observed from this point.

Figure 11: Observation point 9, view towards both of the wind farms (facing northeast)

The following section discusses the visibility of the study area from the three most frequently used observation points. Visibility was modelled using the digital elevation model (DEM) with a point density of 5 m. To further improve the visibility analysis, the DEM data were modified to take account of land use. In forest areas 20 m were added to the terrain elevation in order to take account of the height of the trees. Visibility modelling utilised the "r.viewshed" function in QGIS (QGIS DEVELOPMENT TEAM 2016) to check for visibility between the individual observation points and each of the DEM points in the area in question. The function's observer height is set at 2 m. Where visibility between the points is not blocked by other points of the DEM, such as for example hills or mountain ranges, this DEM point is classified as "visible". Where an obstacle blocks visibility, the point is classified as "not visible". An overall picture arises from these calculations showing which sections of the area examined are visible from a particular observation point. It should be noted that the areas shown depict the visibility at exactly the heights specified but not the intervals between the altitude categories (see Figure 12 to Figure 14).

This approach was repeated for different target elevations above the underlying terrain in order to ascertain the flight altitudes at which flight events can or cannot be observed. The individual target elevations were selected with reference to the selected flight altitude categories (see Section 3.4). It should be noted that modelling was carried out based on the individual observation points' GPS coordinates. However, given that the recorders in the course of the surveys at times moved short distances from the observation points, so as to further observe flight movements at the edge of their field of view for example, the viewsheds depicted should not be taken to be absolute.

Table 5 shows the viewable area within a study radius of 6000 m for the individual observation points as determined by the visibility model.

Table 5: Viewable target elevations according to the visibility analysis

Observation point	Model elevation	Visible area in 6000 m radius [ha]	Share [%] (total appr. 11,300 ha)
5b	0 m	69	0.6
	25 m	334	3.0
	50 m	673	6.0
	80 m	1,030	9.1
	200 m	3,083	27.3
	500 m	6,698	59.3
7	0 m	655	5.8
	25 m	3,648	32.3
	50 m	5,330	47.2
	80 m	7,207	63.8
	200 m	11,186	99.0
	500 m	11,300	100.0
9	0 m	974	8.6
	25 m	3,990	35.3
	50 m	5,699	50.4
	80 m	7,828	69.3
	200 m	11,218	99.3
	500 m	11,300	100.0
Totals	0 m	1,632	14.4
	25 m	6,293	55.7
	50 m	8,024	71.0
	80 m	9,411	83.3
	200 m	11,300	100.0
	500 m	11,300	100.0

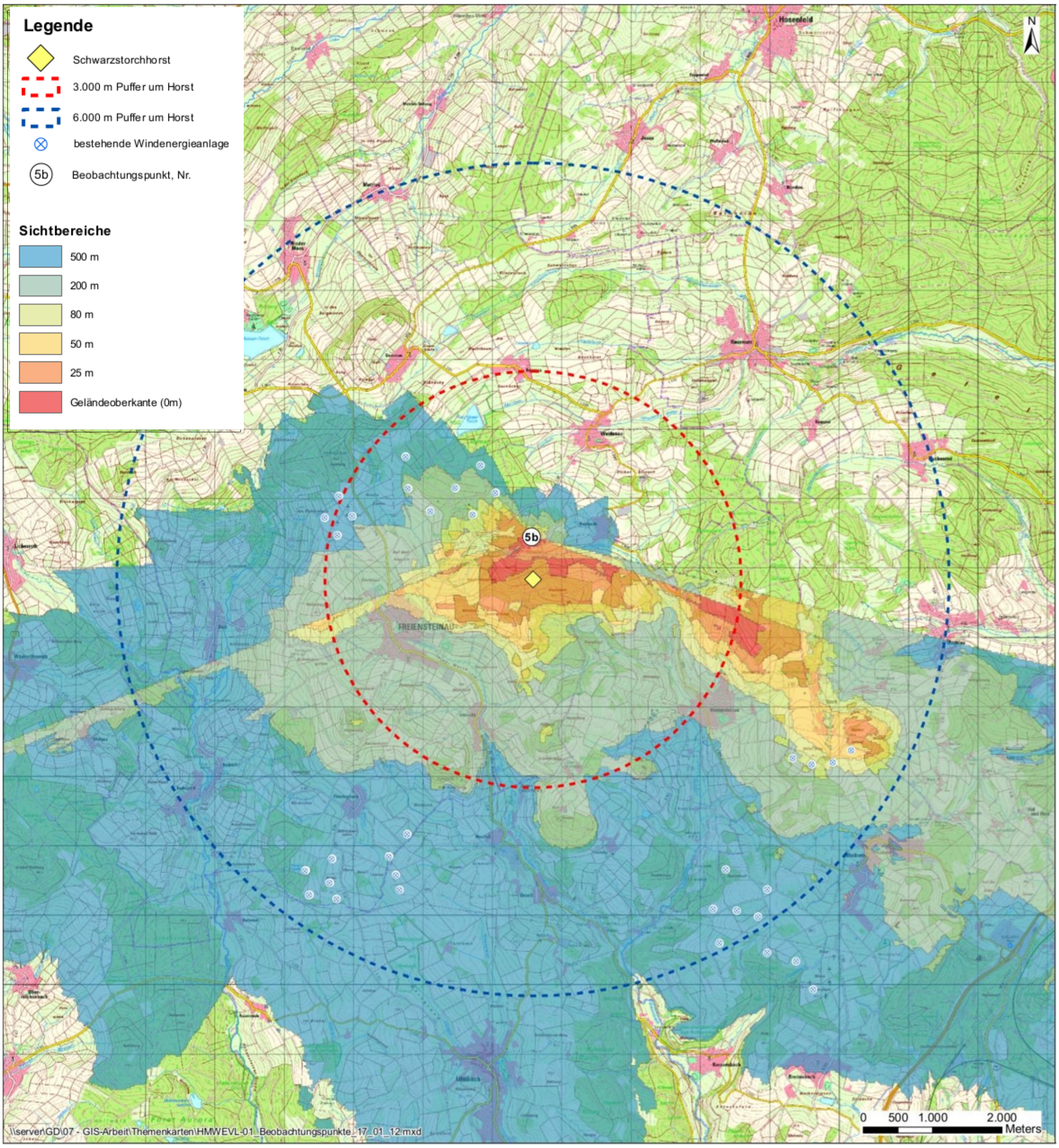

Figure 12: Viewshed of observation point 5b (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key for Figs. 12-14
	(otherwise as in previous maps)
Sichtbereiche	Fields of view
Geländeoberkante (0m)	Ground level (0m)

The viewshed of observation point 5b primarily includes the areas immediately to the north of the nest site and to the east of the observation point, in parts down to ground level. In the southern half of the study area, the higher/upper airspace (between 200 m and 500 m above ground level) was visible. Due to the location of the observation point on the edge of a forest, the northern half of the study area was not within view even at high elevations.

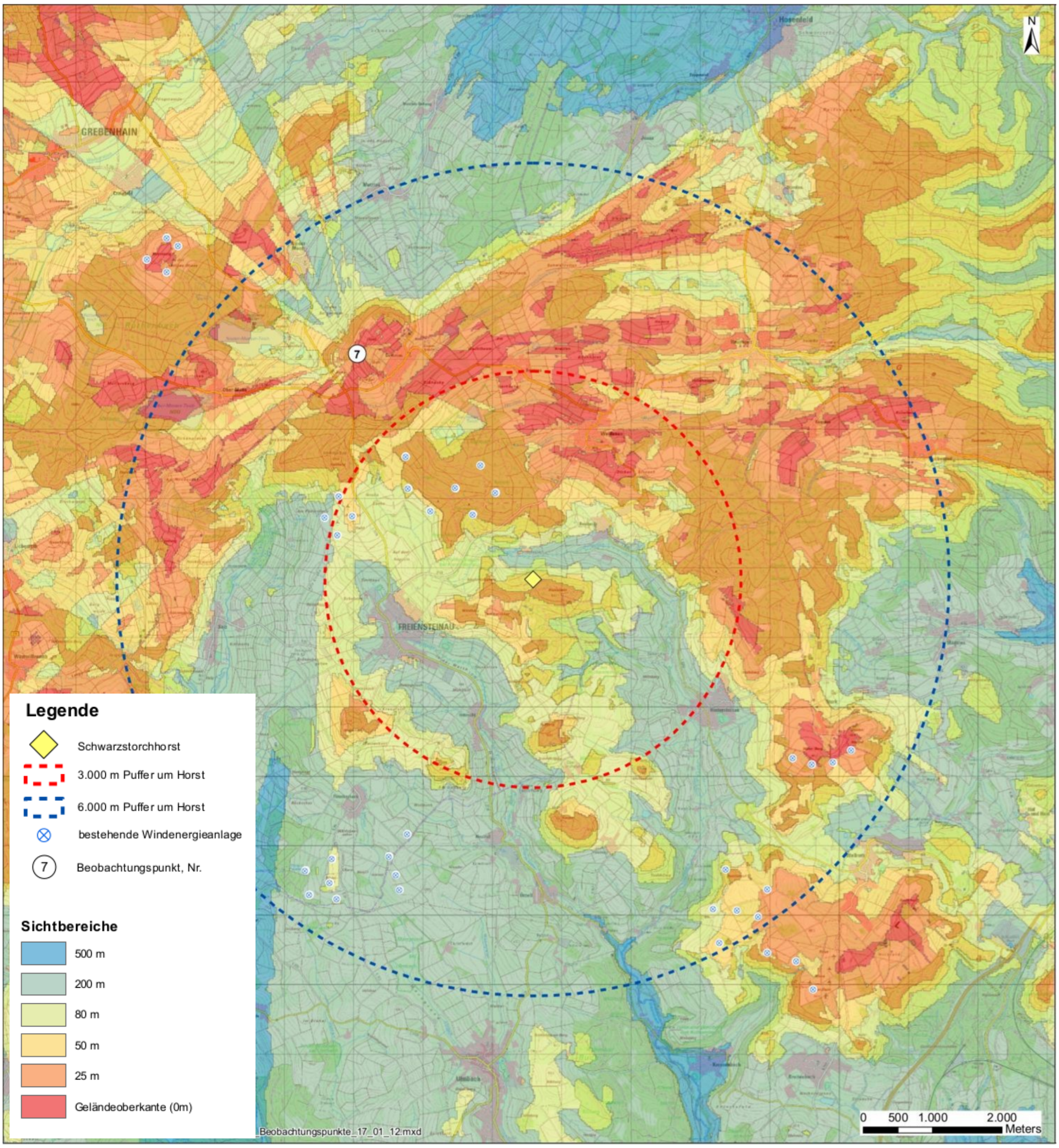

Figure 13: Viewshed of observation point 7 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

The viewshed of observation point 7 included large parts of the study area, especially to the north, west and east of the observation point, as well as areas to the south of the nest site down to ground level or up to a height of 25 m above the ground level, all of which were well visible. The remaining parts of the study area were visible up to an altitude of 200 m. Observation point 7 offered a very good overview of the study area overall.

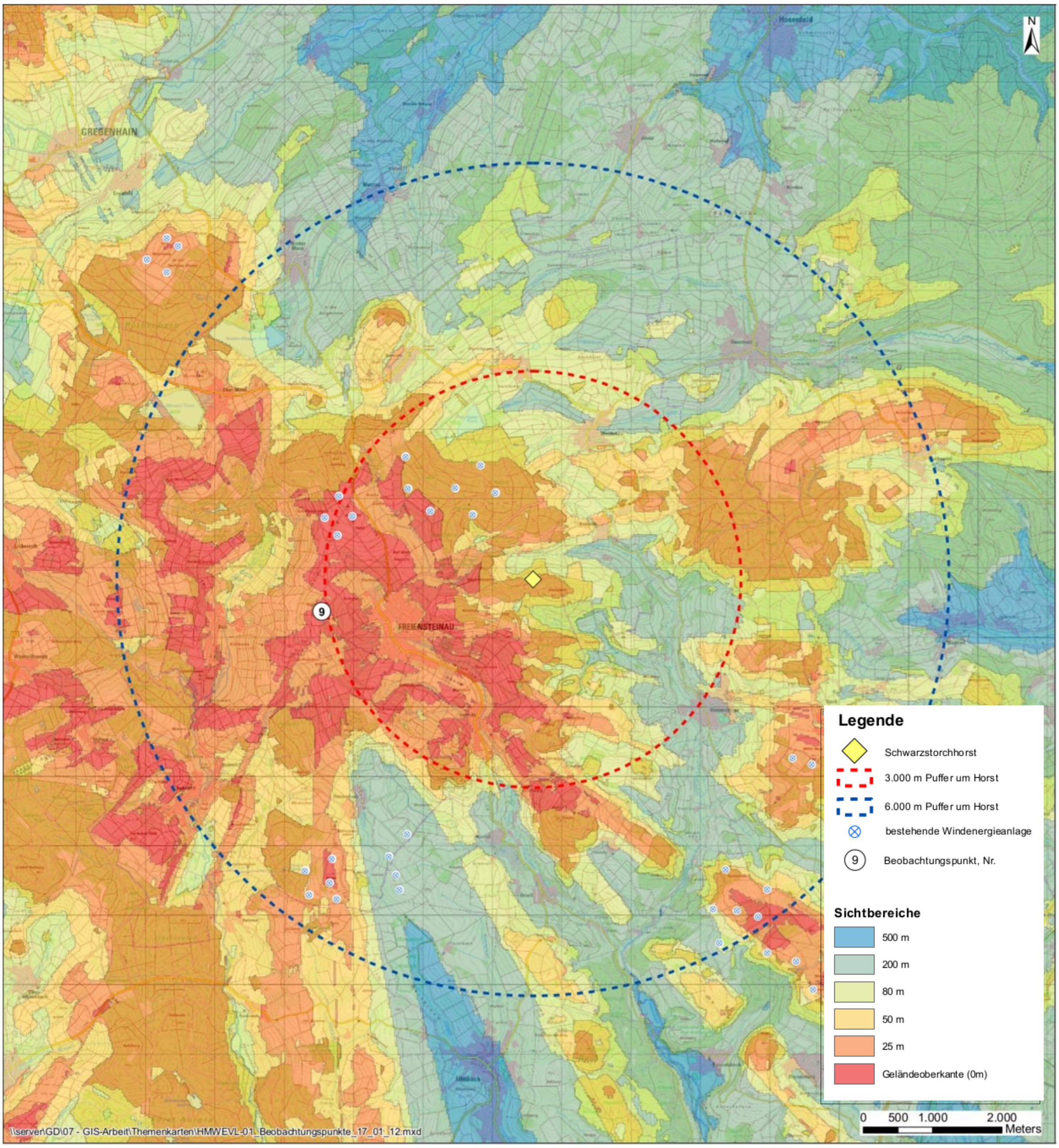

Figure 14: Viewshed of observation point 9 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

The viewshed of observation point 9 included in particular the areas to the west and south of the nest site, in parts down to ground level. To the east of the nest side, large parts of the area were visible up to a height of 25 m above the ground level. The remaining parts of the study area were visible upwards of a height of 200 m above ground level. Observation point 9 offered good visibility overall, especially of the wind farms concerned.

3.4 Determining flight altitude

The visual determination of birds' flight altitude is inherently difficult, a fact also mentioned by Rhode (2009) in his study. A feasible way to circumvent the difficulties is to determine altitude by way of flight altitude categories.

Five flight altitude categories were distinguished for the purposes of this study (see Table 6). As can be seen from the Table, the different categories cover different sized spans. The category parameters were chosen based on existing landmarks; this was to simultaneously allow for taking into consideration the danger zone of modern WTs. This approach to estimating flight altitudes using existing landmarks made it possible for the recorders to provide their best possible estimates. The landmarks described below were examined and calibrated together with the recorders, followed by a joint altitude estimation exercise using large birds in the area, such as kestrels, crows and buzzards, and a systematic calibration of the recorders (see Section 3.5).

Table 6: Flight altitude categories, limits

Category	Altitude	Potential reference points, landmarks
0	0–25 m	Tree height
1	25–50 m	Mobile phone mast, tree height x 2
2	50–80 m	Mobile phone mast x 2, below the E-101 rotor tip
3	80–190 m	Danger zone of E-101 (rotor diameter)
4	>190 m	Above the E-101 upper rotor area

Category 0 represents the space from ground level to a height of 25 m (the space below the forest canopy). This is relatively easy to estimate using existing trees within the field of view. To this end, the height of trees in different areas of the field-of-view of each of the observation points was calculated (Suunto altimeter, Pythagorean theorem/intercept theorem).

Existing trees were also used to determine altitude category 1, i.e. the 25 to 50 m range (the space just above the forest canopy). To this end, the tree height was doubled. The height of existing mobile phone masts was also used as a reference point for this altitude category.

The known heights of the existing Auf der Haid and Hallo wind farms were taken into account for estimating flight altitudes in categories 2-4.

In the Freiensteinauer Gemarkung, a total of 11 Enercon E-101 WTs were erected in two wind farms in 2014 (Figure 11). These WTs have a total height of 186 m, a hub height of 135 m and a rotor radius of 50.5 m. Flight altitudes below the rotor radius therefore fall into categories 0-2.

Category 2, i.e. the 50–80 m range (the space clearly above the forest canopy), comprises the space from doubled the tree height up to the lower limit of the upper rotor-free area. Category 3, i.e. the 80–190 m range, comprises the rotor area and thus the critical height for collisions. Category 4, i.e. the area above 190 m, comprises the space above the WTs.

In cases where observed flight events took place at the interface of two altitude categories, the flight events were assigned to the relevant more highly critical flight altitude category. Flight movements that could not be assigned to a single altitude category were assigned to a summary category.

An additional orientation marker for altitude estimates was the red marking on the WT masts. For the Enercon 101 installation type in question this is a 3 m wide red stripe at a height of 40 m (see Figure 15).

Moreover, additional landmarks such as mobile phone masts or church spires in the vicinity of the observation points were used to refine the altitude estimates.

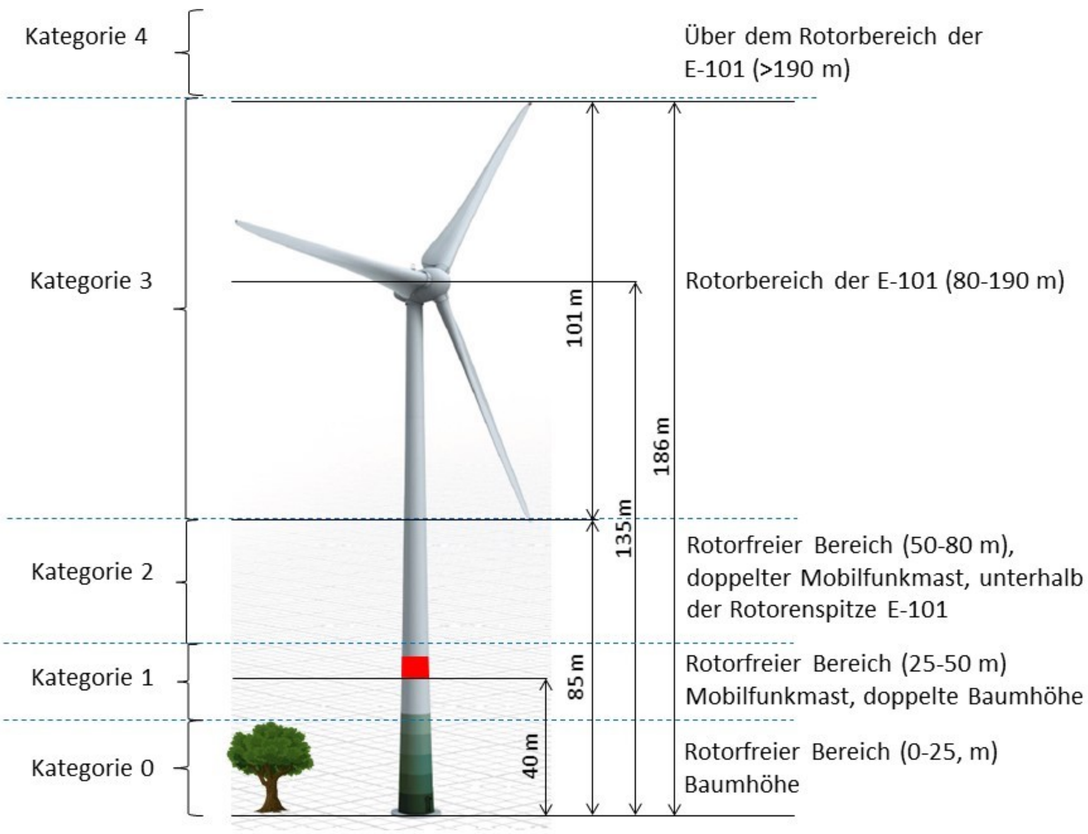

Figure 15: Measurements of an Enercon 101 wind turbine (hub height 135 m), no scale, altered after Enercon product overview (2015)

Kategorie	Category
Über dem Rotorbereich…	Above the rotor area of the E-101 (>190 m)
Rotorbereich …	Rotor area of the E-101 (80-190 m)
Rotorfreier Bereich (50…	Rotor-free area (50-80 m), mobile phone mast x2, below the E-101 rotor tip
Rotorfreier Bereich (25…	Rotor-free area (25–50 m), mobile phone mast, tree height x2
Rotorfreier Bereich (0…	Rotor-free area (0-25 m), tree height

Figure 16: Hallo wind farm with seven turbines (Enercon 101, hub height 135 m), view from observation point 5a

3.5 Calibrating the recorders

The recorders must be well familiar with the interfaces between the different categories, i.e. the 25 m, 50 m, 80 m and 190 m altitudes, in order to be able to estimate the five altitude categories (see Table 6). To allow for the best possible estimates of flight altitudes and the best possible concurrence between observers, the latter were calibrated.

In addition to making use of existing landmarks to estimate flight altitude (see Section 2.5), the recorders were calibrated in the following manner: Given that the focus of the survey was on flight behaviour in the vicinity of WTs and flights in the critical zones were to be recorded as precisely as possible, the recorders observed a flying drone localised in the area of the existing WTs from the relevant observation points (5a, 7, 9).

A Phantom 3 Advanced drone by DJI was used for this calibration process. It could be flown in the core survey area. The drone's flight altitude could be set precisely and was jointly observed by the recorders at the different observation points. The drone was manoeuvred to different altitude categories several times, especially with a view to calibrating the recorders and training them to precisely distinguish between altitude categories. To this end, the drone was flown at small steps of 5 m each at the interfaces between the altitude categories later to be distinguished.

There were two steps to the calibration process. In a first step, the recorders observed the drone at previously announced flight altitudes. Following this joint observation, the recorders had to complete a set of 12 estimates at altitudes not previously announced and secretly note down their estimate. As soon as there was a 95% agreement between the recorders' altitude estimates the calibration process was complete. A minimum of three sets of 12 estimates each were conducted at a calibration session.

The expert recorders were calibrated when the study commenced in April 2016 and for a second time during the surveys in May/June 2016. Moreover, at any point in time they were able to use the known landmarks as reference points and reminders.

In addition to the calibration process for altitude estimates described above, estimates of the location of flying objects were compared. To this end, the recorders estimated the location of a drone as well as of large birds observed by chance and marked the locations on a field map. A comparison of these maps showed a high level of congruence between the recorders' estimates. However, as it was impossible to make accurate comparisons without knowing the precise location of the object observed (this would be possible if birds were fitted with GPS locators), no further error detection actions were taken in this regard.

Figure 17: Calibration process at observation point 5a

3.6 Survey methodology and survey periods

The scope of the survey was tailored to academic research rather than to fact-finding with regard to a wind farm development. Therefore, the survey did not rely on regulations or guidelines for surveys connected to wind farm developments.

The observations were undertaken in 2016, between April and August, on a total of 40 survey days and a daily observation period of eight hours each (Table 12). Two recorders always worked synchronously in the study area; they were in contact by mobile phone and thus assured almost seamless tracking of flights throughout the entire visible area. Radio communication had been trialled but was found to be not feasible given the area's topography. The black storks' main phases of activity must be covered (Table 7) to allow for sound findings.

Table 7: Survey periods after SÜDBECK et al. 2005

March			April			May			June			July			August		
E	M	L	E	M	L	E	M	L	E	M	L	E	M	L	E	M	L
			1.		2.					3.							

The exact survey periods are shown in Table 12. Two surveys were conducted per calendar week (CW). From mid/late June onwards, regular surveys were conducted at dusk and dawn. These dusk/dawn surveys were particularly focused on phases during which the adult birds were devoting increased amounts of time to foraging in order to sufficiently supply their young and thus allowed recorders to also capture early and late flights. A further aim of the dusk/dawn surveys was to record spatial behaviour at relatively undisturbed times as these are also the times during which the juvenile birds fledge.

Table 8: Delimitation of the four breeding phases, based on existing data

Arrival and courtship phase	Incubation phase	Nestling phase	Departure phase
Until early/mid-April	Early/mid-April to early/mid-May	Early/mid-May to early/mid-July	From early/mid-July

In order to determine differences in black stork flight behaviour in relation to weather conditions, surveys were also undertaken under unfavourable weather conditions. To this end, the weather conditions were assessed as follows: Weather conditions were considered to be favourable when there was a high level of solar radiation (low cloud cover) and low wind speeds (favourable conditions for the development of thermals). Correspondingly, weather conditions were considered to be unfavourable when there was a low level of solar radiation and increased wind speeds (unfavourable conditions for the development of thermals).

The recorders used a range of different professional binoculars (i. a. Zeiss Conquest HD 10x42, Leica Geovid 10x42 HD-R) and spotting scopes (Kowa TSN-833 with a TE-11WZ 25-60x eyepiece, Swarovski ATS 65 HD with a 20-60x eyepiece) for their observations of flight movements. Given that the recorders had individual preferences and experience with regard to optical equipment and given that all the equipment was of a very high standard, the equipment was not standardised for the purpose of this study. Moreover, there was no evidence in the course of the calibration sessions of any differences in recording frequency or quality as a result of the use of different equipment.

Tablets (Surface Pro 4 with SurfacePen) and QGIS (2.14 LTR, QGIS Development Team 2016) were used for data entry in the field. This allowed for all behavioural information and flight altitude information to immediately be entered into an input field (Figure 18).

The landmarks/reference points previously used for calibrating altitude estimates were also marked on the map. Additionally, the recorders were able to zoom in and out of the map on the Surface tablet which allowed them to enter information on flight movements as precisely as possible. The data recorded were directly accessible in digital format and quickly available for evaluation. All the recorders had access to the data via the network. Moreover, inaccuracies or errors which may result from the digitisation of paper maps were avoided. The database was supervised internally by GIS experts and secured by way of multiple backups.

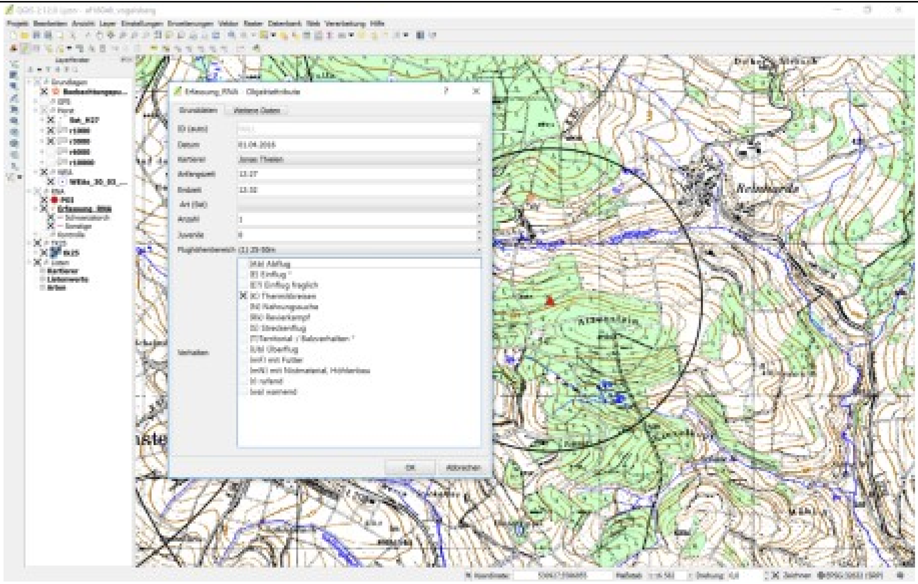

Figure 18: Screen of the Surface tablet showing the background map and dialogue box for black stork observations.

3.7 Behaviour

The observations of black stork flights are conceptually divided into flight movements and flight events. Flight movements describe observations from the first sighting of a black stork to its last sighting. These movements are divided into various flight events that differ in behaviour and flight altitude. Behaviour and flight altitudes were noted for each event.

Changes in behaviour and flight altitude were recorded as a new event. Given the swift increase or decrease in altitude during thermaling flight, it was not always possible to record changes between the different altitudes; in some cases more than one flight altitude was recorded for such flight events.

Behaviours are described in more detail in Section 2.5.

The following different types of behaviour were distinguished:

Table 9: Behaviour

Category	Code	Description
Distance flight	S (for *Streckenflug*)	Straight flights, soaring and rowing flights
Thermaling flight	K (for *Thermikkreisen*)	Passive, upward spiralling flights in thermals
Departure	Ab (for *Abflug*)	Departure from nest site, forest hosting nest site
Approach	E (for *Einflug*)	Approach to nest site, forest hosting nest site
Territorial	T	Courtship flight and defence of forest hosting nest site
Foraging	N (for *Nahrungssuche*)	Low altitude flight movement, searching

3.8 Weather data

Weather data from three different sources were available for the purposes of the project.

The Luftstrom energy company made available the weather data from six WTs (Enercon E-101) as part of the Hallo wind farm northeast of the Freiensteinau municipality. The data had been recorded at nacelle height (135 m). This dataset included information on wind speed, wind direction, rotor revolution speed, outside temperature, and visibility. The rotor tip speeds were calculated from the rotor revolution speeds in combination with the rotor diameter. The data had been recorded at 10 minute intervals.

Additionally, as part of the surveys the current weather at the individual observation points data were recorded every 60 minutes. The parameters recorded included temperature, wind speed, wind direction, cloud cover, precipitation and visibility.

The German Meteorological Office (Deutscher Wetterdienst, DWD) provided the data recorded at the meteorological station on the Hoherodskopf mountain peak. This meteorological station is located approximately 17 km away from the nest location surveyed. This dataset included data on precipitation, sunshine duration, and atmospheric pressure above sea level and at the station's altitude recorded at 10 minute intervals. Additionally, data on the AKTerm dispersion classes after Klug/Manier (VDI 2015) were available at 60 minute intervals.

When precipitation events had been recorded, the information noted in the field sheets was compared to the data recorded by the meteorological station and checked for plausibility. If the plausibility check was successful, the level of precipitation recorded at the Hoherodskopf meteorological station was used for further analysis as the recorders were not in a position to quantitatively record the local amounts of precipitation.

3.9 Data analysis

Flight movements recorded in the course of the surveys were continuously subjected to plausibility checks in order to avoid potential recording errors and to minimise inaccuracies. As a first step, the flight altitude categories recorded for the individual flight events were compared to the modelled viewsheds of the observation points concerned (see Figure 8). In the course of the checks it was found that some of the flight events could not have been visible from the observation point in question in the form and at the flight altitude at which they were recorded. Possible reasons could be misjudgments of altitudes, especially above valleys, or of the spatial location of flights. As it was not possible to clarify for these flight events whether the spatial location or the flight altitude had been wrongly recorded, these flight event records were discarded.

As a second step, all flight events were examined that had been recorded at a distance greater than three kilometres from the observation point in question. These types of flight events were discarded unless it had been possible for the events to be observed simultaneously from two occupied observation points. The recorder notes and the modelled viewsheds of the observation points in question were used as selection criteria. Further details on the discarded flights are given in Section 4.2.

The statistics tool R (R CORE TEAM 2016) was used for statistical analysis and graphics.

As can be seen in Figure 12, Figure 13 and Figure 14, it was inherent in the methodology that the different flight altitude categories could not be observed to the same extent. The areas below height of 25 m that could be viewed were significantly smaller in size than the visible areas above 200 m. This is due to the area's topography as well as to the existing vegetation and the resultant concealment of areas located behind this vegetation as seen from the observation point. This obstruction effect increases with increasing distance from the observation point.

Given the differences in visibility of the different altitude categories from the observation points, the resultant data for the individual flight altitude categories are not comparable or only comparable to a limited extent. Therefore, a statistical analysis was not undertaken with regard to the question as to whether the different meteorological data may have influenced the recorded flight altitude categories.

Instead, an assessment was undertaken to ascertain as to whether it is possible to identify weather conditions in which the black storks preferably fly at rotor height (flight altitude category 3). The different meteorological data were combined to this end. The recording timestamp was used as the basis of allocation. As the meteorological data were presented in either 10 or 60 minute intervals, the recording timestamps were rounded up or down to match the nearest 10 minute or 60 minute step respectively; subsequently the meteorological data were combined based on these rounded timestamps. The meteorological data are therefore available at 10 minute intervals or, in the case of dispersion classes, at 60 minute intervals.

As a next step, each 10 minute step was checked to see whether black stork flight events at flight altitude category 3 had been recorded during the interval in question. To this end, the period of five minutes before and after each timestamp was checked against flight events. The 10 minute steps with associated flight events at altitude category 3 were classified as "1" whereas all others were classified as "0". The aim was a binary coding of data based on flight altitude category 3 to be used for further analysis. All meteorological data other than those associated with survey days (cf. Table 12), were removed from the dataset as it was not possible to make any statements on flight events outside of the survey days. The dataset was then subjected to two types of further analysis.

In the **first variant**, it was examined whether weather conditions impacted on the occurrence of flight events at rotor height (flight altitude category 3), using <u>all</u> the weather data logged during the observation days. This variant did not take into account whether the weather conditions during the observation days might have been unsuitable for flight from the black storks' point of view. Therefore, extreme weather conditions such as strong winds, heavy precipitation or unusually low or high temperatures were included in the analysis in order to increase the variance of available meteorological data.

In the **second variant**, prior to further analysis the data was further tiered down to include only those time intervals during which any black stork flight activity had been recorded. To this end, the period of five minutes before and after each of the 10 minute steps was checked against flight events without taking into account the events' flight altitude categories. Following on from this check, all 10 minute steps during which no flight event had been recorded were eliminated from the dataset. Subsequently, and as in Variant 1, it was examined whether weather conditions impacted on the occurrence of flight events at rotor height (flight altitude category 3). In contrast to Variant 1, this renewed reduction in the number of records included in the dataset meant that consideration was taken of the fact that some weather conditions might have been unsuitable for flight from the black storks' point of view. Extreme weather conditions were thus eliminated from the dataset and the variance of the recorded weather conditions was reduced to a spectrum potentially better suited for flight from the black storks' point of view.

Both variants were subsequently analysed using the statistics tool R (R CORE TEAM 2016) and the same statistical analysis methods. As a first step it was examined whether there was any correlation between individual climate parameters. Where correlating weather parameters were found, any derived parameters were discarded. This was true, for example, for the wind turbines' rotor revolution speed and rotor tip speed as these are primarily influenced by the prevailing wind speed. The next step involved the application of a binomial Generalised Linear Models (GLM) to each of the remaining climate parameters in order to test whether the parameter in question exerted a statistical influence on whether or not flight events occurred within flight altitude category 3. All non-significant climate parameters were then discarded. The remaining parameters were gradually, and in different constellations, combined in a joint GLM. The different GLMs were then tested for goodness of fit using different measures (such as R^2 and AIC) and the best-fit model was selected.

The p-value helps to determine the significance of results. A p-value below 0.05 means that the differences between the datasets tested are significant.

In order to assess the impact of land use on black stork flight behaviour, the recorded flight movements were overlain on the Base Digital Landscape Model (Basis-DLM) and the flight route lengths above the individual land-use types were totalled. The result was compared to the spatial distribution of land-use types in a 6 km radius around the nest site.

The underlying digital terrain model (DTM) was used to analyse the flight movements with a view to the birds' terrain use.

A comprehensive discussion of the limitations of the analysis methods employed is included in Chapter 6 (Discussion).

3.10 Additional black stork studies

The project remit involved the assessment of not only the own research data but also consideration of other suitable studies addressing a variety of issues (see Table 10).

Table 10: Overview of the additional black stork studies

No.	Study	Type of study	Assessment approach
1a	Alpenrod wind farm	**Distance of nest site** to nearest WT: **550 m** Spatial behaviour analysis (2015) with regard to a planned wind farm in the Westerwald in spatial proximity to 5 WTs, flight movements including altitude categories and flight routes, daily logs, digital mapping, data on weather conditions, digital land-use data, digital terrain model	➔ Black stork breeding success ➔ Flight movements in the vicinity of existing WTs, distance to existing WTs ➔ Case-by-case assessment of flight movements in the danger zone ➔ Impact of topography on flight movements/spatial behaviour ➔ Preferential use of certain land-use types/habitats for overflights
1b	Alpenrod wind farm	**Distance of nest site** to nearest WT: **550 m** Monitoring in 2015 of existing wind farm, flight movements, daily logs, digital cartographic representation	➔ Flight movements in the vicinity of existing WTs, distance to existing WTs
2	Hintersteinau wind farm	**Distance of nest site** to nearest WT: **1300 m** Spatial behaviour analysis (2015) with regard to the Hintersteinau wind farm, in spatial proximity to the Hallo wind farm, location of observation points, flight movements including altitude categories, digital cartographic representation	➔ Flight movements in the vicinity of existing WTs, distance to existing WTs ➔ Case-by-case assessment of flight movements in the danger zone ➔ Comparison with own study ➔ Impact of topography on flight movements/spatial behaviour ➔ Preferential use of certain land-use types/habitats for overflights
3	Rabenau wind farm	**Distance of nest site** to nearest WT: **1200 m** Monitoring study from 2016 with regard to existing wind farm, flight movements, daily logs, map entries, survey of flight movements of juvenile storks	➔ Black stork breeding success ➔ Flight movements in the vicinity of existing WTs, distance to existing WTs ➔ Comparison of spatial behaviour before and after WT development ➔ Before-and-after comparison ➔ Flight movements and topography
4	Moskau-Kreuzstein wind farm	No WTs in spatial proximity. Spatial behaviour analysis (2014) in the Kaufungen Forest low mountain range with regard to the planned wind farm development north of Wickenrode, flight movements including altitude categories, digital land-use data, digital terrain model	➔ Spatial behaviour/phenology ➔ Impact of topography on flight movements/spatial behaviour ➔ Preferential use of certain land-use types/habitats for overflights
5	Wohnste wind farm	No nest site in spatial proximity to WTs, important feeding habitat, spatial behaviour analysis (2006) in the Wiegerser forest with regard to the expansion of the Wohnste wind farm, flight movements including altitude categories, cartographic representation	➔ Breeding success, disturbances ➔ Flight movements in the vicinity of existing WTs ➔ Flight altitude categories
6	Data by NABU-Hessen	Flight observations without cartographic representation and observations of foraging black storks on the ground, incidental observations from 2016	➔ Utilised feeding habitats ➔ Case-by-case assessment of flight movements in the danger zone of WTs

4 Results

4.1 Breeding success of black storks in the study area

Four black stork occurrences have been identified in the study area in recent years, three of which successfully bred in 2016 (see Table 11).

Table 11: Breeding success of black storks in the study area

Nest site	2014	2015	2016	Distance to the nearest WT of the Hallo or Auf der Haid wind farms respectively
Atzenstein	No information	3 juveniles	3 juveniles	1.3 km
Holmenstein	4 juveniles	No breeding activity	No breeding activity	1.5 km
Buchenrod	No information	No information	3 juveniles	6.6 km
Sarrod	No breeding activity	3 juveniles	2 juveniles	11 km

Atzenstein nest site

The nest site (nest platform) is located at a distance of approximately 1.3 km from the nearest WT of the Hallo wind farm (Table 11). As part of a field visit on 22.07.2016 the recorders and the state ornithological centre (Staatliche Vogelschutzwarte Frankfurt am Main) jointly checked the nest site.

The first indications of a breeding population in this area date back to 2003 and 2004. There has been regular breeding activity at a natural nest site since 2009. In 2012, an artificial nest platform was established after a nest fell down; this platform has been adopted by the black storks in recent years. Hatching success has varied over recent years (pers. comm. Hormann 2016). As the 2017 hatch had also been successful (pers. comm. Hormann 2016, 22.11.2017), the nest site can be considered a habitual nest site. Habitual nest sites have a highly positive effect on breeding success and on the number of offspring.

In 2011, only a single juvenile successfully fledged the Atzenstein nest while two additional juveniles were found dead on the ground below the nest (KARL 2012). The nest platform is located in a beech tree (BHD 60) at a height of approximately 16 m. Strong undergrowth, including ash trees and young beech trees, has become established underneath the nest platform in recent years (see Figure 19).

The closest human settlement is located approximately 400 m north of the nest site.

Sightings of juveniles in 2016

A local farmer sighted foraging adult and juvenile black storks when he was spreading slurry in July 2016. Two and three birds respectively were active on two different grassland sites located adjacent to the forest hosting the Atzenstein nest site.

On 11.07.2016 two juvenile black storks were seen leaving the nest and flying in a north-easterly direction at an altitude of 10 m.

Disturbances at the nest site

On 02.06.2016 silvicultural activities were carried out at a distance of approximately 150–200 m from the Atzenstein nest site (skidding, storage and removal of logs). The recorders informed the forestry office in Schotten with the works being halted as a result. The ornithological centre (Staatliche Vogelschutzwarte Frankfurt am Main) further notes the following permanent disturbance risks: forest tracks at terrain altitudes below 300 m that experience a medium level of usage, wind turbines at altitudes below 3000 m, and a medium risk from powerlines at altitudes below 3000 m.

Figure 19: Atzenstein nest site in 2016

Holmenstein nest site

A further black stork occurrence has been recorded at Holmenstein. This nest site is located approximately 4.5 km west of the Atzenstein nest site and roughly 1.5 km from the nearest WT as part of the Auf der Haid wind farm.

Black storks first nested here in 1999. Additional successful hatches are known to have occurred up to 2014 (pers. comm. Hormann, 2016). The natural nest was built on a side branch of a beech tree (BHD 80) beside a regularly frequented track (see Figure 20). Given this suboptimal nest location, a nest platform was attached to a beech tree (BHD 40) in the immediate vicinity but away from the track. The platform has not been used for nesting to date. According to the nest attendant (pers. comm. Jäger 2016) the forest hosting the nest site is subject to regular disturbance by the local population (agricultural traffic).

Figure 20: Nest site at Holmenstein 2016

Buchenrod nest site

A further black stork occurrence is known in the Buchenrod area, approximately 6 km east of the Atzenstein nest site. In 2016 a successful hatch produced three juvenile black storks here. The nest was a natural nest (beech tree) in a brown-mull beech forest (Asperulo-Fagetum) interspersed with some spruce trees, at a distance of approximately 6.6 km from the nearest WT as part of the Hallo wind farm.

Sarrod nest site

A further black stork occurrence has been recorded in a narrow forest belt south of Sarrod and approximately 11 km south of the Atzenstein black stork nest site. The nest location was first occupied in 2015. Three juvenile black storks successfully fledged in 2015 and two in 2016. The nest site is located at a distance of approximately 11 km to the nearest WT as part of the Auf der Haid wind farm. The WTs near Fleschenbach are significantly closer, being located approximately 5.6 km away.

4.2 Overview of the data recorded

In 2016, the period under review, surveys were conducted on a total of 40 days, 14 of which also included dawn or dusk periods. The total observation time was 640 hours. As all field visits include the observations undertaken by two recorders, the total synchronous observation time was 320 hours, which were unevenly distributed between the observation points. Table 12 provides an overview of the survey days, the observation locations and the duration of observations.

Table 12: Overview of survey days in 2016
Recorders: FI=Florian Iser, JT=Jonas Thielen, MJ=Matthias Jurczyk, NR=Nils Reischke, SB=Sebastian Berg, SF=Stefanie Fronczek, = Surveys at dawn/dusk

Date in 2016	Time period	Observation point/duration [h]									Duration [h]	Duration [h] in month	Recorders
		1	4	5a	5b	6	7	8	9	10			
01.04.	08:00-16:00	2	2	2	2	2	2	2	2		16		JT, NR
06.04.	09:00-17:00			4	4				4	4	16		FI, SB
07.04.	10:00-18:00						4	4	4	4	16		FI, SB
13.04.	10:00-18:00				4		4		8		16		FI, SB
14.04.	08:00-16:00						8		8		16	160	NR, SF
15.04.	10:00-18:00				4		4		8		16		FI, SB
19.04.	10:00-18:00				4		4		8		16		FI, SB
21.04.	07:50-15:50						8		8		16		NR, SF
28.04.	08:15-16:15						8		8		16		NR, SF
29.04.	09:00-17:00				4		4		8		16		FI, SB
02.05.	08:15-16:15						8		8		16		NR, SF
06.05.	09:00-17:00						8		8		16		FI, SB
12.05.	08:15-16:15						8		8		16		NR, SF
13.05.	04:30-12:30			1	1		7		7		16	128	FI, SB
16.05.	07:40-15:40						8		8		16		NR, SF
20.05.	09:00-17:00						8		8		16		FI, SB
23.05.	09:00-17:00						8		8		16		FI, SB
25.05.	08:00-16:00						8		8		16		NR, SF
01.06.	09:00-17:00						8		8		16		FI, SB
02.06	08:00-16:00				8				8		16		JT, NR
09.06.	08:00-16:00				8		4		4		16		NR, SF
10.06.	09:00-17:00						8		8		16		FI, SB
14.06.	09:00-17:00						8		8		16	144	FI, SB
16.06.	09:00-17:00				8		4		4		16		MJ, SF
20.06.	09:00-17:00						8		8		16		FI, SB
23.06.	05:00-13:00				8				8		16		MJ, SF
30.06.	13:40-21:40				8				8		16		MJ, NR

Date in 2016	Time period	Observation point/duration [h]									Duration [h]	Duration [h] in month	Recorders
		1	4	5a	5b	6	7	8	9	10			
01.07.	05:00-13:00				4		4		8		16	144	FI, SB
05.07.	14:00-22:00				8				8		16		FI, SB
07.07.	05:15-13:15				4		4		8		16		MJ, SF
11.07.	04:45-12:45				8				8		16		FI, SB
13.07.	14:00-22:00				8				8		16		NR, SF
18.07.	14:00-22:00				8				8		16		FI, SB
20.07.	05:00-13:00				8				8		16		NR, SF
25.07.	13:30-21:30				8				8		16		FI, SB
28.07.	13:15-21:15				8				8		16		MJ, NR
03.08.	13:30-21:30				8				8		16	64	FI, SB
05.08.	06:20-14:20				8				8		16		JT, NR
10.08.	13:30-21:30				8				8		16		FI, SB
11.08.	12:00-20:00				8				8		16		JT, NR
Totals		2	2	7	159	2	157	6	297	8	640	640	

Flight movements and flight events

In the course of the surveys, a total of 130 flight movements involving a total of 320 different flight events were recorded. A total of nine flight movements and 17 flight events were discarded in the course of the plausibility checks (see Section 3.9). Seven of the flight events were discarded since the recorder would not have been able to view the trajectory of the flight as recorded given the viewsheds as identified for the observation points in question. A further seven flight events were discarded given their distance to the observation point and the lack of validation by a second observer. An additional three flight events were not taken into consideration in the further data analysis, given that they had been based on information provided by a local farmer. Following the plausibility check, a total of 121 flight movements involving a total of 303 flight events remain. Any flight movements and flight events considered to be implausible were given no further consideration in the analysis. The plausible total recorded distance flown by the black storks was approximately 904 km (Table 13).

Table 13: Overview of flight events recorded in 2016

Flight altitude category	Total number	Plausible number	Plausible distance flown
0 (0–25 m)	12	12	14,251 m
1 (25–50 m)	42	37	58,624 m
2 (50–80 m)	63	60	111,547 m
3 (80–190 m)	88	88	263,865 m
4 (>190 m)	44	43	161,884 m
Multiple flight altitudes	65	63	294,245 m

Flight altitude category	Total number	Plausible number	Plausible distance flown
No flight altitude	6	-	
Totals	**320**	**303**	**904,416 m**
Behaviour			
Departure (Ab = Abflug)	2	2	617 m
Approach (E = Einflug)	22	22	10,698 m
Thermaling (K = Thermikkreisen)	130	127	600,779 m
Foraging (N = Nahrungssuche)	9	6	5,133 m
Distance flight (S = Streckenflug)	145	139	277,562 m
Territorial behaviour (T)	7	7	9,627 m
Other behaviour	5	-	
Totals	**320**	**303**	**904,416 m**
Survey month			
April	79	79	184,937 m
May	94	90	243,980 m
June	85	78	262,869 m
July	62	56	212,630 m
Totals	**320**	**303**	**904,416 m**

Flight altitude categories

Out of a total of 303 plausible flight events recorded in the course of the black stork survey in 2016, 88 events took place within flight altitude category 3, 63 events spanned multiple flight altitude categories, and 60 events took place within flight altitude category 2 (see Figure 21). With regard to Figure 21 it should be noted that visibility into the different flight altitude categories differed (cf. Section 3.9) and that the flight altitude categories comprised different ranges which means that it would not be meaningful to establish arithmetical ratios between them.

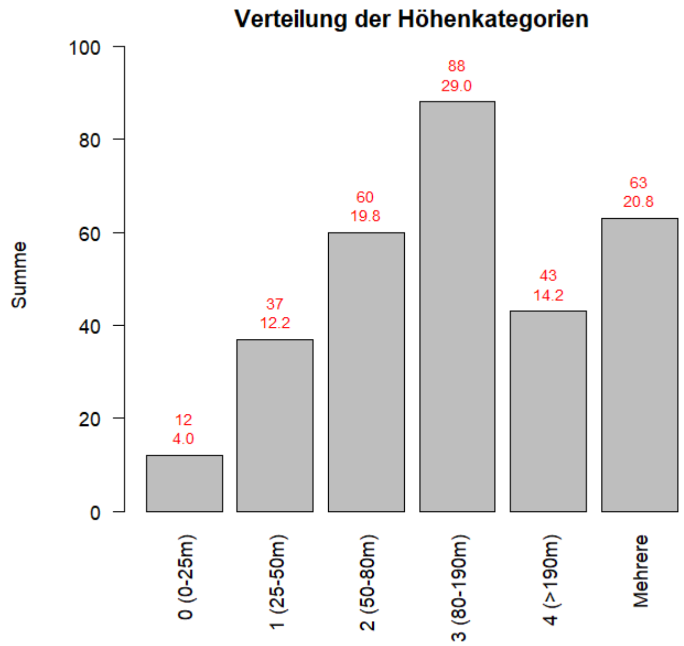

Figure 21: Distribution of flight events by altitude categories in Freiensteinau 2016

Verteilung…	Distribution of altitude categories
Summe	Totals
Mehrere	Multiple

Flight distances from the nest site

Flight movements commencing or ending in the vicinity (500 m radius) of the nest site were considered. This condition was met by 50 out of a total 121 plausible flight movements.

Twenty-five of these flights (50% of the flights) took place at a distance of up to 1000 m around the nest site. A further 21 flights (42%) covered longer distances, having been recorded in a 1000–3000 m radius around the nest site. A further four flight movements (8%) out of a total of 50 which commenced or ended near the nest site were observed in a 3000–6000 m radius around the nest site (see Figure 22).

It should be noted in this context that this information is based solely on the flight events recorded during the 2016 survey and that there are limitations to the visibility into the entire study area.

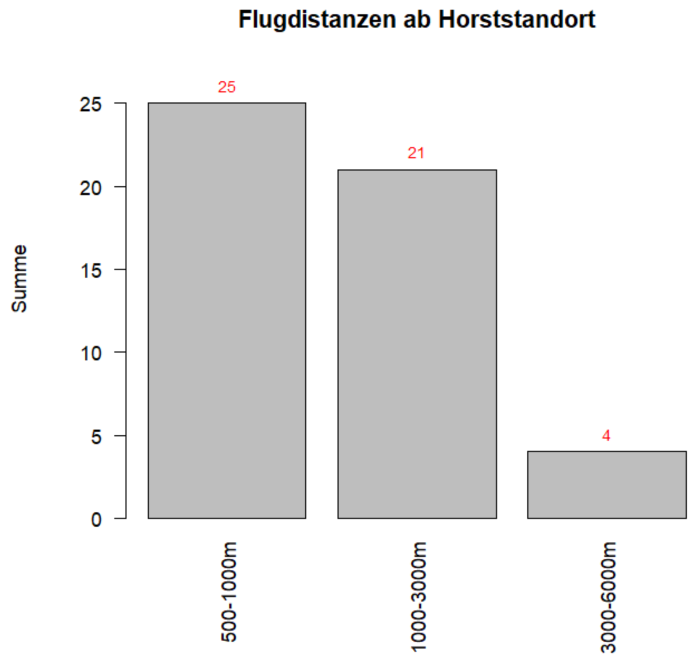

Figure 22: Flight distances from the Atzenstein nest site

Flugdistanzen…	Flight distances from the nest site
Summe	Totals

Spatial behaviour

A complete overview of the 121 plausible flight movements of the Freiensteinau study is given in Figure 23. There is a clear focus of movements within the 3000 m radius which can be explained by the location of the observation points.

The grid view transforms the spatial behaviour results by assigning colour gradients and thus denoting focal areas of activity. To this end the study area was divided into 250 x 250 m tiles. All flight events recorded within a given grid cell were totalled, with flight events exiting and re-entering a cell only being counted as one event. The visualisation given in Figure 24 is based on 303 plausible flight events.

In contrast to Figure 24, a weighting was assigned to the individual tiles in Map 1 "Weighted focal areas of activity", taking into consideration that due to the differences in total observation time at the various observation points, some areas of the study area were observed for longer time periods than others. Longer observation periods and a degree of overlap between the viewsheds would mean that some areas of the study area were to be overrepresented. To assign a weighting to the cells, the individual flight events were divided by the observation time spent at the observation points from where the events would have been visible according to the visibility analysis. In this manner, a flight event that took place in a well covered area was assigned a lower weighting for the purposes of the grid presentation than a flight event that was only recorded from a single observation point with a lower survey effort. The individual flight events' altitude categories were not taken into consideration in this context, as the plausibility check had ensured that all flight events were located within the individual observation points' viewsheds and that the airspace at the specific flight altitude had been within the field of view during the survey periods.

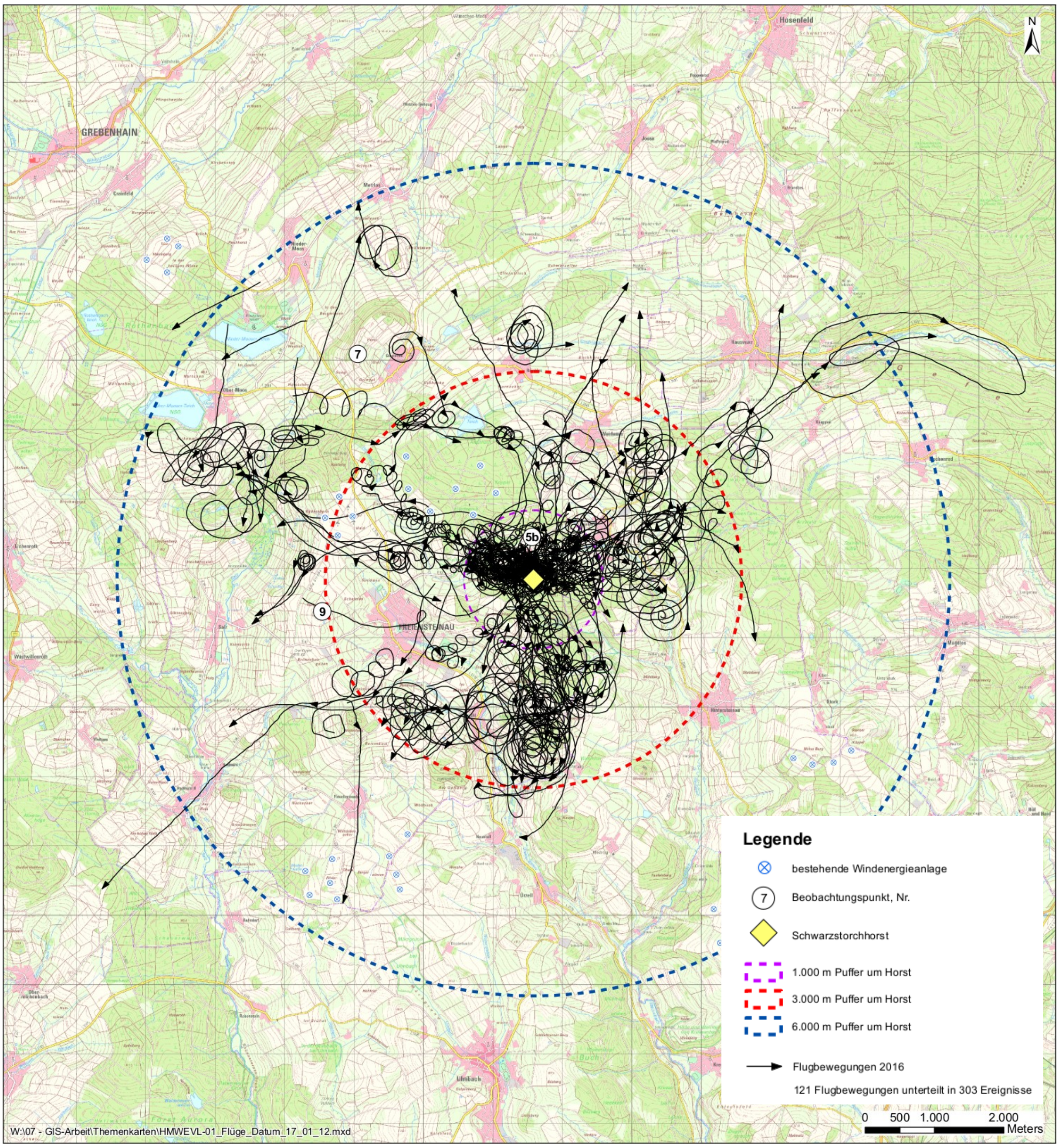

Figure 23: Complete overview of plausible flight movements at Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Flugbewegungen…	Flight movements in 2016
121…	121 flight movements subdivided into 303 events

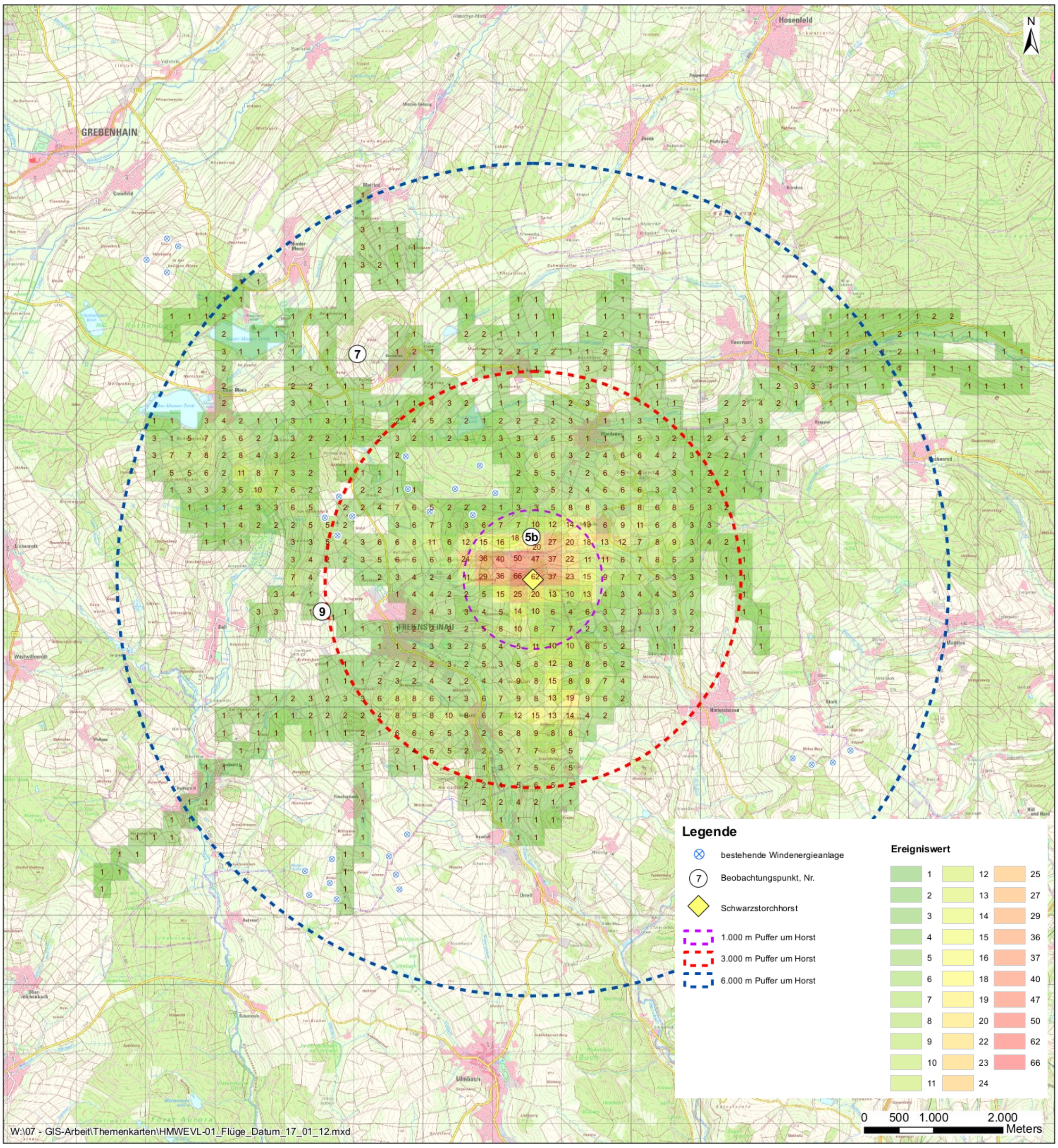

Figure 24: Focal areas of activity at Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Ereigniswert	Event value

Spatial behaviour within the study area was displayed in an area of approximately 4650 ha, with 50% of the activity taking place within an area of approximately 62.5 ha, 75% within 125 ha, and 95% of the activity taking place within an area of roughly 1440 ha (cf. Figure 25). It should be noted in this context that spatial behaviour was assessed using a visual survey method which did not allow for full visibility into all areas of the study area.

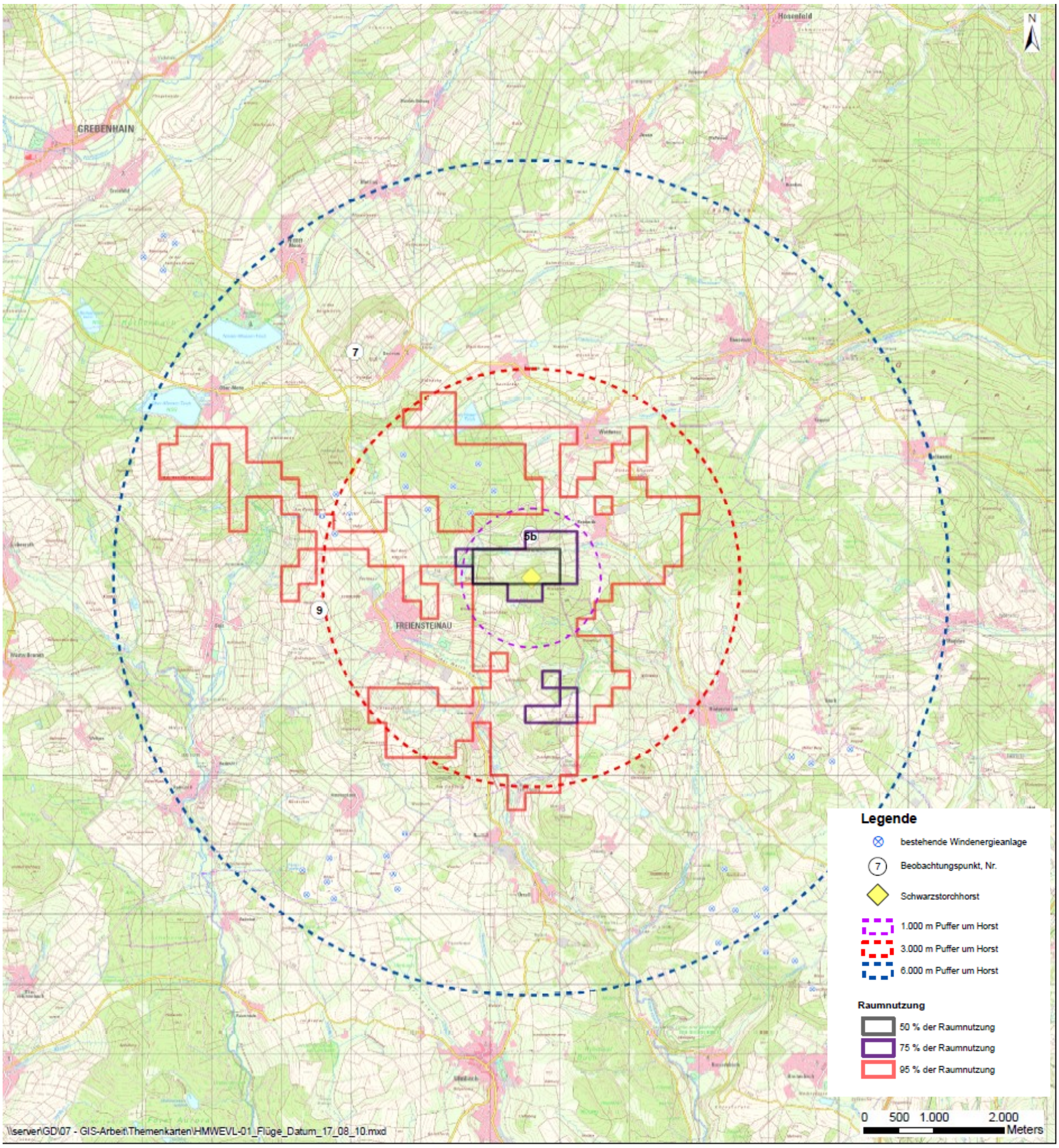

Figure 25: Home range representing 50%, 75% and 95% respectively of flight movement activity (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	(Key otherwise as in previous maps)
Raumnutzung	Spatial behaviour
… % der Raumnutzung	… % of spatial behaviour

4.3 Altitudinal distribution of flight events

A total of 12 of the 303 flight events were recorded at altitudes between 0 and 25 m (altitude category 0) in the course of the surveys (see Figure 26). These were mostly approaches to and departures from the nest area as well as some very low-altitude distance flights. With a 6293 ha viewshed and a 55% visible share of the 6 km buffer zone, altitude category 0 is the category that is least viewable from the three observation points primarily used. It is therefore reasonable to assume that a greater proportion of the flights within this range of altitudes were obscured from view.

Table 14: Overview of distribution of flight altitude categories

Flight altitude category	Number	Plausible distance flown
0 (0–25 m)	12	14,251 m
1 (25–50 m)	37	58,624 m
2 (50–80 m)	60	111,547 m
3 (80–190 m)	88	263,865 m
4 (>190 m)	43	161,884 m
Multiple flight altitudes	63	294,245 m
Totals	**303**	**904,416 m**

The 37 flight events observed in altitude category 1 (25–50 m) were similarly focused on the nest area (see Figure 27). A further focus was in the area south of the villages of Ober-Moos and Gunzenau, with other areas of the study area also being well viewable at this altitude range (cf. Figure 13). While distance flight events were also in the majority here, approaches to and departures from the nest area as well as thermaling flight and territorial behaviour were observed in this altitude category.

A total of 60 flight events (see Figure 28) took place at altitudes between 50 and 80 m (altitude category 2). Once again, flights at these altitudes were focused in the area around the nest site. Distance flights and thermaling flights were the most frequently observed behaviour in this altitude category. With a 9411 ha viewshed and an 83.3% visible share this flight altitude category was well viewable.

A total of 88 flight events were recorded within altitude category 3 at between 80 and 190 m (see Figure 29), almost all of which were distance flights or thermaling flights. The focal areas of these flights were the nest area and areas to the south and northwest of same.

Forty-three flight events were recorded at altitudes above 190 m within altitude category 4 (see Figure 30), all of which were either distance flights or thermaling flights. Flight events within this altitude category were focused to the east of the nest area in open countryside around the village of Reinhards.

Sixty-three flight events could not be assigned clearly to one of the five flight altitude categories (see Figure 31). This problem arose primarily where the birds were thermaling and covered multiple flight altitude categories as part of one flight event.

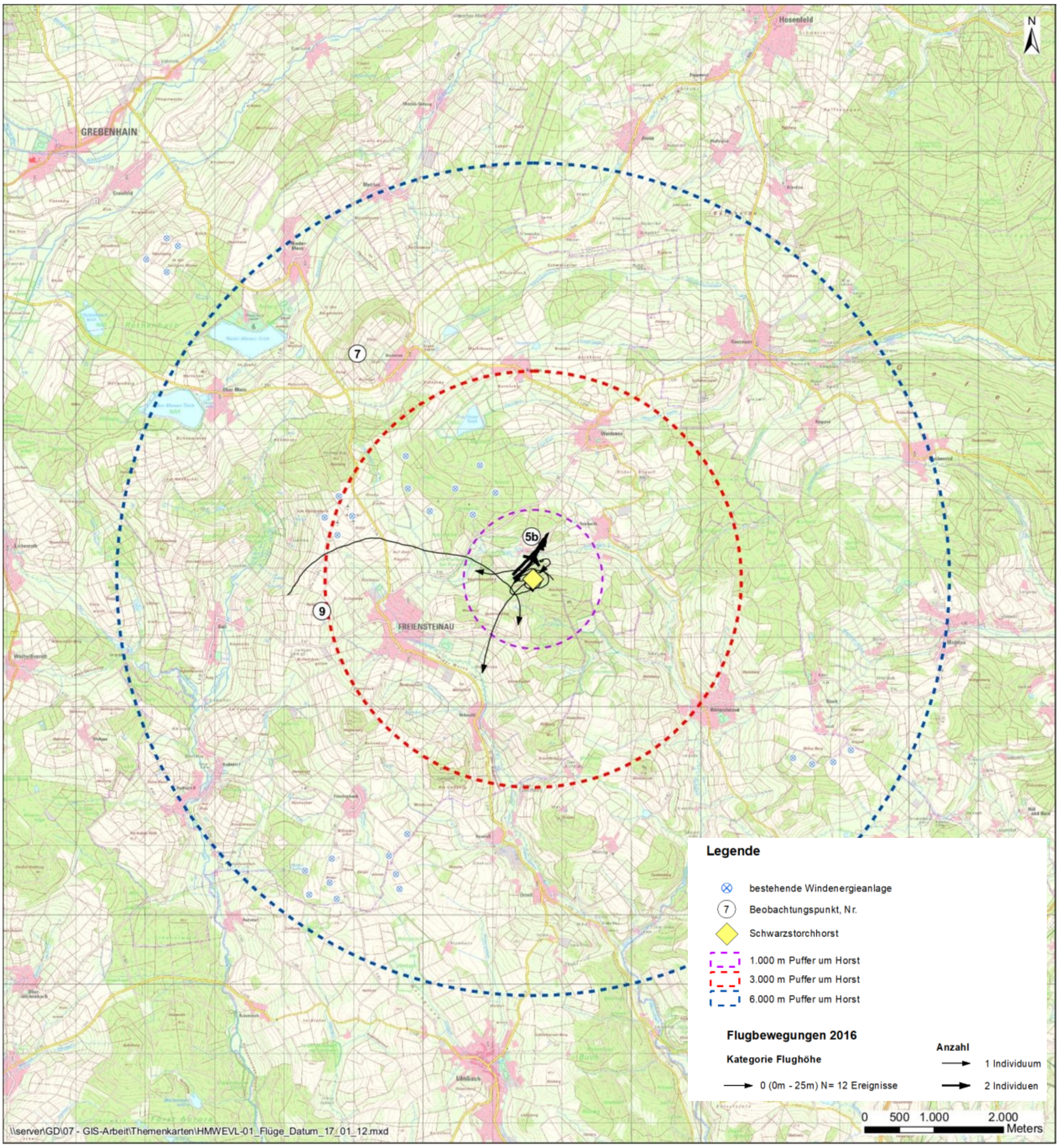

Figure 26: Flight events in altitude category 0 (0–25 m, N=12/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key for Figs. 26–31
	(otherwise as in previous maps)
Flugbewegungen 2016	Flight movements in 2016
Kategorie Flughöhe	Flight altitude category
…Ergebnisse	…results
Anzahl	Number
1 Individuum	1 individual
2 Individuen	2 individuals

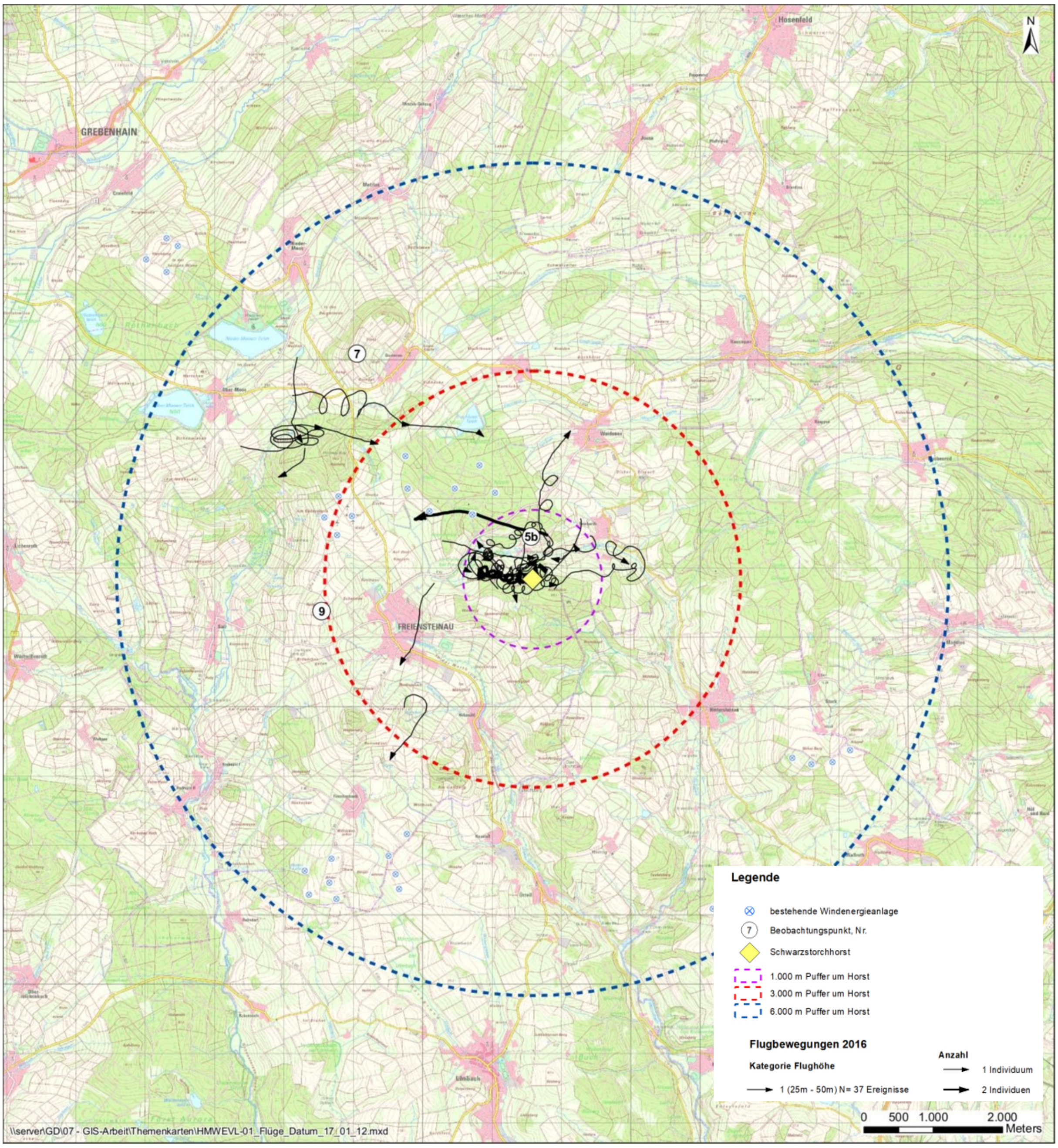

Figure 27: Flight events in altitude category 1 (25–50 m, N=37/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

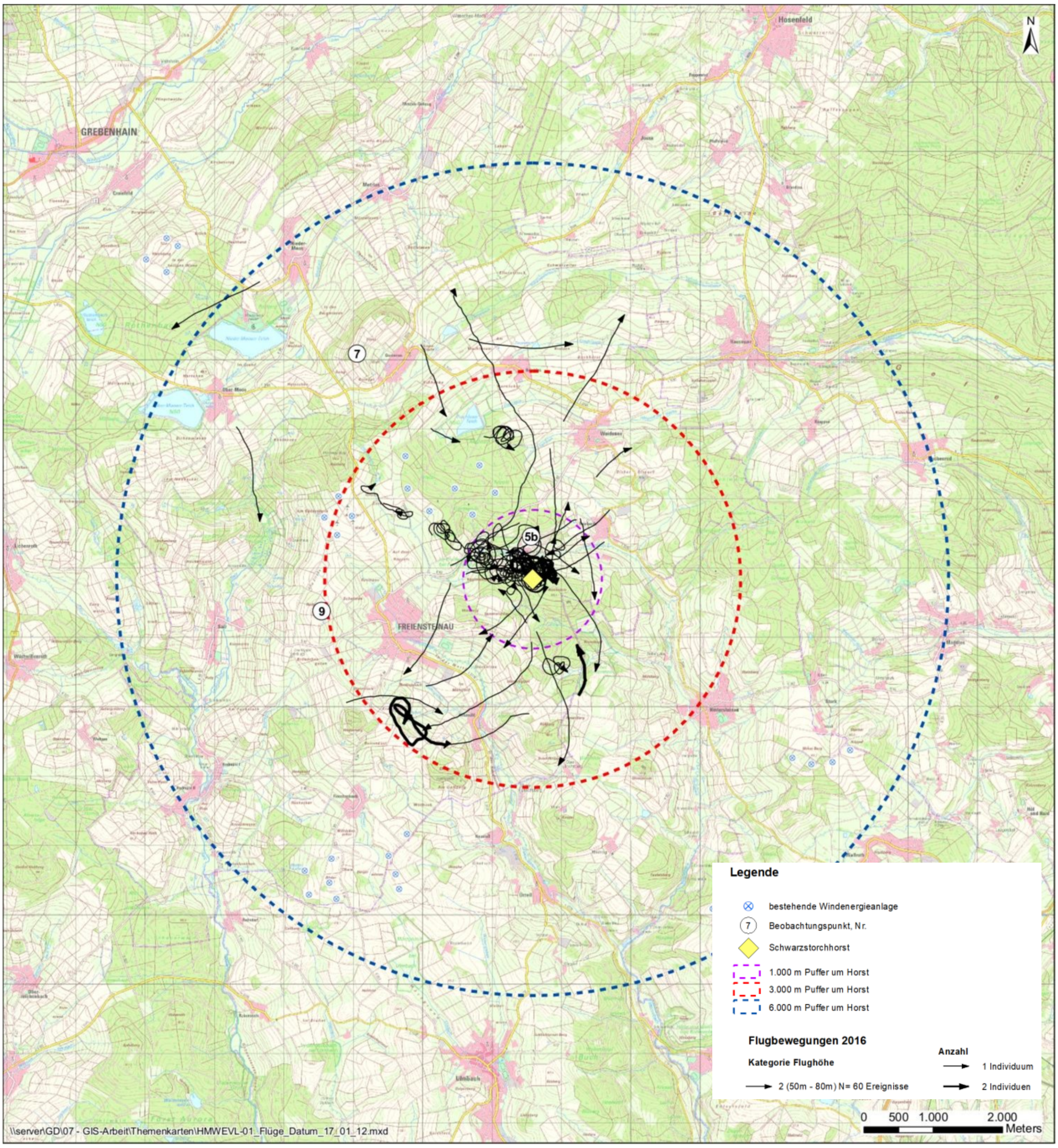

Figure 28: Flight events in altitude category 2 (50–80 m, N=60/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

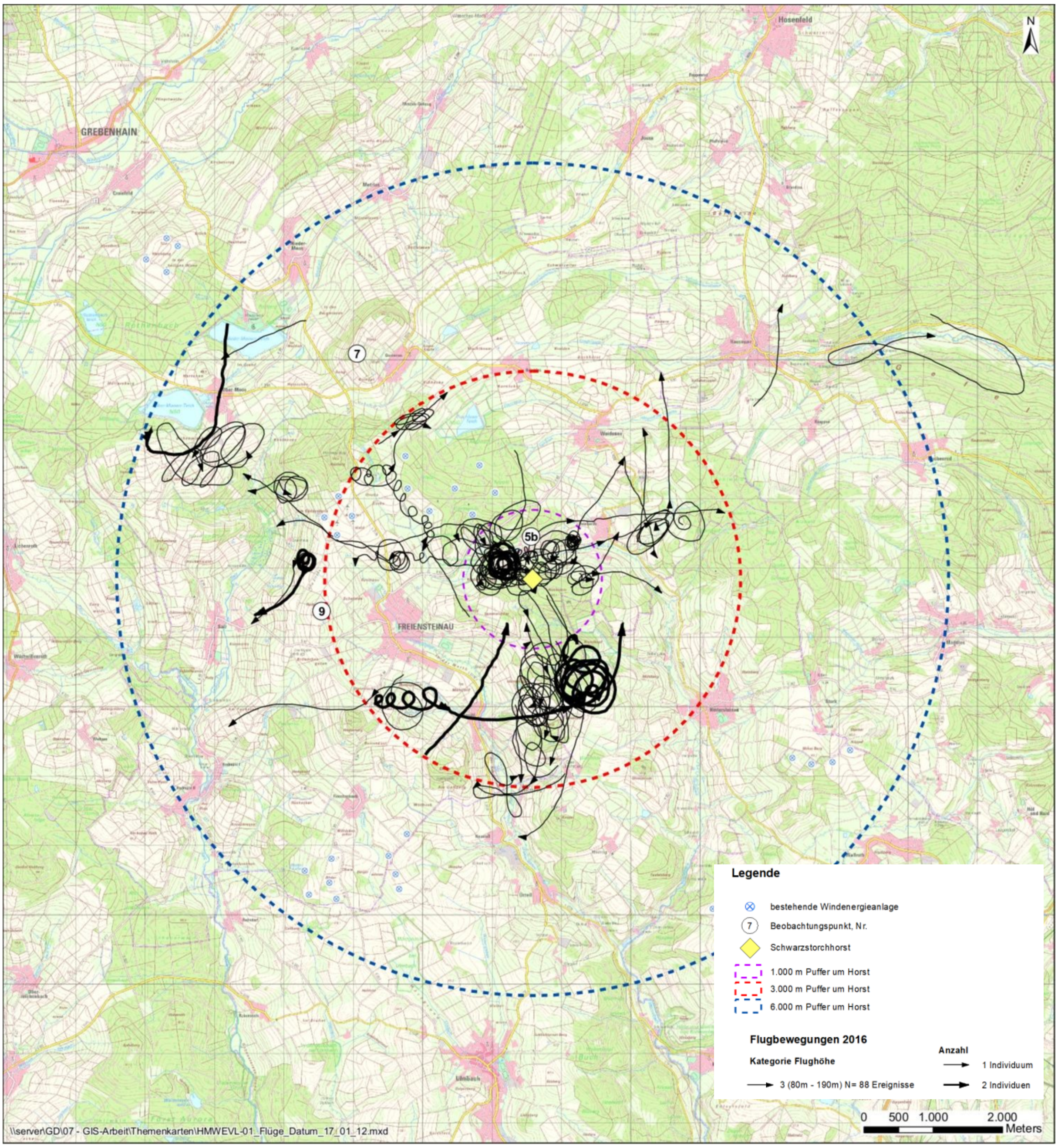

Figure 29: Flight events in altitude category 3 (80–190 m, N=88/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

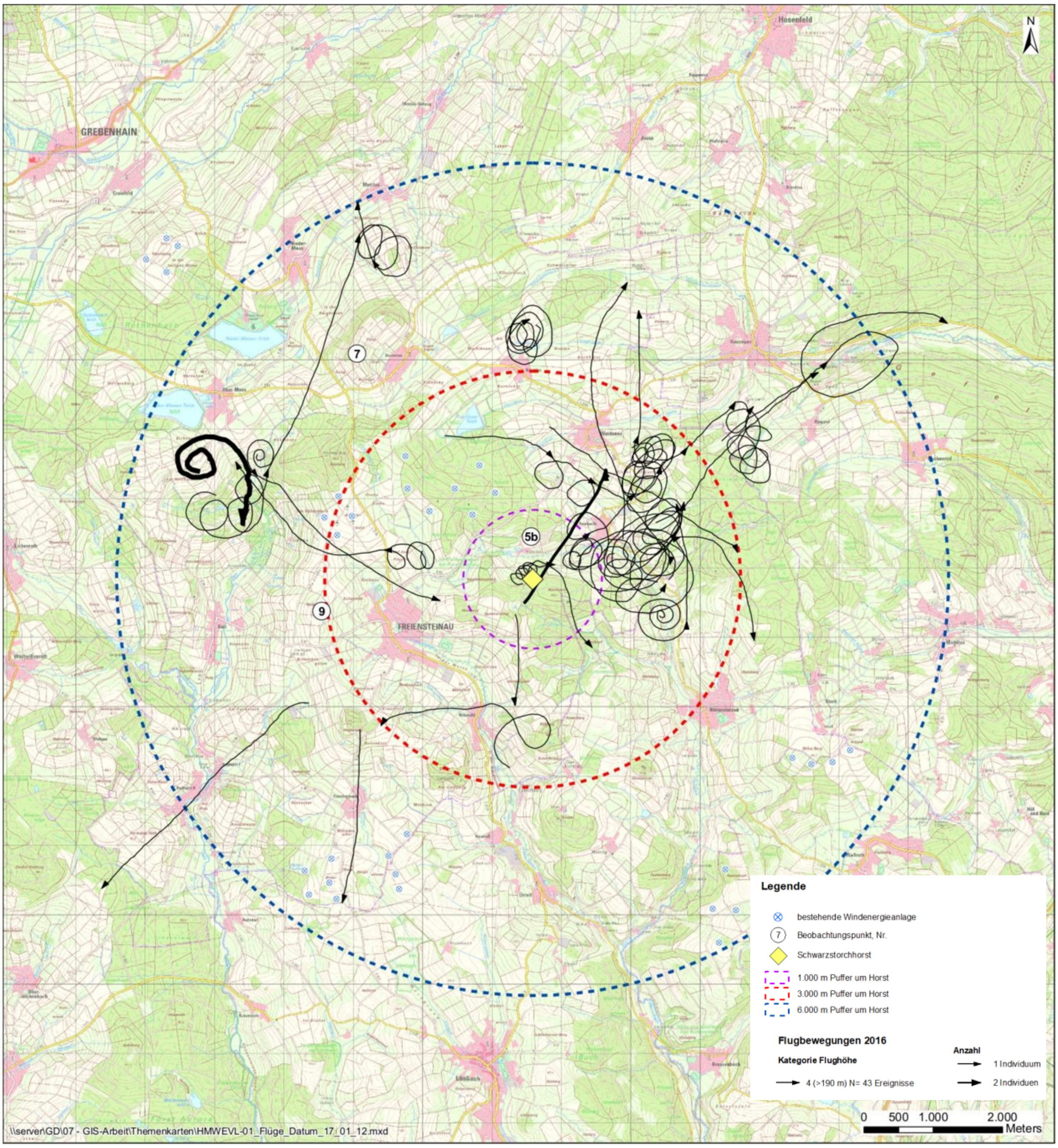

Figure 30: Flight events in altitude category 4 (>190 m, N=43/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

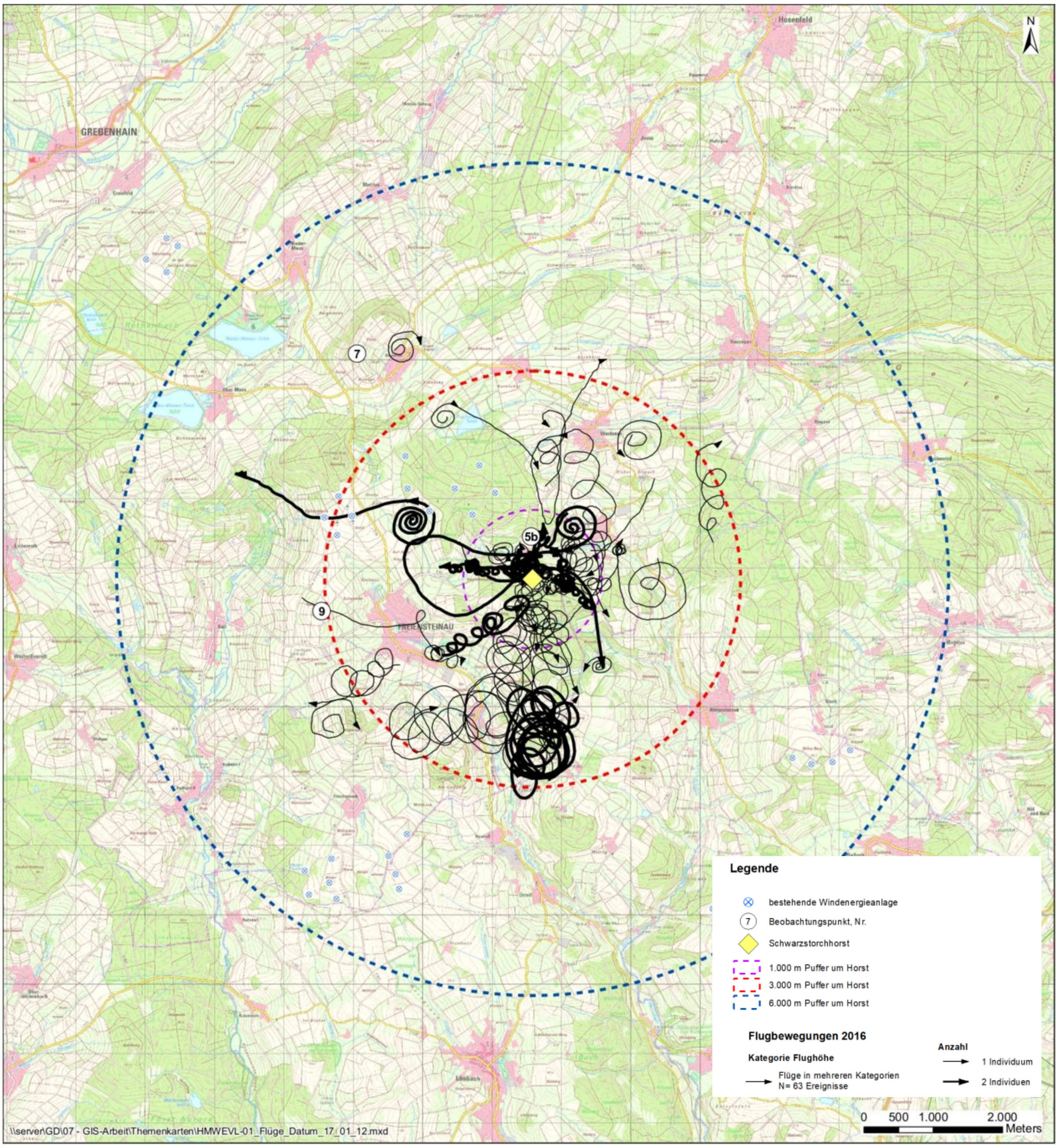

Figure 31: Flight events in multiple altitude categories (N=63/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

4.4 Flight behaviour

Out of the total of 303 flight events observed in the course of the surveys, 139 or almost half of the observed flight events were distance flights. As can be seen from Figure 94 (cf. Appendix), most of the distance flights were flights to or from the nest area and were focused in particular on the areas to the south, west and northeast of the nest site. However, account should be taken of the fact that distance flights generally occurred in higher and therefore more viewable flight altitude categories and also that the generally longer distances flown allowed for easier observation than components of other behaviours.

Table 15: Behaviour

Behaviour	Number	Distance flown
Departure (Ab = Abflug)	2	617 m
Approach (E = Einflug)	22	10,698 m
Thermaling (K = Thermikkreisen)	127	600,779 m
Foraging (N = Nahrungssuche)	6	5,133 m
Distance flight (S = Streckenflug)	139	277,562 m
Territorial behaviour (T)	7	9,627 m
Totals	**303**	**904,416 m**

Thermaling was observed a total of 127 times. This behaviour was focused on the vicinity of the nest site as well as on areas to the east and south of the nest location (see Figure 95). Here too account should be taken of the fact that this type of behaviour is particularly easy to observe given the flight altitude and duration.

Other behaviours (Figure 96) were recorded a total of 37 times. Territorial behaviour as well as approaches to and departures from the nest area were focused on a radius of 1000 m around the nest site, and particularly to the west of the nest location. As these types of behaviour mostly involve low-altitude flight and are mostly of shorter duration, they are more difficult to observe. Foraging behaviour was primarily observed along the Steinaubach stream to the north of the nest site. It is not clear whether this was due to the location of observation point 5b or the area's particular suitability.

4.5 Flight movements by observation point

A total of 20 flight movements or 46 flight events were observed from observation point 5b, which was located in spatial proximity to the nest location (see Table 16). Given the observation point's location it was particularly suited to observations of flights in spatial proximity to the nest site. Due to its valley location and the vegetation cover, especially towards the north of the observation point, more distant events, and particularly those in the lower altitude categories, could only be recorded to a limited extent (see Figure 12). The observation point was however very well suited to observing flight events in proximity of the nest site.

Table 16: Distribution of activities by observation point

Observation point	Duration [h]	Flights	Flights/h	Events	Events/h	Distance flown
5b	159	20	0.13	46	0.29	101,570 m
7	157	44	0.28	119	0.76	416,894 m
9	297	57	0.19	138	0.47	385,952 m
Overall results	**613**	**121**	**0.19**	**303**	**0.47**	**904,416 m**

A total of 44 flight movements or 119 flight events were recorded from observation point 7 (see Table 16 und Figure 98). Observation point 7 provided good visibility over much of the survey area at the different flight altitude categories (see Figure 13). Particular consideration should be given to the fact that while only half as much observation time was devoted to this point compared to observation point 9, with both having viewsheds of roughly similar sizes (see Table 5), merely about 20% fewer observations were recorded. This is expressed as a significantly higher number of flights per hour.

A total of 57 flight movements or 138 flight events were recorded at observation point 9 (see Table 16 und Figure 99). Almost twice as much observation time was devoted to this observation point compared to the others. This was due to the good views it offered into the survey area, rendering it particularly well suitable (see Figure 14), and to the fact that it offered the largest viewshed in the study area (see Table 5).

4.6 Phenological distribution of flight movements

When examining the phenological distribution of the recorded flight movements, it can be seen that the majority of flight movements recorded as part of the surveys were observed in the month of May. Similarly, May is the month with the highest level of observed activity at 0.3 flight movements per hour of observation time if observation hours per month are taken into account (see Table 17 and Figure 32). All other months are close to the overall average of 0.19 movements per hour of observation and there are no particular focal periods of activity.

As part of the surveys in the month of August, a total of 64 hours of observation time yielded no records of black stork activity.

Figure 32 supplements Table 17 by depicting the phenological distribution of activity of the flight events observed. When considering the results, the distribution of survey times over the different observation points must also always be taken into account (see Table 12). For example, the slump in activity in the month of May at OP5b can be explained by the fact that the observation effort largely shifted to OP7 during this month. The significant drop in activity at OP7 during June and July can be similarly explained.

Table 17: Phenological distribution of flight movements and flight events

Survey month	Flight movements		Flight events [n]				Distance flown [m]
	[n]	[n/h]	OP5b	OP7	OP9	Total	
April	29	0.18	8	37	34	79	184,937
May	38	0.3	0	48	42	90	243,980
June	29	0.2	20	10	48	78	262,869
July	25	0.17	18	24	14	56	212,630
August	0	0	0	0	0	0	0
Overall results	**121**	**0.19**	**46**	**119**	**138**	**303**	**904,416**

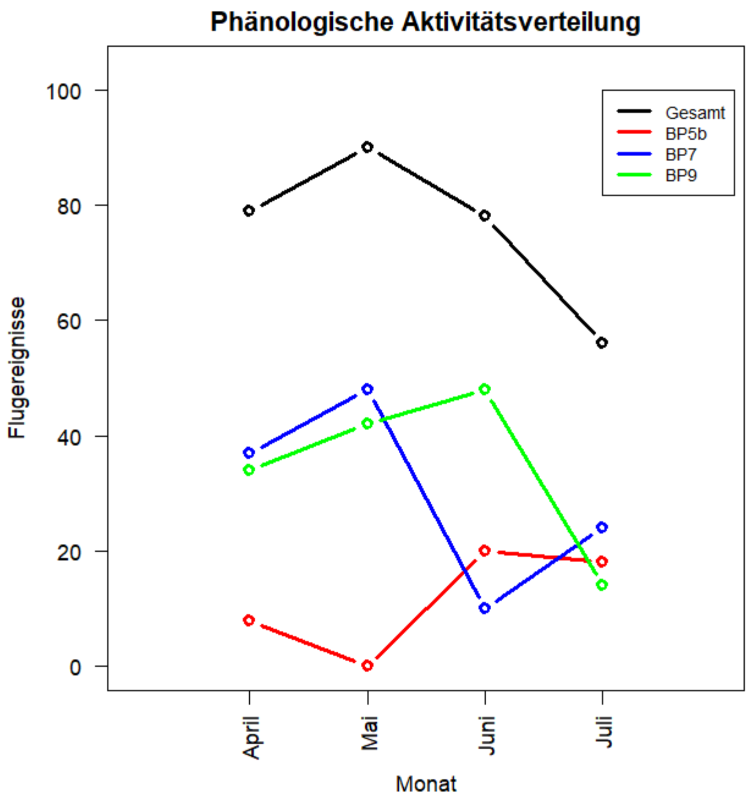

Figure 32: Flight events in the course of 2016

Phänologische …	Phenological distribution of activity
Flugereignisse	Flight events
April …	April May June July
Monat	Month
Gesamt…	Totals OP5b OP7 OP9

In order to be able to discern potential changes in the observed black stork pair's spatial behaviour in addition to the variable levels of activity between the observation months as evident from Table 17 und Figure 32, the distances flown in the individual months of observation were also analysed. To this end, the study area was divided into eight sectors based on cardinal and ordinal directions and starting from the nest location. It was then overlain with the recorded flight events, and the distances flown were totalled by sector and month.

Looking at the different observation months and sectors it is evident that there were significant changes in the black stork pair's spatial behaviour (Figure 33). In April the birds focused on the sectors to the northwest and northeast of the nest location. However, consideration must also be given to the fact that increased incidences of thermaling flight were observed in these areas in the month of April, which means that purely from the point of view of distance covered the sectors are more strongly represented (also see Figure 100 in the Appendix). While the focus of activity in April was in the vicinity of the nest site, a number of long distance flights into the 6000 m radius study area were also recorded.

In the observation month of May the activity shifted to the eastern and north-eastern sectors. It can be seen from Figure 101 (see Appendix) that the activity is particularly focused on agricultural areas in these sectors within the 3000 m radius study area and on the nest location. However, some individual flights were also observed in the 6000 m radius study area and beyond. The areas to the northeast of the nest location were often used for thermaling flight. Over time the activity shifted towards the southern and western sectors. There were significantly fewer observations of activities in those sectors which had been focal areas in May. Similar to the months prior, frequent thermaling flight could be observed in the focal sectors. As in the month of May, the observed activities were particularly focused on areas within a radius of 3000 m. In contrast, flight movements in a radius of 6000 m and beyond were much less frequently observed than in the months prior (also see Figure 102). When considering the distribution of activity, account must be taken of the fact that in June less observation time was devoted to OP7 compared to the month of May, shifting to OP5b instead. OP7 offered better visibility into the focal areas. It is therefore possible that some of the reduced activity could be due to changes in observation intensity.

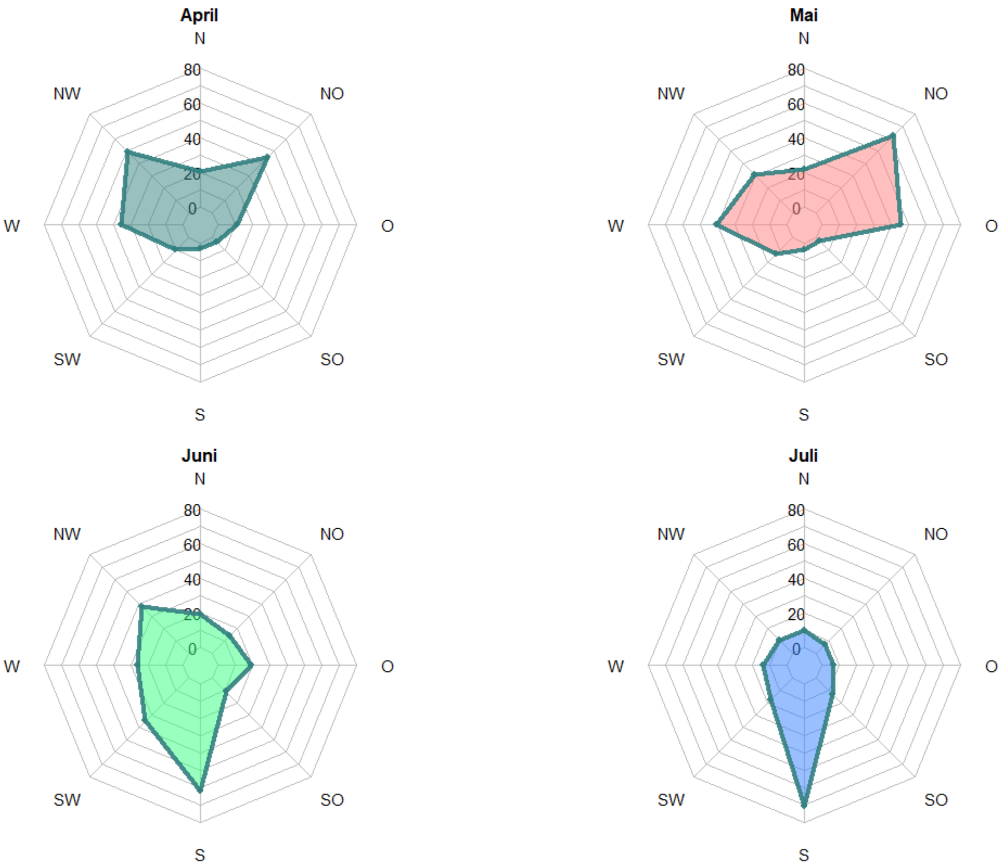

Figure 33: Total distance flown by cardinal and ordinal directions and month (from top left to bottom right: April, May, June, July 2016)

Months: April, May, June, July
Wind directions: O (Osten) = E (East), otherwise as in English

In the observation month of July the focus of activity shifted first and foremost to the southern sector where intensive thermaling flight was observed during July. Significantly less activity took place in the other sectors compared to the southern sector. Once again the observed activities focused on areas within the 3000 m radius study area. Significantly fewer observations were made in the 6000 m radius study area (also see Figure 103). As for the other observation months, the survey effort devoted to the individual observation points and their associated viewsheds as part of the study area must be taken into account for the month of July. A mere eight hours of observations were conducted at OP7 in favour of OP5b which means that in reality activities in the north-eastern sectors may have been more intense than the records indicate.

4.7 Distribution of weather parameters during the survey periods

Conditions during the survey periods mostly fell into dispersion classes (after Klug/Manier, VDI 2015) 3 or 4, denoting neutral stable and neutral unstable atmospheric stability respectively (Figure 34, top left). Wind speeds during the surveys mostly measured between 3 and 7 m/s, averaging 5.19 m/s. The maximum wind speed was 14.27 m/s. The rotor rotational speed averaged 7.93 revolutions per minute. The rotor tip speed averaged 151 km/h and reached a maximum speed of 279.3 km/h in the course of the survey periods (Figure 34 and Table 18).

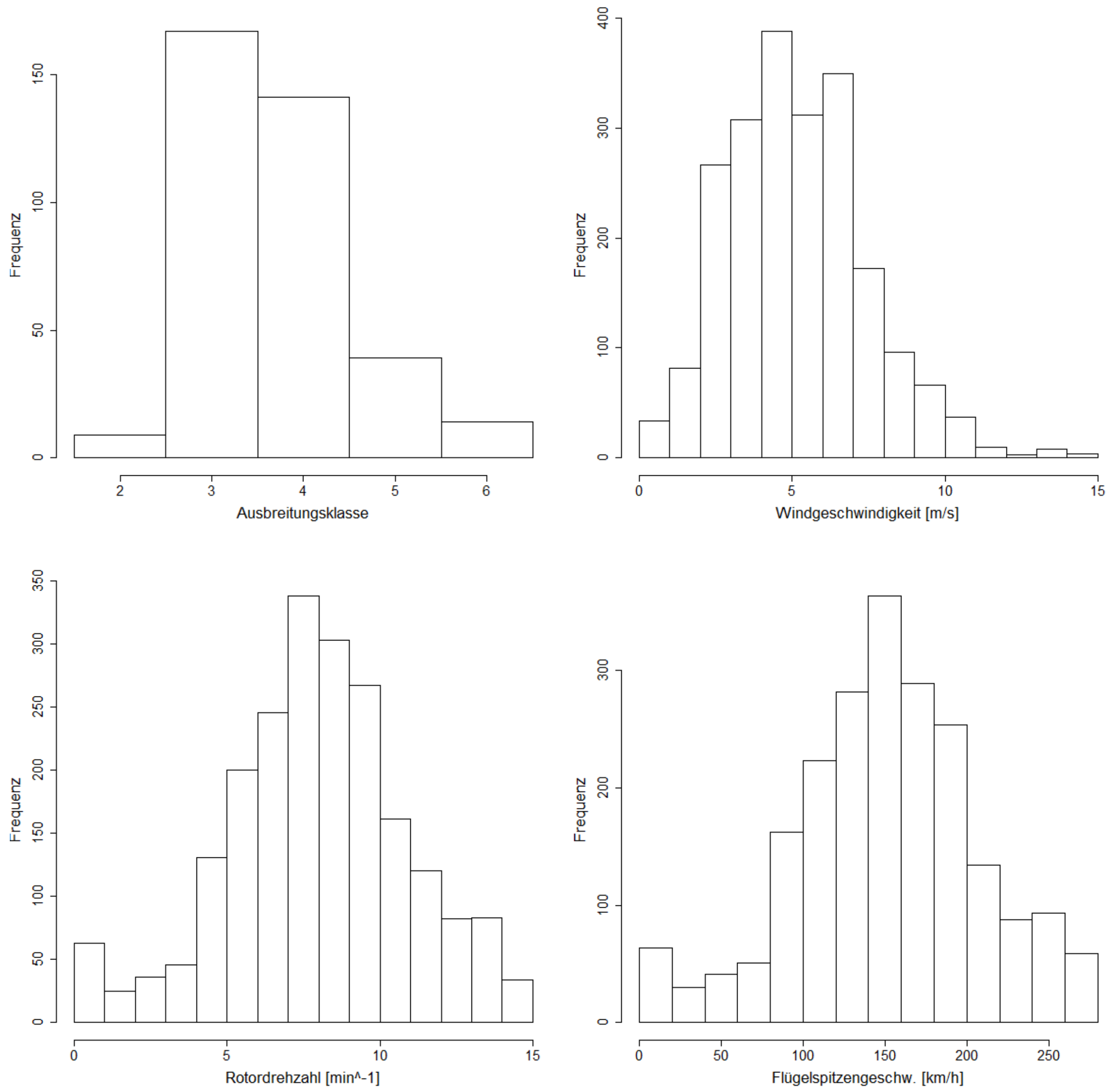

Figure 34: Distribution of weather parameters: Dispersion class and wind speed as well as rotor rotational speed and rotor tip speed

Frequenz	Frequency
Ausbreitungsklasse	Dispersion class
Windgeschwindigkeit…	Wind speed [m/s]
Rotordrehzahl…	Rotor rotational speed [min^-1]
Flügelspitz…	Rotor tip speed [km/h]

Average visibility during the survey periods was approximately 74 km. The average temperature was approximately 15 °C, ranging between 0 °C and 28 °C. The temperature minimum of 0 °C was measured on 01.04.2016 and 28.04.2016 (measured at the nacelle height of 135m). On the morning of 01.04.2016 there was even snow on the ground in the study area.

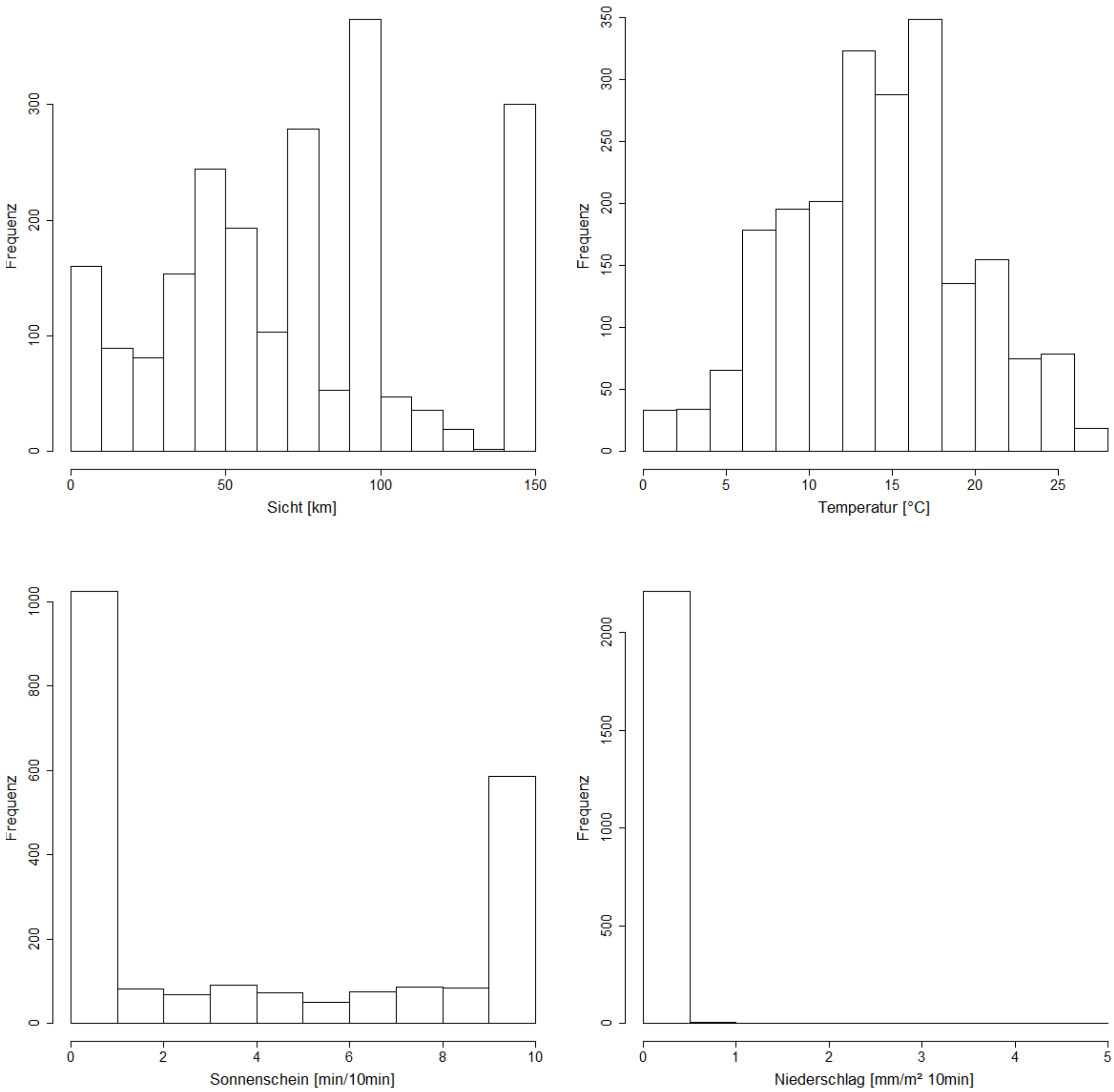

Figure 35: Distribution of visibility, temperature sunshine duration and precipitation

Frequenz	Frequency
Sicht…	Visibility [km]
Temperatur…	Temperature [°C]
Sonnen…	Sunshine duration [min/10min]
Nieder…	Precipitation [mm/m2 10min]

Sunshine duration is given in minutes per 10 minute interval. Two maxima can be seen in the chart: while there were more than 1000 10 minute intervals in which there was less than one minute of sunshine, there are also approximately 600 intervals with sunshine duration of between nine and ten minutes per interval. Other values per interval were more rarely measured. Weather conditions were dry during the majority of survey hours. Average precipitation was 0.19 mm/m² per 10 minutes. There was no precipitation for more than 75% of the survey time. A heavy rainfall event was experienced on one of the survey days when 5 mm/m² of rain fell (see Figure 35 and Table 18).

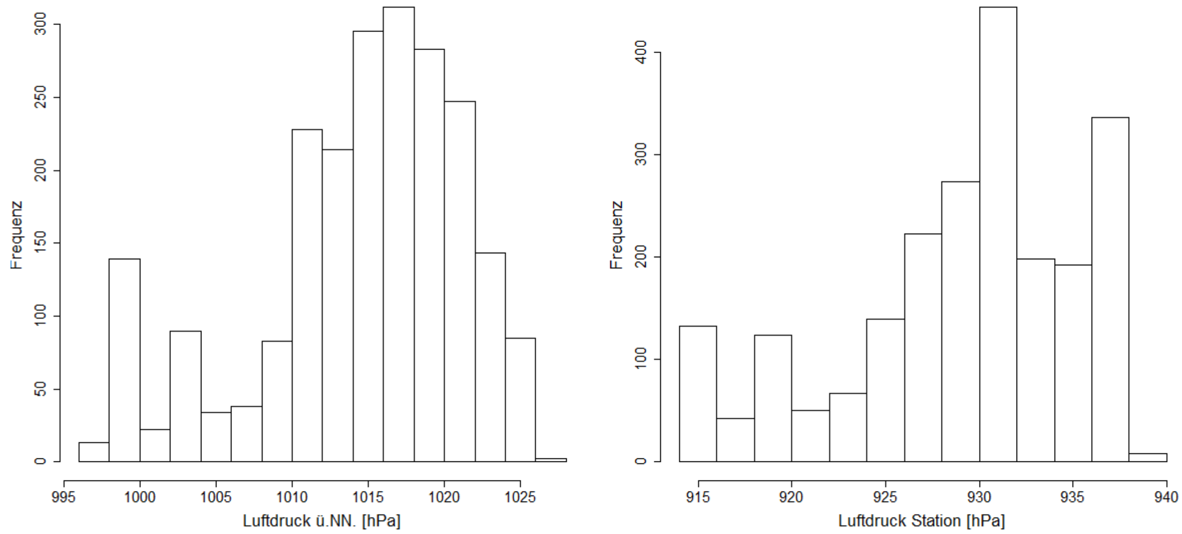

Figure 36: Distribution of weather data: Atmospheric pressure above sea level and at the station's altitude

Frequenz	Frequency
Luftdruck üNN	Atmospheric pressure a.s.l. [hPa]
Luftdruck Station	Atmospheric pressure at station [hPa]

Atmospheric pressure at the meteorological station's altitude fluctuated between 915 and 938 hPa during the survey period. The average atmospheric pressure was 930 hPa (Figure 36 and Table 18). Atmospheric pressure data were recorded on top of the Hoherodskopf mountain (764 m).

Table 18: Distribution of weather data during the survey periods

	Minima	**1st quartile**	**Median (2nd quartile)**	**Average**	**3rd quartile**	**Maxima**
Dispersion class	2	3	4	3.7	4	6
Wind speed [m/s]	0.44	3.5	5	5.2	6.6	14.3
Rotor revolution speed [min^{-1}]	0*	6.1	8	7.9	9.8	14.7
Rotor tip speed [km/h]	0	116.5	151.5	151	186.6	279.3
Visibility [km]	0	43	74	73.9	100	150
Temperature [°C]	0	11	15	14.62	18	28
Sunshine duration [h]	0	0	3	4.2	10	10
Precipitation [mm/m² 10 min]	0	0	0	0.19	0	4.95
Atmospheric pressure a.s.l. [hPa]	997	1,011	1,016	1,015	1,019	1,026
Atmospheric pressure at station [hPa]	914.5	926.1	930.5	929.2	933.9	938.2

* Rotors stopped at windspeeds ≤0.44 m/s. The lowest measured wind speed at which there was a minimum rotor rotation of 0.1 min^{-1} was 0.46 m/s.

4.8 Statistical analysis

Variant 1: Dataset including all climate data for the observation days

The results of the statistical analyses of the data set containing all climate data are given below. Spearman's rank correlation coefficient was used to individually test all variables for correlation to each other. The results of the test series are given in Table 19. It can be seen that the variables wind speed, rotor speed and rotor tip speed are correlated to each other. This is to be expected as the wind turbines' rotor blades turn faster with increasing wind speed. Similarly, a correlation is to be expected between rotor tip speed and rotor speed as the former is calculated from the latter. Yet another foreseeable correlation exists between wind speed and nacelle alignment. Additionally, atmospheric pressure at sea level correlates with atmospheric pressure at the meteorological station's altitude but this correlation is not as unambiguous as the variables dependent on wind speed. There is a negative correlation between dispersion class and data based on wind speed. Following the results of the correlation tests, the variables dispersion class, rotor speed, rotor tip speed, wind direction, and atmospheric pressure above sea level were discarded from the further analysis.

Table 19: Correlation of the different meteorological parameters for all climate data

Variables	Flight altitude category	Dispersion class	Wind speed	Wind direction	Rotor speed	Rotor tip speed	Nacelle alignment	Visibility	Temperature	Sunshine duration	Precipitation	Atmospheric pressure a.s.l	Atmospheric pressure at station	Julian date
Flight altitude category		0.08	-0.02	-0.04	-0.03	-0.03	-0.04	0.01	0.02	0.13	-0.04	0.05	0.06	-0.06
Dispersion class	0.08		-0.50	-0.20	-0.52	-0.52	-0.19	-0.10	0.10	0.25	0.06	0.02	0.07	-0.02
Wind speed	-0.02	-0.50		-0.13	0.99	0.99	-0.15	0.06	-0.01	-0.03	-0.01	-0.11	-0.10	-0.04
Wind direction	-0.04	-0.20	-0.13		-0.12	-0.12	0.96	-0.04	-0.06	-0.24	0.00	0.14	0.11	0.22
Rotor speed	-0.03	-0.52	0.99	-0.12		1.00	-0.14	0.04	-0.04	-0.05	0.01	-0.12	-0.13	-0.07
Rotor tip speed	-0.03	-0.52	0.99	-0.12	1.00		-0.14	0.04	-0.04	-0.05	0.01	-0.12	-0.13	-0.07
Nacelle alignment	-0.04	-0.19	-0.15	0.96	-0.14	-0.14		-0.07	-0.06	-0.23	-0.01	0.16	0.13	0.21
Visibility	0.01	-0.10	0.06	-0.04	0.04	0.04	-0.07		0.42	0.18	-0.10	0.14	0.24	0.26
Temperature	0.02	0.10	-0.01	-0.06	-0.04	-0.04	-0.06	0.42		0.13	-0.05	-0.07	0.22	0.65
Sunshine duration	0.13	0.25	-0.03	-0.24	-0.05	-0.05	-0.23	0.18	0.13		-0.22	0.21	0.26	-0.13
Precipitation	-0.04	0.06	-0.01	0.00	0.01	0.01	-0.01	-0.10	-0.05	-0.22		-0.15	-0.16	-0.01
Atmos. pressure a.s.l.	0.05	0.02	-0.11	0.14	-0.12	-0.12	0.16	0.14	-0.07	0.21	-0.15		0.94	0.19
Atmos. pressure at station	0.06	0.07	-0.10	0.11	-0.13	-0.13	0.13	0.24	0.22	0.26	-0.16	0.94		0.36
Julian date	-0.06	-0.02	-0.04	0.22	-0.07	-0.07	0.21	0.26	0.65	-0.13	-0.01	0.19	0.36	

Table 20: Statistical results of the univariate models for all climate data; top section: model parameters including estimate and (standard error), * = p <0.05, ** = p<0.01, *** = p=0; bottom section: different coefficients of determination of the models in question

Univariate models	**Wind speed**	**Nacelle pos.**	**Visibility**	**Temp.**	**Sunshine**	**Precipitation**	**Atmos. press.**
Intercept	-3.114*** (0.333)	-2.716*** (0.321)	-3.535*** (0.264)	-3.720*** (0.397)	-4.377*** (0.264)	-3.365*** (0.129)	-46.502* (21.968)
Wind speed	-0.065 (0.063)						
Nacelle pos.		-0.004* (0.002)					
Visibility			0.001 (0.003)				
Temp.				0.018 (0.024)			
Sunshine					0.172*** (0.033)		
Precipitation						-1163.381 (63260.931)	
Atmos. press.							0.046* (0.024)
Coefficients of determination							
Aldrich-Nelson R-sq.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
McFadden R-sq.	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Cox-Snell R-sq.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nagelkerke R-sq.	0.0	0.0	0.0	0.0	0.1	0.0	0.0
phi	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Likelihood-ratio	1.1	5.2	0.2	0.6	31.8	6.9	4.2
p	0.3	0.0	0.7	0.4	0.0	0.0	0.0
Log-likelihood	-257.9	-255.8	-258.3	-258.1	-259.2	-271.7	-273.0
Deviance	515.7	511.7	516.6	516.2	518.4	543.3	546.0
AIC	519.7	515.7	520.6	520.2	522.4	547.3	550.0
BIC	530.8	526.7	531.7	531.3	533.5	558.5	561.2
N	1866	1866	1866	1866	1959	1959	1959

Table 20 shows the results of the individual GLMs applied to the different climate variables as described in Section 3.9. The Table's bottom section shows the different coefficients of determination for the individual GLM. Out of the climate variables tested, only nacelle position, sunshine duration and atmospheric pressure were shown to have a significant impact. However, account should be taken of the fact that the different R-sq values shown assume a value of 0.1 only for sunshine duration, and only in part. The R-sq values for all other variables are 0.0. R-squared (or R^2) is a measure of goodness-of-fit of linear regressions. If a model has an R-sq close to 1, it means that the tested independent variable (in this case the climate variable in question) is well suited to explaining the dependent variable (in this case the presence of flight movements in the danger zone). An R-sq close to 0 is not well suited to explaining the dependent variable. This means that the significant variables nacelle position, sunshine duration and atmospheric pressure are not well suited to explaining the presence of flight movements within the danger zone.

Table 21: Statistical results of the multivariate models for all climate data; top section: model parameters including estimate and (standard error), * = p <0.05, ** = p<0.01, *** = p=0; bottom section: different coefficients of determination of the models in question

Multivariate models	**Nacelle + sunshine**	**Nacelle + atmospheric pressure**	**Sunshine + atmospheric pressure**	**Totals**
Intercept	-4.119*** (0.459)	-45.887* (21.049)	-17.663 (21.051)	-17.284 (20.992)
Nacelle pos.	-0.001 (0.002)	-0.004** (0.002)		-0.001 (0.002)
Sunshine	0.158*** (0.035)		0.167*** (0.034)	0.152*** (0.036)
Atmos. pressure		0.047* (0.023)	0.014 (0.023)	0.014 (0.023)
Coefficients of determination				
Aldrich-Nelson R-sq.	0.0	0.0	0.0	0.0
McFadden R-sq.	0.1	0.0	0.1	0.1
Cox-Snell R-sq.	0.0	0.0	0.0	0.0
Nagelkerke R-sq.	0.1	0.0	0.1	0.1
phi	1.0	1.0	1.0	1.0
Likelihood-ratio	28.0	9.7	32.2	28.4
p	0.0	0.0	0.0	0.0
Log-likelihood	-244.4	-253.6	-259.0	-244.2
Deviance	488.8	507.1	518.0	488.4
AIC	494.8	513.1	524.0	496.4
BIC	511.4	529.7	540.7	518.6
N	1866	1866	1959	1866

Following the determination of individual significant variables as part of the univariate GLMs (see Table 20), multivariate GLMs were tested (Table 21). This involved the testing of all possible combinations of the three significant variables nacelle position, sunshine duration and atmospheric pressure. It can be seen for the different models that sunshine duration, insofar as it is included in the model, always is of significant impact. The variables atmospheric pressure and nacelle position have significance only in the model that does not take into account sunshine duration. Once again, account must be taken of the fact that the different R-sq values are all close to 0. Despite these significances, the different models are therefore not well suited to explaining the flight events observed in the danger zone.

Variant 2: Dataset including all climate data during observed flight events

Similar to Table 19, Table 22 shows the correlation between different weather data. These too were tested using Spearman's rank correlation coefficient. However, this section only takes into consideration climate data relating to the times during which black stork flight activity had been observed (cf. Section 3.9). Similar to the model involving all climate data, wind speed-based variables are also correlated to each other in this dataset, as are the two atmospheric pressures, nacelle position and wind speed, and temperature to Julian date. In contrast to the dataset involving all climate data, the correlation between dispersion class and wind speed is lower still. In this dataset, however, temperature is correlated with visibility. Based on these results, wind speed, nacelle position, temperature, sunshine duration, precipitation, and atmospheric pressure at station altitude were taken into consideration for further analysis. The other variables were discarded.

Table 22: Correlation of the different meteorological parameters for climate data relating to periods during which flight events were observed

Variables	Flight altitude category	Dispersion class	Wind speed	Wind direction	Rotor speed	Rotor tip speed	Nacelle alignment	Visibility	Temperature	Sunshine duration	Precipitation	Atmospheric pressure a.s.l	Atmospheric pressure at station	Julian date
Flight altitude category		0.08	0.08	-0.07	0.09	0.09	-0.08	-0.06	-0.03	0.04	-0.07	0.03	0.01	-0.06
Dispersion class	0.08		-0.43	-0.08	-0.43	-0.43	-0.03	0.05	0.32	0.40	-0.05	0.34	0.45	0.07
Wind speed	0.08	-0.43		-0.30	0.99	0.99	-0.30	0.12	0.01	-0.25	-0.13	-0.29	-0.20	-0.05
Wind direction	-0.07	-0.08	-0.30		-0.29	-0.29	0.96	0.09	-0.08	-0.18	0.03	-0.03	-0.09	0.17
Rotor speed	0.09	-0.43	0.99	-0.29		1.00	-0.30	0.11	-0.01	-0.25	-0.10	-0.28	-0.20	-0.06
Rotor tip speed	0.09	-0.43	0.99	-0.29	1.00		-0.30	0.11	-0.01	-0.25	-0.10	-0.28	-0.20	-0.06
Nacelle alignment	-0.08	-0.03	-0.30	0.96	-0.30	-0.30		0.06	-0.07	-0.18	0.02	-0.01	-0.08	0.18
Visibility	-0.06	0.05	0.12	0.09	0.11	0.11	0.06		0.53	0.15	0.05	0.13	0.29	0.48
Temperature	-0.03	0.32	0.01	-0.08	-0.01	-0.01	-0.07	0.53		0.33	0.05	-0.02	0.30	0.79
Sunshine duration	0.04	0.40	-0.25	-0.18	-0.25	-0.25	-0.18	0.15	0.33		-0.13	0.27	0.39	0.05
Precipitation	-0.07	-0.05	-0.13	0.03	-0.10	-0.10	0.02	0.05	0.05	-0.13		-0.09	-0.08	0.10
Atmos. pressure a.s.l.	0.03	0.34	-0.29	-0.03	-0.28	-0.28	-0.01	0.13	-0.02	0.27	-0.09		0.92	0.12
Atmos. pressure at station	0.01	0.45	-0.20	-0.09	-0.20	-0.20	-0.08	0.29	0.30	0.39	-0.08	0.92		0.30
Julian date	-0.06	0.07	-0.05	0.17	-0.06	-0.06	0.18	0.48	0.79	0.05	0.10	0.12	0.30	

Table 23: Statistical results of the univariate models for climate data relating to periods during which flight events were observed; top section: model parameters including estimate and (standard error), * = p <0.05, ** = p<0.01, *** = p=0; bottom section: different coefficients of determination of the models in question

Univariate models	Dispersion class	Wind speed	Nacelle pos.	Temperature	Sunshine	Precipitation	Atmos. press.
Intercept	-1.458** (0.508)	-1.301*** (0.345)	-0.299 (0.307)	-0.657 (0.354)	-0.913*** (0.254)	-0.674*** (0.119)	7.323 (18.807)
Dispersion class	0.181 (0.115)						
Wind speed		0.116 (0.067)					
Nacelle pos.			-0.002 (0.001)				
Temperature				-0.006 (0.022)			
Sunshine					0.032 (0.031)		
Precipitation						-42.022 (2232.644)	
Atmos. Press.							-0.009 (0.020)
Coefficients of determination							
Aldrich-Nelson R-sq.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
McFadden R-sq.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cox-Snell R-sq.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nagelkerke R-sq.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
phi	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Likelihood-ratio	2.5	3.0	2.5	0.1	1.0	2.5	0.2
p	0.1	0.1	0.1	0.8	0.3	0.1	0.7
Log-likelihood	-202.7	-178.5	-178.8	-180.0	-203.4	-202.7	-203.8
Deviance	405.4	357.0	357.5	360.0	406.8	405.4	407.6
AIC	409.4	361.0	361.5	364.0	410.8	409.4	411.6
BIC	416.9	368.4	368.8	371.3	418.3	416.9	419.2
N	320	287	287	287	320	320	320

Table 23 shows the results of the univariate models using the dataset reduced to phases of black stork activity. In contrast to the full dataset, none of the tested variables are of significant impact. Here too it is important to note that all the R-sq values are 0 which means that the goodness-of-fit of the underlying GLMs is inadequate.

Conclusions of the statistical analysis

A combined assessment of the statistical analysis of Variants 1 and 2 shows that no variables could be found that could explain the occurrence of weather-related flight movements in the danger zone of flight altitude category 3.

While the variables sunshine duration, nacelle position and atmospheric pressure were significant in the Variant 1 analysis, the underlying statistical models do not sufficiently explain the datasets. The results can be attributed, in part, to the chosen tiering down of the data. The inclusion of all weather data for the survey days without taking into account the weather conditions' suitability for flight increases the variance of the weather data. This greater variance can result in the variables reaching significance levels while the underlying models have little practical significance. The Variant 2 analysis aimed at addressing this issue. The question as to the potential occurrence of weather-related flight movements in the danger zone of flight altitude category 3 is the same as for Variant 2.

With regard to Variant 1 it is notable that sunshine duration as part of the full dataset, and in both the individual GLM and the combined models, often reaches significance level (Tables 20, 21). Despite the inadequate R-squared values of the individual underlying GLMs, this could indicate that the sunshine duration in the observed 10 minute intervals may influence black stork flight behaviour.

In Variant 2 of the analysis, the weather parameters were reduced to the events during which the black storks displayed flight behaviour, i.e. those which were suited for the species to engage in flight activity. With this reduced dataset and the associated reduction in the variance of weather data, no significant variables could be found at all. It was not possible to replicate the indication seen in Variant 1 of a possible influence of sunshine duration.

The limitations of the assessment methods used are discussed in detail as part of the overall discussion (see Chapter 6).

4.9 Examination of individual flight movements in the vicinity of WTs

This section individually examines 10 flight movements out of a total of 121 which entered the vicinity – defined as the 250 m zone – around the existing WTs and thus the horizontal danger zone around the installations.

The vertical danger zone references the birds' flight altitude with flight altitude category 3 which relates to the rotor height of the WTs in the Hallo and Auf der Haid wind farms that is considered the critical zone. As the survey did not only record flight altitude categories but also estimated flight altitudes, the latter will also be taken into account for the purposes of assessing the conflict potential of specific flight movements. The observed behaviours are listed in Table 24. The conflictual danger zone comprises the airspace of the defined flight altitude categories (FAC) and the horizontal 250 m area around the installations (Table 25).

Table 24: Observed black stork behaviour in the vicinity of WTs

Plane	Term	Description
horizontal	Avoidance flight	Flying around the periphery of a WT or wind farm or fully passing by the installations; minor directional changes
	Traversing flight	Flying directly in between multiple WTs
vertical	Overflight	Flight movements above the rotor tip
	Critical flight	Flight movements at rotor height
	Low-altitude flight	Flight movements below the rotor tip

Table 25: Determination of conflict potential inside and outside of the danger zone

	Outside of WT danger zone	**Inside of WT danger zone** (horizontal 250m area around WTs)
Above the rotor tip: FAC* 4	low-risk	Low-risk, but could be conflictual where flight approaches FAC 3
Rotor height, FAC* 3	low-risk	Conflictual (Differentiation, where possible: within / outside of rotor area)
Below rotor tip, FAC* 0, 1, 2	low-risk	Low-risk, but could be conflictual where flight approaches FAC 3

* FAC = flight altitude category

Table 26: Overview of weather parameters associated with flight movements in the WT danger zone; n.a. = no information, data gap; *: weather parameters at nacelle height

Parameter / Flight ID	52.3 1 bird	61.1 1 bird	99.1 1 bird	100.2 100.3 1 bird	125 1 bird	82.2 1 bird	94.1 1 bird	91.1 91.2 91.3 2 birds	110.1 1 bird
Date in 2016	06.05.	13.05.	23.06.	30.06.	18.07.	10.06.	23.06.	20.06.	07.07.
Observation point	5b	9	5b	9	9	9	5b	9	9
Wind farm concerned	Hallo	Hallo Haid	Hallo	Hallo	Haid	Haid	Hallo	Haid Hallo	Haid
Flight altitude category	3	3	3	3	3	4	2	1, 4	0
Flight altitude in m	125	150	80-150	90	100	200	50–80	30, 250	25
Rotor blade position relative to the bird's direction of flight	parallel	at angle/ parallel	perpen-dicular	parallel/ perpen-dicular	perpen-dicular	parallel	perpen-dicular	parallel/ at angle	perpen-dicular
Wind direction	NE	SSW	NNW	NE	ESE	NE	NNW	ENE	WNW
Wind speed in m/s*	3.4–5.4	6.7	6.6	5.5	3.0	2.5	6.0	4.5	3.0
Rotor tip speed* in km/h	n. a.	190	187	160	100	84	176	142	105
Visibility in km*	n. a.	38	100	150	150	43	100	50	75
Precipitation/ mm	0	0	0	0	0	0	0	0	0
Flight behaviour	K	S	K	S, K	S	S	K	S, K	S
Temperature/ °C*	19	17	26	20	25	20	23	15	18
Sunshine duration/observation interval in minutes*	n. a.	5-10	10	0	10	6	10	4	10
Assessment of weather conditions	Light to moderate winds, optimum visibility							Light to very light winds, optimum visibility	
Behaviour (horizontal)	Flight around wind farm periphery, slight changes in direction								
Behaviour (vertical)	At rotor height					Flight slightly above wind farm or low-altitude flight		Low-altitude flight or overflight	
Conflict situation	Conflictual					Moderate conflict		Little conflict	

The following maps (horizontal view) suggest a spatial precision of flight movement recording that in reality is not feasible as part of a survey involving only direct visual observation (i.e. unaided by transmitter technology). It is therefore not permissible to state or measure distances between individual flight movements and individual WTs. It was not possible to define the observational error for the visual survey.

FlightID 52

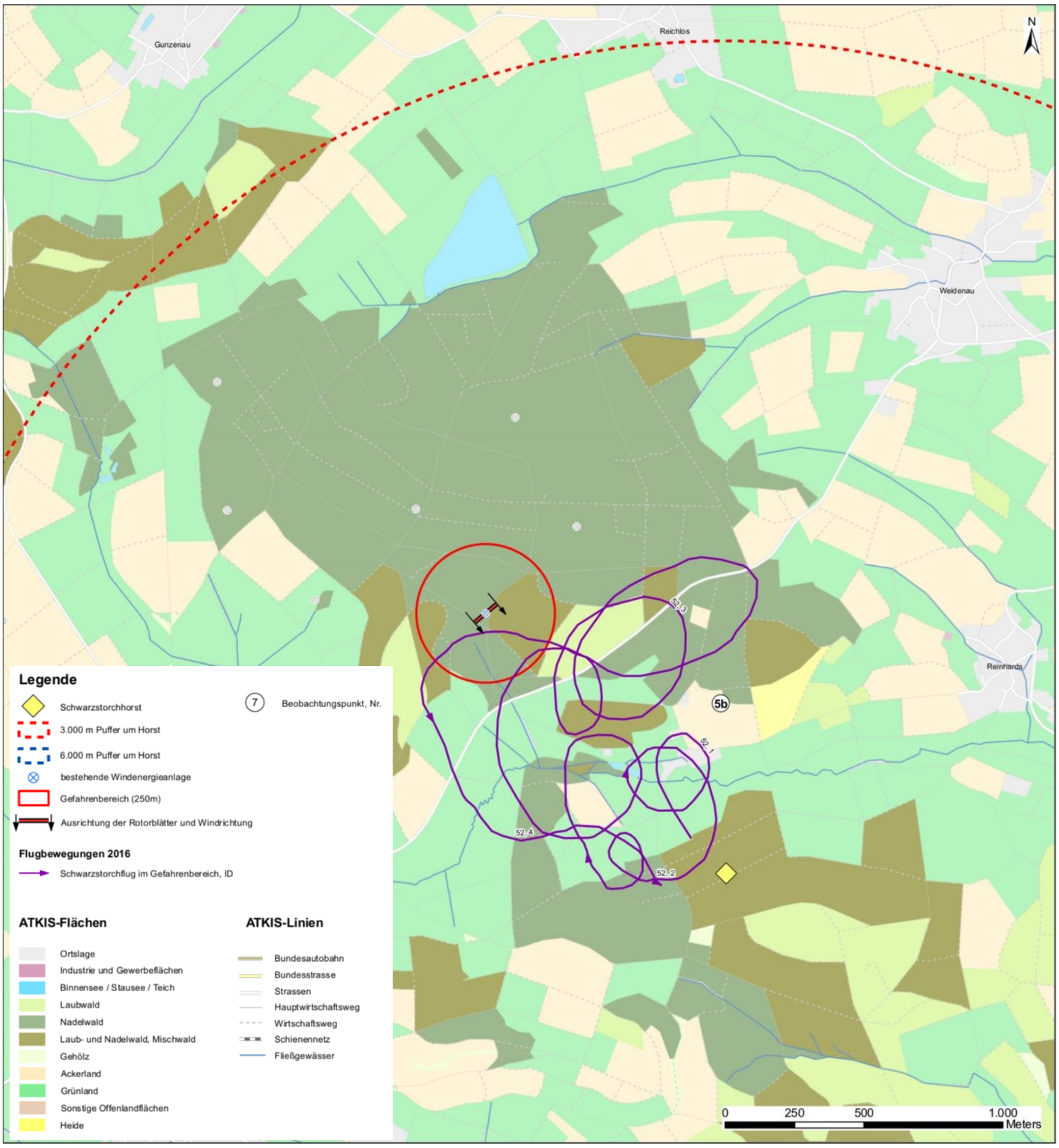

Figure 37: FlightID 52 in the danger zone in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map legend for Figs. 37-45
	(otherwise as in previous maps)
Gefahrenbereich…	Danger zone (250m)
Ausrichtung …	Alignment of rotor blades and wind direction
Flugbewegungen 2016	**Flight movements in 2016**
Schwarzstorchflug…	Black stork flight in danger zone, ID
Flugrichtung	Direction of flight
Durchflug…	Passage corridor with rotor-free zone
Rotorbereich	Rotor area
ATKIS Flächen	**ATKIS spatial objects**
Ortslage	Built-up area
Industrie…	Industrial, commercial area
Binnen…	Lake, reservoir, pond
Laub…	Deciduous forest

Nadel…	Coniferous forest
Laub- und Nadel…	Deciduous and coniferous forests, mixed forest
Gehölz	Copse
Ackerland	Arable land
Grünland	Grassland
Heide	Heathland
ATKIS Linien	**ATKIS linear objects**
Bundesautobahn	Federal motorway
Bundesstrasse	Federal road
Strassen	Roads
Haupt…	Rural hard-surface roads
Wirtschafts…	Rural tracks
Schienennetz	Rail network
Fliessgew…	Watercourses

On 06.05.2016 at 11:24 hrs a black stork soared upwards on thermals from the nest area to an altitude of approximately 80 m (ID 52.1+2). The bird subsequently continued its thermaling flight to the south of the Hallo wind farm up to a flight altitude of 125 m. In the course of this flight the bird approached a WT from its lee side. The rotor blades were positioned parallel to the direction of flight at this time (ID 52.3). The bird then flew back in the direction of the forest hosting the nest site while rapidly losing altitude (ID 52.4). Meteorological data from the WT are not available for the duration of this flight movement.

Flight movement summary: Conflictual avoidance of a WT as part of a wind farm, with rotor alignment parallel to flight direction in low wind conditions.

FlightID 61

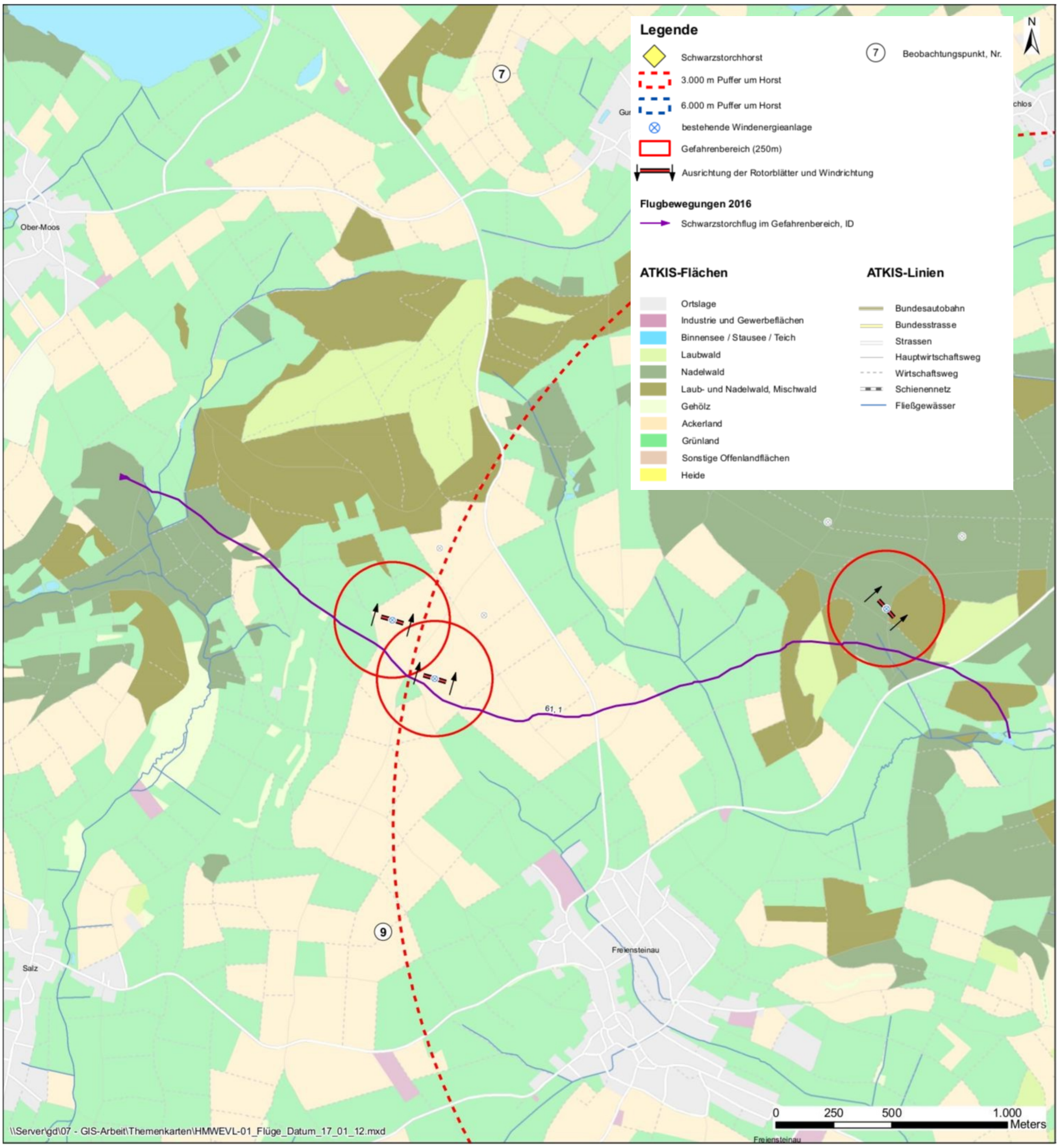

Figure 38: FlightID 61 in the danger zone in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Flight movement 61 was observed on 13.05.2016 between 11:02 and 11:08 hrs with the bird flying in a westerly direction at an altitude of 150 m from the forest hosting the nest site towards the feeding habitat. In the course of this flight, the bird entered the danger zone of a WT as part of the Hall wind farm, the rotor blades of which were positioned at an angle to the flight direction. In the further course of the flight, and continuing at an altitude of 150 m, the bird traversed the danger zone of two WTs as part of the Auf der Haid wind farm. Their rotor blades were positioned parallel to the flight direction which means that the bird passed the installations on their lee side. The bird then continued its flight in a west-north-west direction while dropping to an altitude of approximately 100 m.

Flight movement summary: Conflictual avoidance of both wind farms involving critical approaches to three WTs, the first of which was aligned perpendicular and the others parallel to the flight direction in moderate wind conditions.

FlightID 99

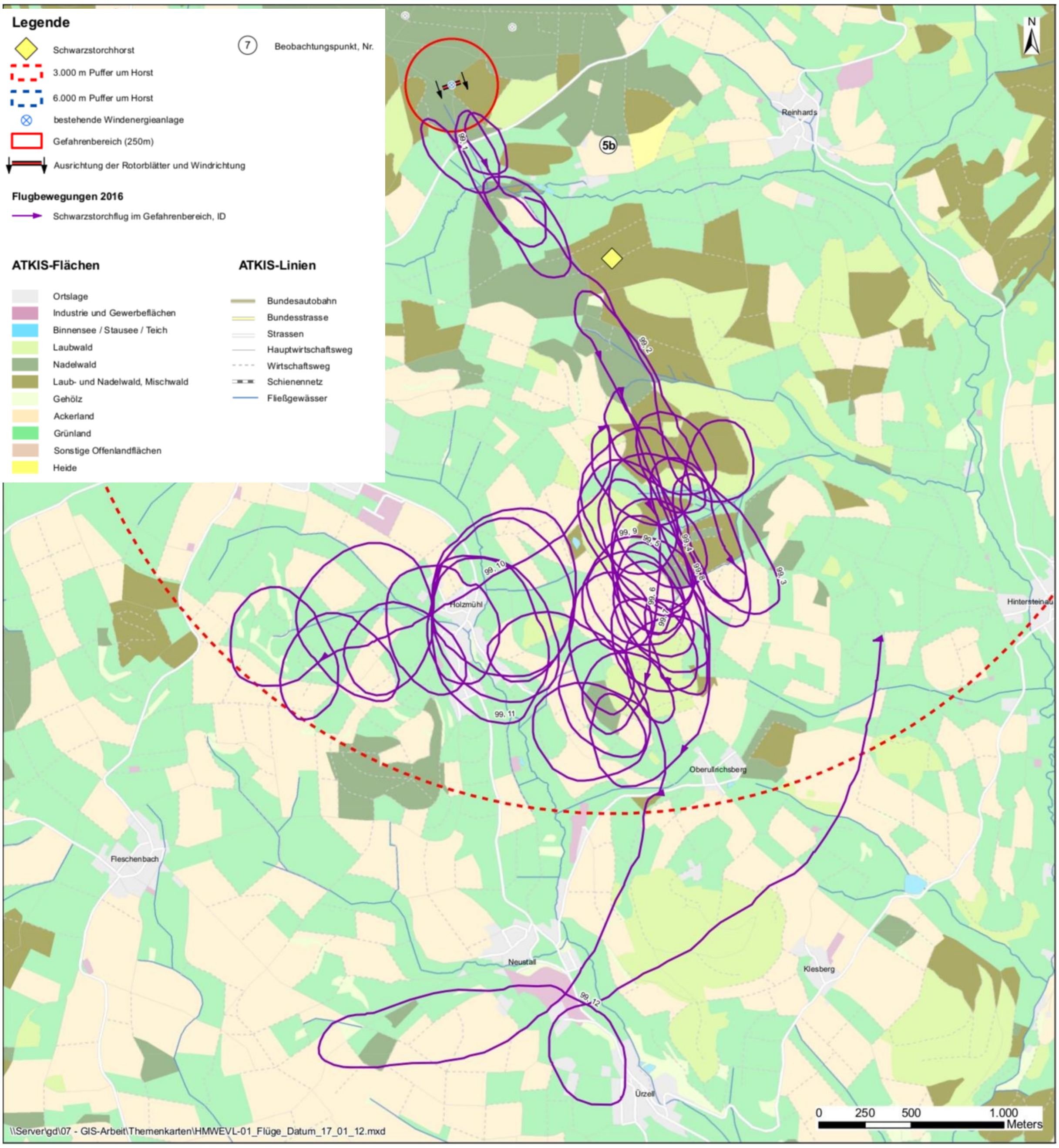

Figure 39: FlightID 99 in the danger zone in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

At 12:07 hrs on 23.06.2016 a black stork was spotted in thermaling flight to the northwest of the nest location. The bird was circling at altitudes between 80 and 150 m. In the course of this flight it entered the danger zone around one of the WTs as part of the Hallo wind farm at multiple times. The wind blew from the north-north-west at the time which means that the bird was located in the lee of the wind turbine. The bird subsequently flew towards the southeast where it was observed as very intensively soaring in thermals until 12:50 hrs.

Flight movement summary: Conflictual flight near the periphery of a WT as part of the Hallo wind farm, with rotors aligned perpendicular to the flight direction, in conditions of moderate winds and excellent visibility.

FlightID 100

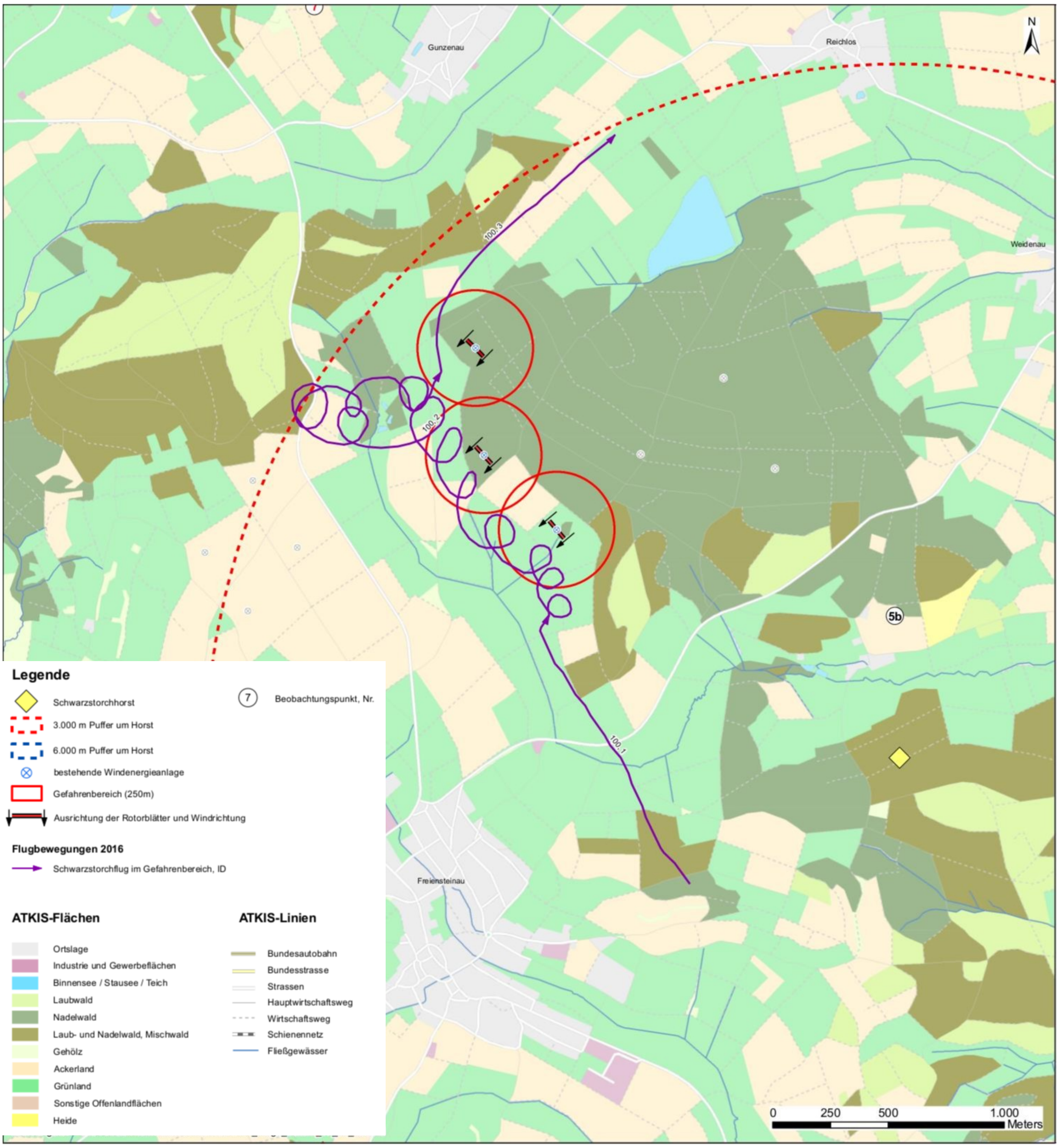

Figure 40: FlightID 100 in the danger zone in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

On 30.06.2016 a black stork was observed between 17:10 and 17:23 hrs. The bird came from a south-south-westerly direction and flew at an altitude of approximately 90 m (rotor area) to the area of open countryside located between the Hallo and Freiensteinau wind farms. It continued to soar in the thermals along the forest edge without gaining altitude. In the course of this flight the bird approached several installations of the Hallo wind farm from their rear. The wind turbines' rotor blades were aligned parallel to the flight direction at that time. The bird then continued its flight to the north of the wind farm in a north-easterly direction and traversed the danger zone of a further WT the rotor blades of which were aligned perpendicular to the flight direction.

Flight movement summary: Conflictual flight near the periphery of the wind farm, passing three WTs as part of the Hallo wind farm under conditions of moderate winds and excellent visibility. Rotors were aligned in parallel with the direction of flight twice, perpendicular to the direction of flight once.

FlightID 125

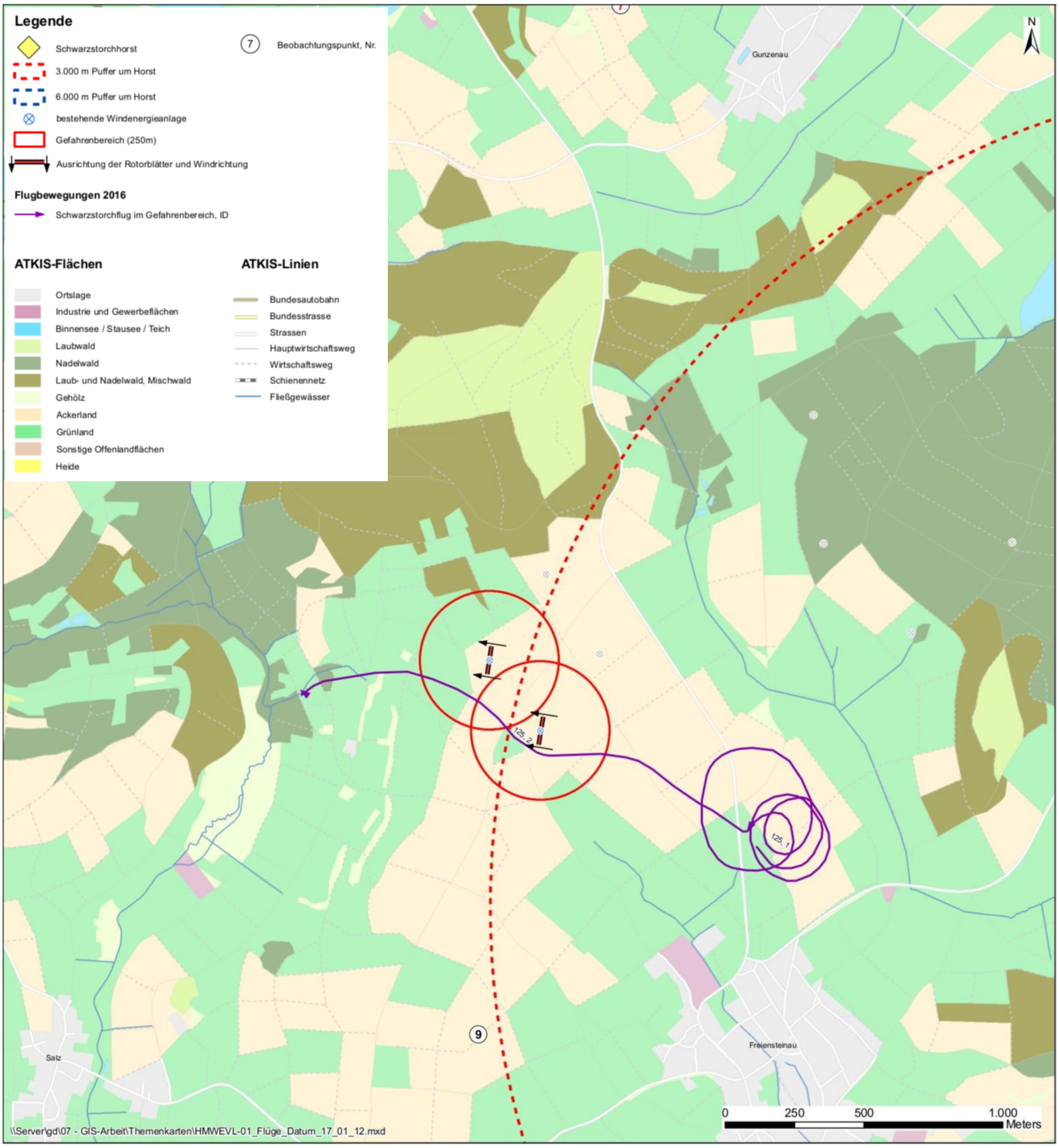

Figure 41: FlightID 125 in the danger zone in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

FlightID 125 denotes a flight movement observed on 18.07.2016 between 14:54 and 15:03 hrs. At first the bird was seen circling at altitudes of up to 190 m to the north of Freiensteinau (ID 125.1). It then flew towards the NNE, approached a WT as part of the Auf der Haid wind farm from its front, with the turbine's rotor blades aligned perpendicular to the flight direction at that time, then flew around the turbine and after passing the installation turned westwards and away from it while losing altitude, dropping down to an altitude of 100 m (rotor area) (ID 125.2).

Flight movement summary: Conflictual flight, passing along the periphery of two WTs as part of the Auf der Haid wind farm; slight change in direction, low wind conditions, with rotors aligned perpendicular to the flight direction, and very good visibility.

FlightID 82

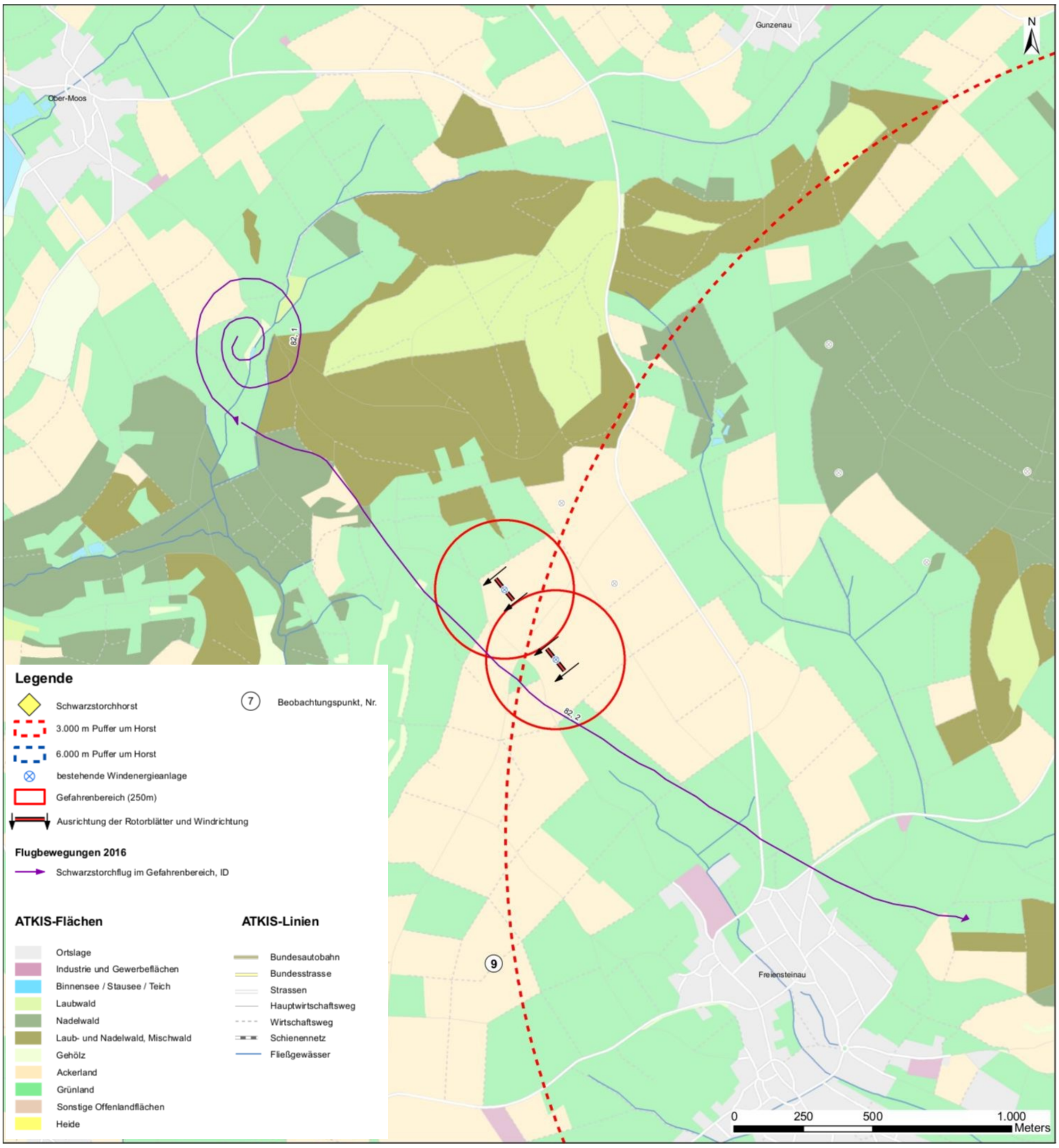

Figure 42: FlightID 82 in the danger zone in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Figure 42 shows flight movement 82 involving the events 82.1 and 82.2. On 10.06.2016 around 12:35 hrs a black stork was observed in thermaling flight to the south of the Ober-Moos pond at altitudes of between 200 and 300 m (ID 82.1). The bird subsequently flew south-eastward in the direction of the nest site, while dropping to an altitude of approximately 200 m and passing the WTs as part of the Auf der Haid wind farm to the southwest. The wind blew from the northeast at that time, meaning that the rotor blades were aligned parallel to the direction of flight. There were six minutes of sunshine within the relevant 10 minute interval, so it was partly cloudy.

Flight movement summary: Close peripheral overflight of two WTs under low wind conditions. Rotor blades parallel to the direction of flight, moderate conflict.

FlightID 94

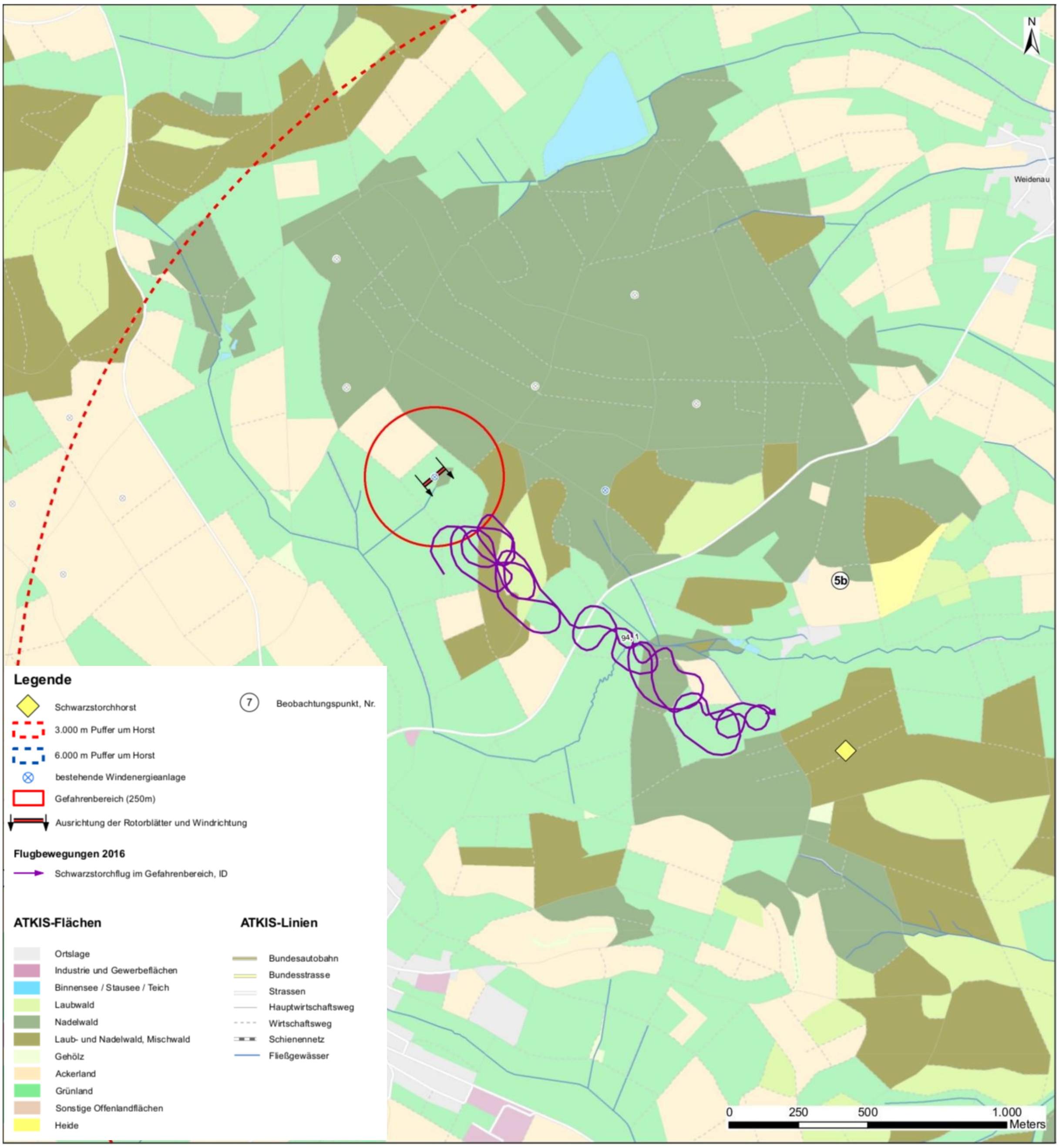

Figure 43: FlightID 94 in the danger zone in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

FlightID 94 was recorded on 23.06.2016 between 09:11 and 09:19 hrs. The bird circled at altitudes of between 50 and 80 m while drifting south-eastward towards the nest site. At the start of the flight movement the bird entered the danger zone (underneath the rotor area) of a WT as part of the Hallo wind farm multiple times. The rotor blades were aligned perpendicular to the flight direction at that time; the black stork approached the installations from its lee side.

Flight movement summary: Low-altitude flight (just underneath the rotor tip) on the periphery of a WT under conditions of moderate winds and optimum visibility. Rotor blades perpendicular to the direction of flight, moderate conflict.

FlightID 91

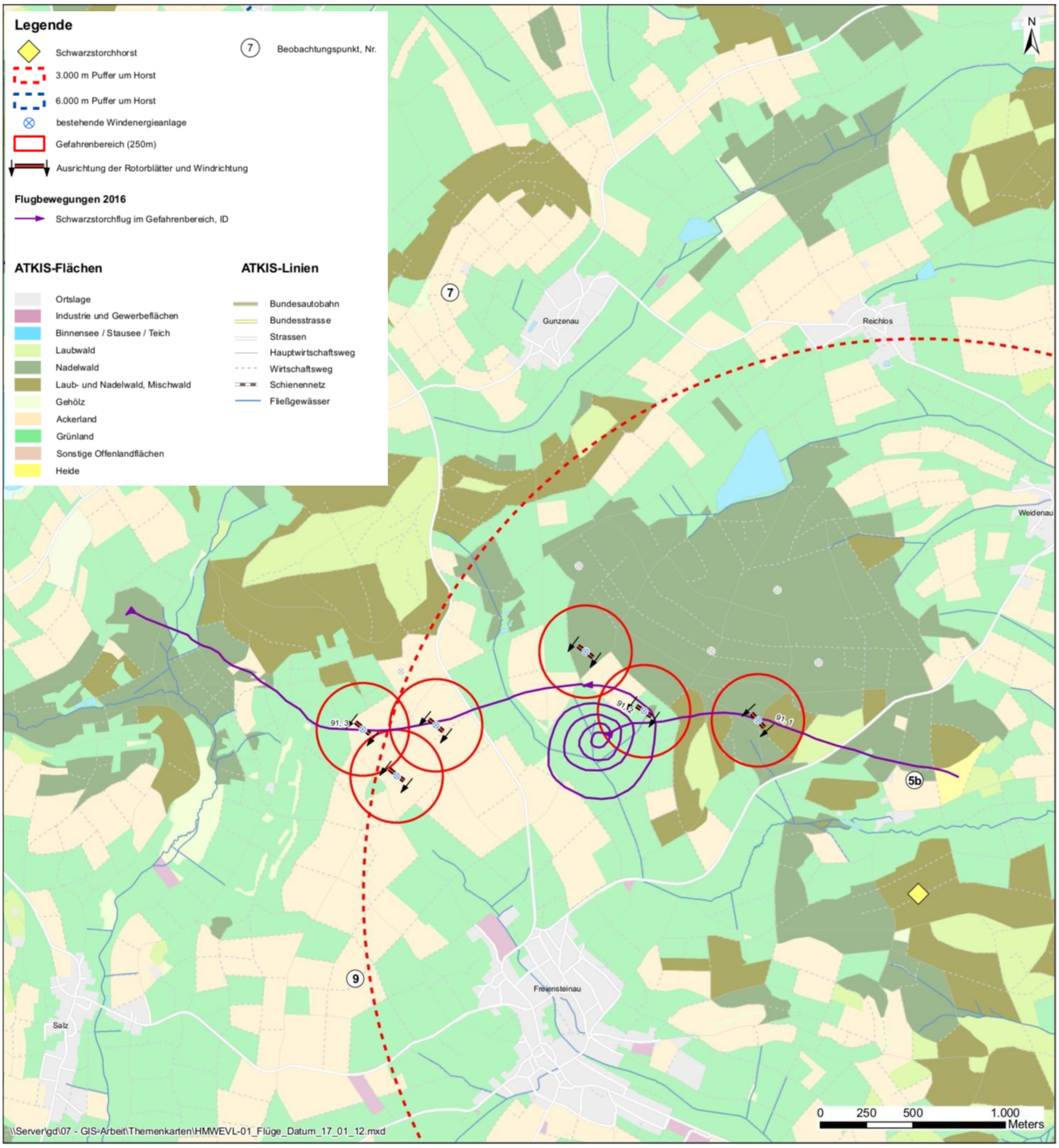

Figure 44: FlightID 91 in the danger zone in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Flight movement ID 91 was observed on 20.06.2016 between 10:08 and 10:19 hrs and included two individuals flying in close formation out of the Steinaubachtal valley. At the start, both birds flew at a low altitude of approximately 30 m in the westerly direction, passing underneath the rotor area of two WTs the rotor blades of which were aligned parallel to the flight direction at that time (ID 91.1). To the west of the Hallo wind farm the birds circled at an altitude of approximately 250 m and, as they departed, flew over a WT the rotor blades of which were aligned parallel to the flight direction (ID 91.2). In the further course of the flight, both birds grazed the danger zone of a further WT as part of the Hallo wind farm on their westward distance flight at an altitude of approximately 250 m (above the rotor area). In the course of this distance flight, and continuing at 250 m altitude, they flew over two WTs as part of the Auf der Haid wind farm, the rotors of which were aligned perpendicular to the flight direction at that time. There were four minutes of sunshine during the relevant 10 minute interval.

Flight movement summary: Low-altitude flight along the periphery of two WTs and overflight of two WTs at sufficient vertical distance under conditions of low winds and good visibility. Rotors were aligned in parallel with the direction of flight twice, and at an angle to the direction of flight twice; low-conflict flight movement.

FlightID 110

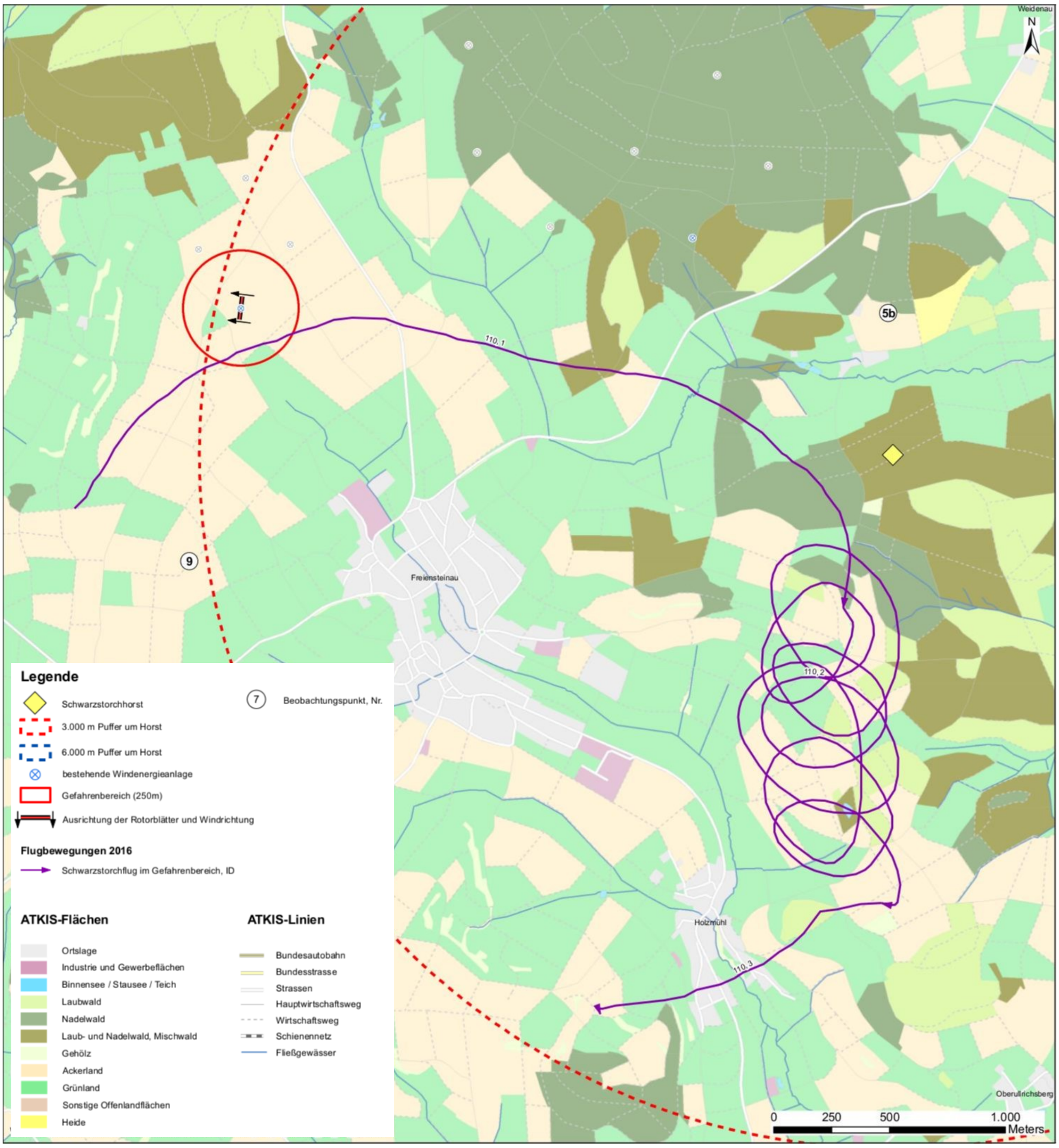

Figure 45: FlightID 110 in the danger zone in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

FlightID 110 was recorded on 07.07.2016 between 10:39 and 10:45 hrs. The black stork initially flew at altitudes of no more than 25 m over agricultural land north of Freiensteinau. In the course of that flight it traversed the danger zone of a WT of the Auf der Haid wind farm, the rotor blades of which were aligned perpendicular to the direction of flight (ID 110.1). The bird then circled to the east of Freiensteinau, climbing to altitudes of up to 190 m (ID 110.2). From the south of Freiensteinau, at an altitude of between 50 and 80 m, it then left the area in a westward direction (ID 110.3).

Flight movement summary: Low-altitude flight on the periphery of a WT under conditions of low winds and good visibility. Rotors aligned perpendicular to flight direction; low-conflict flight movement.

Conclusions on flights in the danger zone

Out of a total of 121 flights recorded in the study area, 10 flights were found to have entered the wind turbines' danger zone. All flights took place in good weather conditions (light to moderate winds, optimum visibility). Five flights (ID 52, 61, 99, 100, 125) out of these 10 flights in the horizontal danger zone entered the airspace of the rotors and were thus considered conflictual. During these flights the black storks approached the WTs but flew around them on their periphery. One slight change in direction on approach was detectable (ID 125).

In the case of the less conflictual other five flights, the birds flew around the WTs either below or above rotor height. There were no observations of any conflictual flights traversing the wind farm.

The reason for the storks' spatial approaches to the vicinity of WTs may be due to the fact that the WTs are located on the periphery of the natural flight route leading westwards from the nest site to feeding habitats 13 and 9, and to the fact that there are areas with good thermals along the forest edge in the vicinity of the nest site.

4.10 Land use and topography

This section describes the observed flight events in combination with the underlying land use and topography. It should be noted that the statements made below are based solely on the flight events observed as part of the surveys conducted in 2016 and are subject to the limitations with regard to the individual target elevations' visibility as discussed in Section 3.3 and elsewhere in this report. Given these limitations the authors refrained from quantitative considerations in this context.

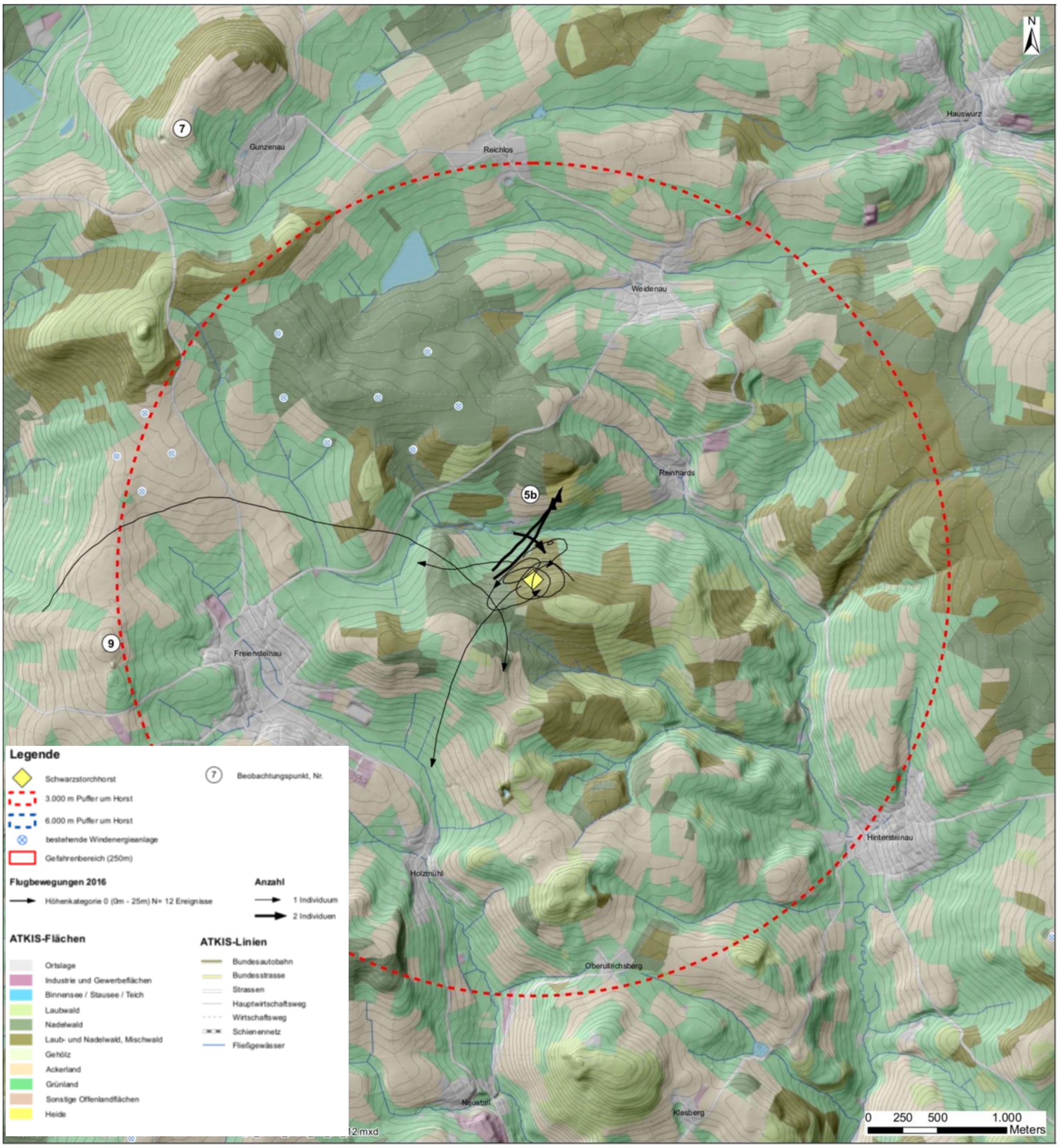

Figure 46: Flight events superimposed on DLM and DTM, altitude category 0 (0–25 m) in Freiensteinau 2016
(Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map legend for Figs. 46–51
	(otherwise as in previous maps)
Flugbewegungen 2016	Flight movements in 2016
Höhenkategorie	Altitude category
Flüge in mehreren..	Flights in multiple categories
Ereignisse	events
1 Individuum	1 individual
2 Individuen	2 individuals
3 Individuen	3 individuals
ATKIS areas etc. as in Figs. 37 ff	

The flight events in altitude category 0 (0–25 m) primarily took place in the vicinity of the nest site and therefore above the different types of forest (mixed forest, coniferous forest) and adjacent open habitats (grassland and arable land) (Figure 46).

Flights in altitude category 0 (0–25 m) were predominantly located in the area around the nest site at 445–450 m a.s.l. and traversed both the adjacent valleys and the slopes of the Atzenstein (478.4 m a.s.l.) and the Windberg (485–490 m a.s.l.).

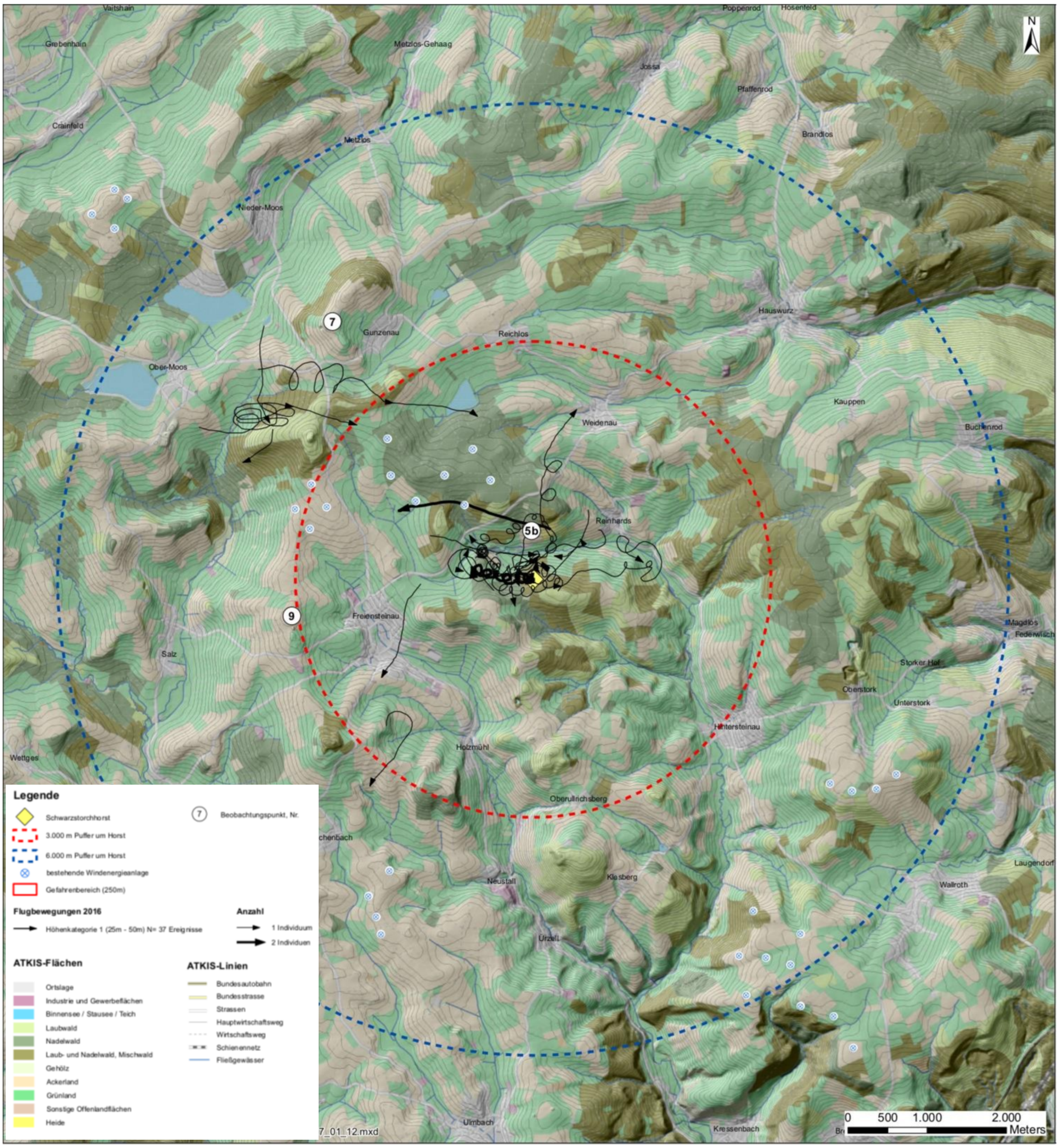

Figure 47: Flight events superimposed on DLM and DTM, altitude category 1 (25–50 m) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

The flight events in altitude category 1 (25–50 m) are focused on the area around the nest site as well as on the vicinity of feeding habitats potentially visited by the storks (Figure 47). Their course predominantly follows the forested slopes of the Atzenstein and adjacent open habitats. The birds avoided overflights of the Naxberg (553.6 m a.s.l.), the highest hilltop in the study area, and instead traversed the area at a lower elevation of 525 m a.s.l. by flying over the adjacent saddle. Four events were recorded in this category at this altitude.

There were also occasional records of flights at this altitude above the village of Freiensteinau and above the Reichlos pond.

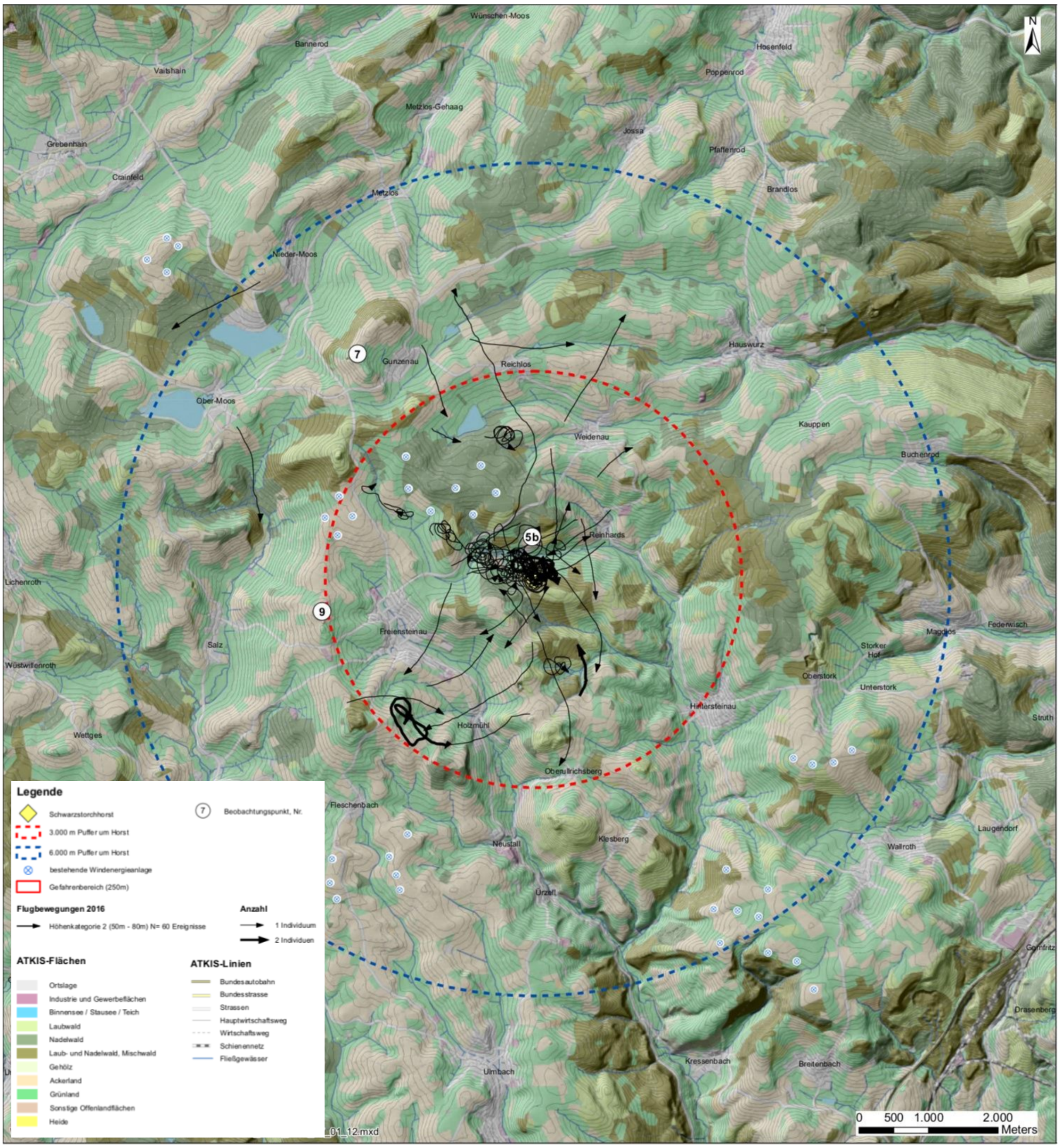

Figure 48: Flight events superimposed on DLM and DTM, altitude category 2 (50–80 m) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

The flight events in altitude category 2 (50–80 m) were strongly focused on the area around the nest site and took place above all forest types (mixed forest, coniferous forest, deciduous forest) and adjacent open habitats (grassland, arable land) (Figure 48). Individual flight events in this altitude category were occasionally recorded at distances of more than 3 km from the nest site, in the course of which the birds overflew all forest types, the open habitats, and the villages of Freiensteinau (including the industrial and business park), Holzmühl and Reinhards.

The flights in altitude category 2 consisted of shorter flight movements and thermaling flight along the forested slopes surrounding the forest hosting the nest site (445–450 m a.s.l.) and longer distance flights above the surrounding valleys. The birds flew around exposed hilltop locations such as the tops of the Naxberg (553.6 m a.s.l.) and Windberg (495–500 m a.s.l.).

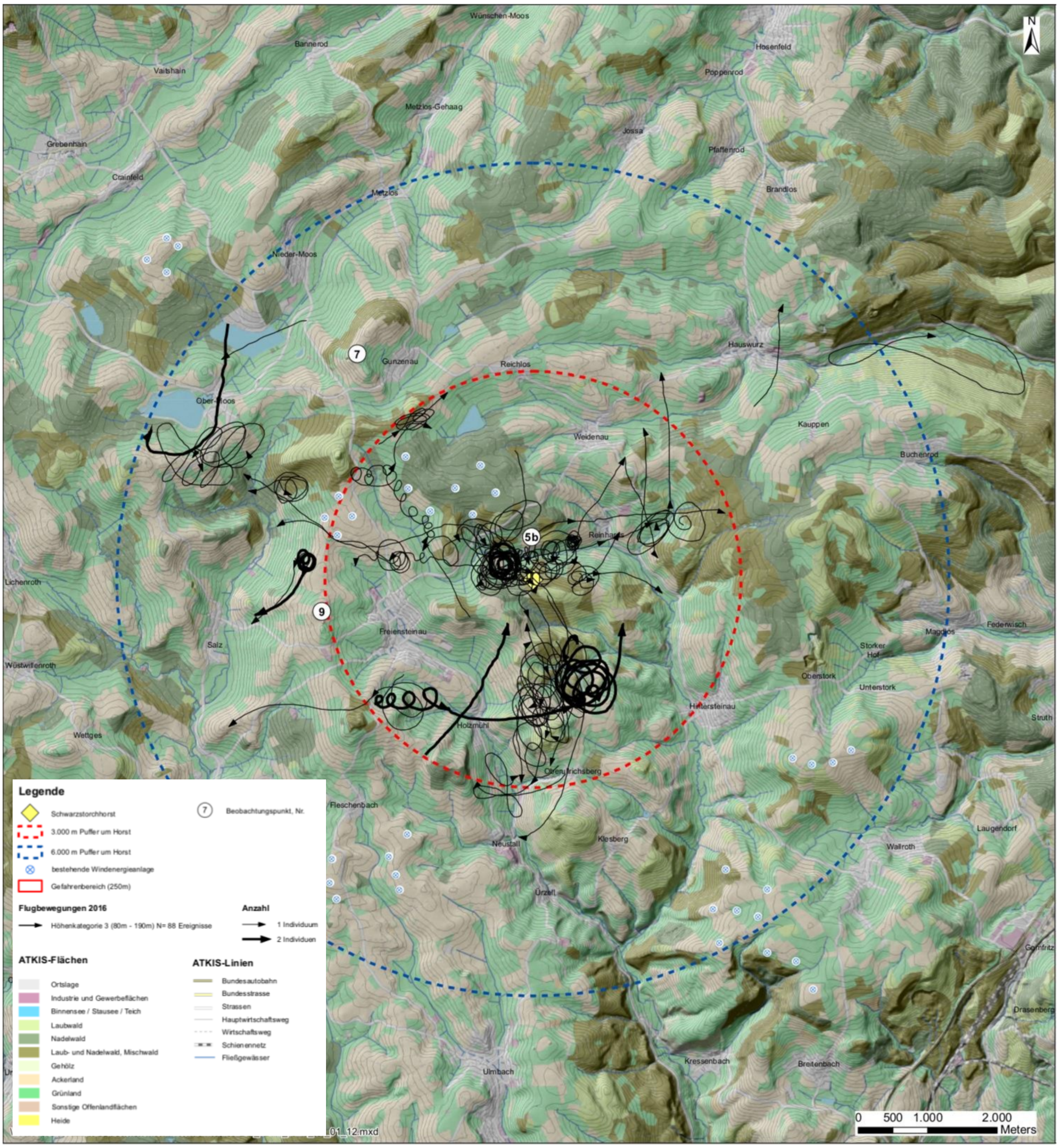

Figure 49: Flight events superimposed on DLM and DTM, altitude category 3 (80–190 m) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

The flight events in altitude category 3 (80–190 m) took place above all landscape types (grassland, arable land, mixed forest, coniferous forest, deciduous forest, standing waters) and above the villages of Ober-Moos, Hauswurz, Reinhards, Holzmühl, Oberullrichsberg and Neustall (Figure 49).

Flights at altitudes of between 80 m and 190 m traversed some of the lower hilltops in the study area. These included the Röllberg (481 m a.s.l.), Auf dem Roppels (475–480 m a.s.l.) and Dicker Strauch

(465.5 m a.s.l.). Four flight events were recorded above areas located at between 510 and 525 m a.s.l. west to southwest of the Naxberg hill.

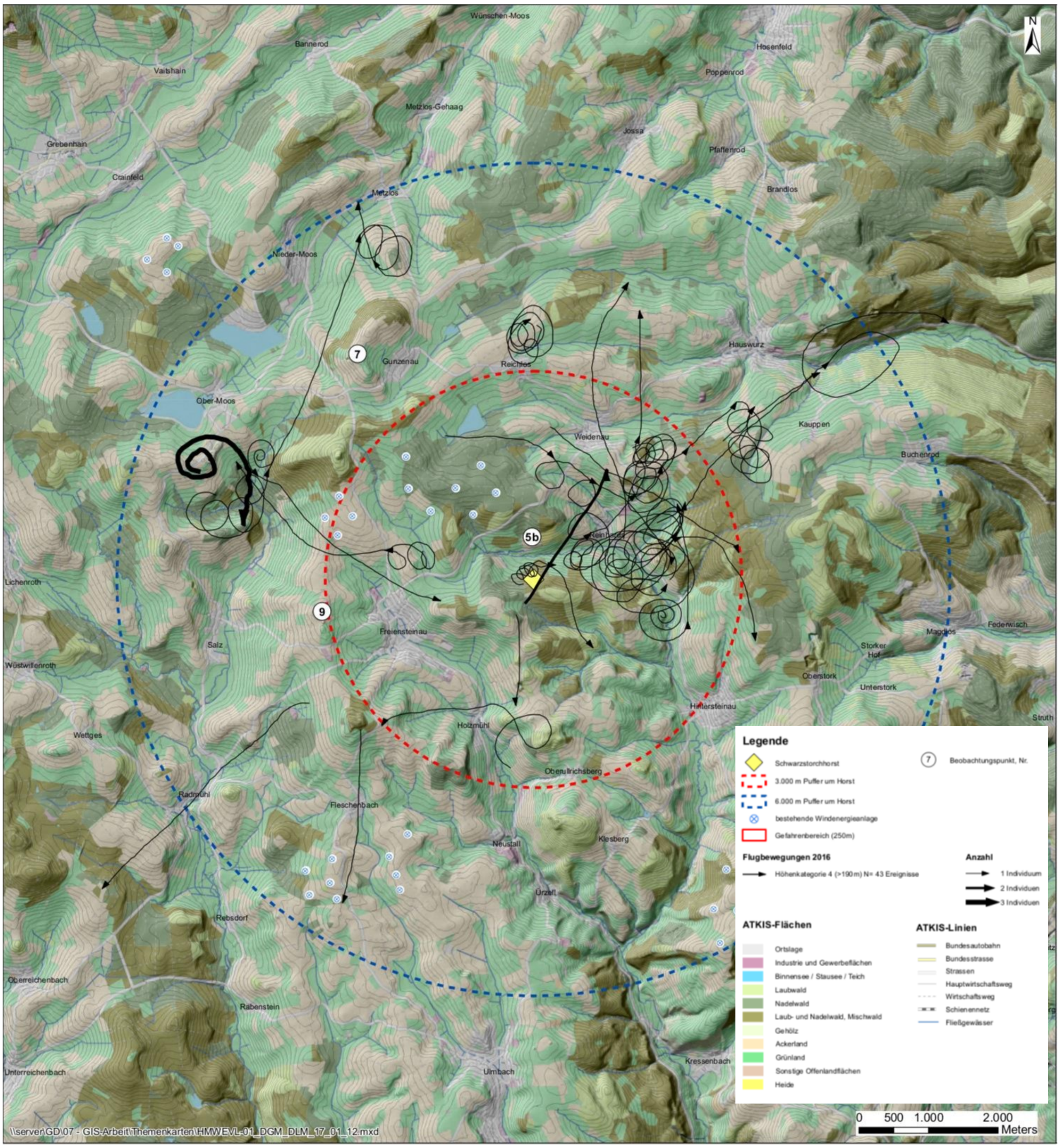

Figure 50: Flight events superimposed on DLM and DTM, altitude category 4 (>190 m) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

The flight events in altitude category 4 (>190 m) were predominantly located to the east of the nest site, with the birds overflying the land cover types grassland, arable land, mixed forest, coniferous forest, deciduous forest and the villages of Weidenau, Reichlos, Freiensteinau, Holzmühl, Fleschenbach and Reinhards (Figure 50).

In this altitude category, slopes in the vicinity of forest edges were used for thermaling flight. In the course of the surveys there were no records of overflights of exposed hilltop locations.

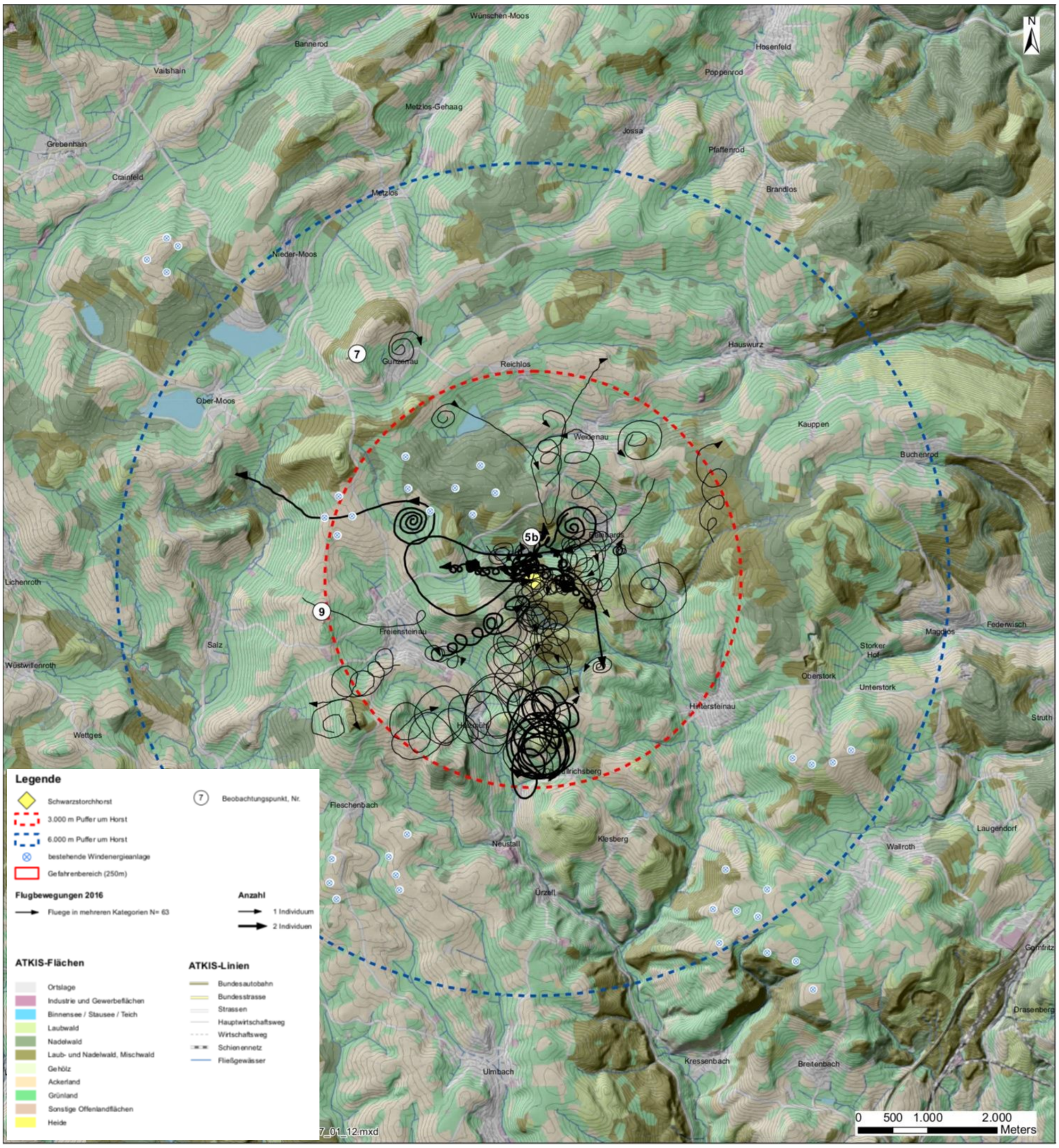

Figure 51: Flight events superimposed on DLM and DTM, multiple altitude categories (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Flight events assigned to multiple altitude categories primarily took place in the vicinity of the nest site as well as to its south (Figure 51). The birds also overflew exposed hilltop locations such as the Röllberg (481 m a.s.l), Windberg (495–500 m a.s.l.), and Appenstück (495–500 m a.s.l.). Two events were recorded at higher elevations at the Winterberg at approximately 520 m a.s.l. and in the area of the southern slope at Gunzenau, also at 510–520 m a.s.l.

Summary of flight movements in Freiensteinau with reference to topography

Flights generally took place at elevations of between 350–355 and 520–525 m a.s.l. Ten flight events were recorded at higher elevation locations between 510 and 525 m a.s.l. For comparison, the Hallo wind farm comprises elevations of between 480 and 512 m a.s.l. and the Auf der Haid wind farm comprises elevations of between 480 and just under 500 m a.s.l. The birds therefore overflew locations at elevations comparable to those of the existing wind farms. However, the birds flew around the highly exposed hilltop of the Naxberg.

Land use in the 6 km radius around the occupied nest site at the Atzenstein is strongly shaped by agricultural management of grassland and arable land with open habitats comprising 70% of the area (see Figure 52, top left). Forests (deciduous, coniferous or mixed) are the second most common land-use type. The remaining areas are under non-forest woody vegetation, settlements, miscellaneous land uses, or business parks and industrial estates.

The bottom left section of Figure 52 shows the flight distance covered (flight density) by land use. A comparison of the charts at the bottom left and top left respectively shows that the distribution of flights is not congruent with the distribution of land-use types.

Compared to their proportion in land use around the nest site, the different forest types are utilised significantly more frequently than arable land or grassland, despite the fact that the latter cover a significantly higher proportion of the area. The comparatively high flight densities above the other land-use types must be considered in a more nuanced way as their proportional share in land cover was very small. A small number of overflights of these areas combined with their small area strongly inflates the flight density in m/ha and gives a false impression of flight frequencies.

Figure 52 at the bottom right graphs the proportional share in land cover of land-use types in the 6 km radius around the nest site against the proportional share in flight density. With an increasing share of a land-use type in the total area one would expect a proportionate increase in flight density above that land-use type.

The red lines demarcate the range, including a ± 5% deviation, in which supply (land use) and demand (flight density) are balanced.

For land-use types that are clearly located outside of this range, there is a significant shift in the ratio between area and flight density above the land-use type in favour of either the share in land cover or of flight density. As already outlined above this is the case for arable land and grassland, both of which have a large share in the total area but which are overflown more rarely than would have been expected given their proportional share in land cover.

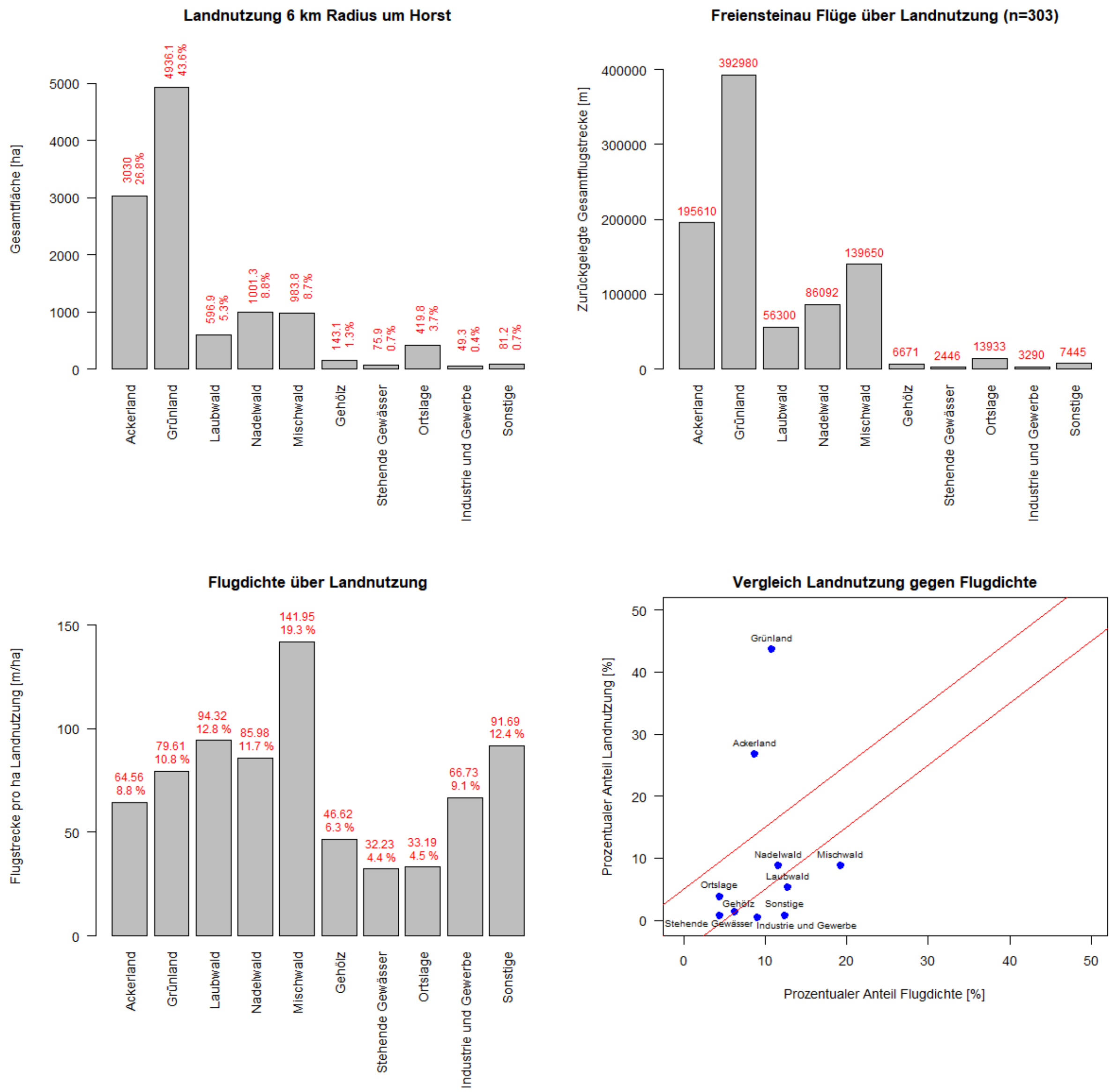

Figure 52: Land use in Freiensteinau 2016

Landnutzung 6km Radius um Horst	**Land use 6 km radius around nest site**
Gesamtfläche [ha]	Total area [ha]
Freiensteinau Flüge über Landnutzung…	**Freiensteinau flights by land use [n=303]**
Zurückgelegte Flugstrecke [m]	Flight distance covered [m]
Flugdichte über Landnutzung	Flight density by land use
Flugstrecke pro ha Landnutzung [m/ha]	Flight distance per ha land use [m/ha]
Vergleich Landnutzung gegen Flugdichte	**Comparison of land use and flight density**
Prozentualer Anteil Landnutzung [%]	Percentage share land use [%]
Prozentualer Anteil Flugdichte [%]	Percentage share flight density [%]
Ackerland	Arable land
Grünland	Grassland
Laubwald	Deciduous forest
Nadelwald	Coniferous forest
Mischwald	Mixed forest
Gehölz	Non-forest woody vegetation
Stehende Gewässer	Standing waters
Ortslage	Built-up area
Industrie und Gewerbe	Industry and commerce
Sonstige	Other

4.11 Potential and utilised feeding habitats

The spatial delineation of potential and utilised black stork feeding habitats (see Map 2) is based on the data analysed in Section 3.2 ff. Potential feeding habitats are those that are well resourced, well structured and offer a good food supply.

For utilised feeding habitats, observations were at hand confirming foraging black storks or flight movements involving behaviour indicative of food searching behaviour. In addition to own observations, third-party records obtained in the course of the surveys (representatives of voluntary conservation organisations, farmers) and data from existing expert reports by PLANUNGSGRUPPE GRÜN (2016b), SOMMERHAGE (2016a) und SOMMERHAGE (2016b) were analysed and taken into consideration for the purposes of delineating the habitats.

Table 27: Overview of potential and utilised feeding habitats

No.	Status **P = potential U= utilised**	Name	Notes
1	U	Ürzell stream valley between Freiensteinau and Holzmühl	Stream valley with periodically wet meadows, intensively managed in parts, black stork sightings, see Figure 53.
2	U	Upper reaches of the Jossa (stream)	Semi-natural stream, pond, amphibians, fish, black stork sighting, aquatic and humid habitats
3	U	Schwarzellerbach (stream)	Semi-natural stream valley, contains water also in summer months, fish, amphibians, black stork sighting, creation of small waterbodies/ widened stream beds (Hallo wind farm mitigation measures)
4	U	Kreidenbach (stream) and Ziegelteich (pond)	Stream valley, semi-natural in sections, black stork sighting, amphibians and fish in the Ziegelteich pond, creation of small waterbodies/widened stream beds (Hallo wind farm mitigation measures at Weiherwiese and Kemmete)
5	P	Pond at Eschenbach	Pond hosting amphibians; fish likely present
6	U	Reichlos pond	Amphibians, fish, black stork sighting, aquatic and humid habitats, relatively undisturbed, foraging flight to Reichlos pond
7	U	Moosbach (stream) with grassland	Black stork sighting, fish
8	U	Humid riparian zone, shallow water Nieder-Mooser-Teich (pond)	Amphibians, fish, black stork sighting
9	U	Ober-Mooser-Teich (pond)	Amphibians, fish, reptiles, black stork sighting
10	P	Hängsberger Wasser (stream)	Fish, semi-natural stream, aquatic and humid habitats
11	U	Upper Steinaubach stream valley	Amphibians, aquatic and humid habitats, stork landing, multiple ponds, see Figure 57, black stork sighting
12	U	Steinaubach (stream) to Reinhards	Nature reserve "Im Pfaffendriesch bei Freiensteinau", fish, amphibians, reptiles, grasshoppers, aquatic insects, semi-natural stream, aquatic and humid habitats, black stork sighting, numerous foraging flights
13	U	Wet meadows northeast of the Salz (stream)	Nature reserve "Bruchwiesen bei Salz", fish, amphibians, semi-natural stream, aquatic and humid habitats, black stork sighting, see Figure 59
14	U	Steinaubach (stream) below Reinhards	Fish, semi-natural stream, aquatic and humid habitats, creation of small waterbodies/widened stream beds (Hallo wind farm mitigation measures at Reinhards), black stork sighting

No.	Status P = potential U= utilised	Name	Notes
15	P	Ürzeller Wasser (stream) at Ürzell	Fish, amphibians, semi-natural stream, aquatic and humid habitats
16	U	Ürzeller Wasser (stream) and “In den Kehreiswiesen”	Fish, amphibians, semi-natural stream, aquatic and humid habitats, black stork foraging flight
17	P	Middle section of Steinebachtal (stream valley)	Fish, semi-natural stream, aquatic and humid habitats
18	P	Salz (stream) at Radmühl	Fish, semi-natural stream, aquatic and humid habitats
19	P	Upper reaches of the Salz (stream) at Speckenmühle	Fish, aquatic and humid habitats
20	P	Tributary to Steinaubach (stream) at Schrumpfmühle	Fish, amphibians, semi-natural stream, pond
22	P	Hinterkippel pond	Pond hosting amphibians incl. smooth newt and Alpine newt
23	P	Upper reaches of the Salz (stream)	Fish, semi-natural stream, aquatic and humid habitats, man-made ponds
24	P	Flooded quarry north of Stork	Pond hosting amphibians, reptiles
25	P	Kemmete	Fish, amphibians, semi-natural stream, aquatic and humid habitats
26	P	Ürzell stream above Ürzell	Fish, amphibians, semi-natural stream, aquatic and humid habitats
27	P	Lower Steinebachtal (stream valley)	Fish, semi-natural stream, aquatic and humid habitats
28	P	Engelbach (stream)	Semi-natural stream, aquatic and humid habitats
29	U	Wöllbach (stream) at Fleschenbach	Existing pond and creation of new small watercourse (Hallo wind farm mitigation measures), black stork sighting, amphibians
30	P	Fahrbachswiesen (meadows) and stream	Semi-natural stream, aquatic and humid habitats
31	P	Kaupener Graben (stream)	Semi-natural stream, aquatic and humid habitats
32	P	Buchenroder Graben (stream)	Semi-natural stream, aquatic and humid habitats
33	P	Steinaubach (stream) and small valley forest meadows at the Kieselkopf hill	Semi-natural stream, spring-outflow streams, fish, reptiles, grasshoppers, aquatic and humid habitats
34	P	Steinaubach (stream) tributary	Semi-natural stream, aquatic and humid habitats
35	P	Steinaubach (stream) tributary	Semi-natural stream, aquatic and humid habitats
36	U	Holzmühl pond at Heiertsborn	Existing pond and creation of new small watercourse (Hallo wind farm mitigation measures). Ample food supply of small fish and amphibians, especially common water frogs, was recorded at own site visit on 30 June 2016.

Description of selected areas

No. 1: Ürzell stream valley between Freiensteinau and Holzmühl

The feeding habitat is located on the periphery of the black storks' focal area of flight activity. There are own observations as well as third-party sightings of foraging back storks for this site.

The feeding habitat features a rapidly flowing low mountain stream with sufficient substrate diversity (streambed structure insignificantly altered, quality grade 2 after GESIS 2013) and an adjacent floodplain hosting some periodically wet grassland. Given the site's proximity to a built-up area, a certain level of human disturbance is likely. Black storks have also been sighted at this section by NABU Freiensteinau (pers. comm. Mr. Ondra, July 2016).

Black storks searching for food or flight movements involving behaviour indicative of food searching behaviour were observed on four separate occasions:

- 23.05.2016: 15:03 to 15:05 hrs: 1 black stork flying very low (20 m) from the nest site towards the stream valley (ID 67.1)
- 10.06.2016, 9:46 to 9:50 hrs: 1 black stork flying at an altitude of approximately 80 m above Freiensteinau into the stream valley at the sports ground and descending to 15 m in the process (Id 80.1)
- 10.06.2016, 10:15 to 10:27 hrs: 2 black storks searching for food ascend from the stream valley at the sports ground (ID 81.1)
- 18.07.2016, 14:36 to 14:44 hrs: 1 black stork searching for food ascends and circles in thermals at 75 m, then re-enters the stream location (Id 124.1)

Figure 53: Periodically wet grassland with large marsh grasshopper, a feeding habitat frequently visited by black storks, located to the east of Freiensteinau in the Ürzell floodplain below the sports ground

Figure 54: Ürzell stream with riparian woodland, diverse streambed substrate and adjacent grassland floodplain vegetation

No. 3 Schwarzellerbach (stream)

The Schwarzellerbach is a small semi-natural low mountain stream with high substrate diversity and a meandering course; it is lined by riparian woodland and situated in a structurally rich floodplain consisting of grassland and marshy fallow land. The stream's lower reaches host river trout. The feeding habitat is relatively free of disturbance, with highly frequented agricultural tracks and roads being located well away from the site. The stream carries water year-round.

As part of the mitigation measures for the Hallo wind farm (PLANUNGSGRUPPE GRÜN 2016a), in several places the Schwarzellerbach was either widened or new small water bodies were established in wet depressions with a view to increasing the abundance of amphibians and small fish as a food supply. During an own site visit on 19.06.2016 two black storks were seen departing the Schwarzellerbach. Moreover, on 30.06.2016 the site was found to have an ample supply of small fish and amphibians, a finding further supported by the photo of a foraging black stork contained in the monitoring report prepared by PLANUNGSGRUPPE GRÜN (2016a).

Figure 55: Watercourse widening at Schwarzellerbach

No. 11 Upper Steinaubach (stream)

The feeding habitat is located on the periphery of the focal area of black stork flight activity. Spatial use was confirmed by an observed flight.

The value of the Steinaubach's upper reaches as a feeding habitat is due to the mosaic of wetland habitats consisting of marshy fallow land, wet meadows, several small ponds and a larger man-made pond.

A low-altitude foraging flight was observed at the upper reaches of the Steinaubach on 28.04.2016 between 14:32 and 14:37 hrs (ID 24.2). It is likely that the stork was searching for fish at the stocked man-made pond or for amphibians present in the smaller ponds.

In the ex-ante study for the Hallo wind farm the feeding habitat was classified as a preferred feeding habitat.

In the course of the investigations in Hintersteinau a foraging flight over the meadows at the Steinaubach was noted on 22.06.2015. This sighting was a random observation seen in passing while driving to the observation point.

Figure 56: Marshland complex at the upper reaches of the Steinaubach

Figure 57: Black storks utilise the man-made pond at the "Große Lache" on the upper reaches of the Steinaubach

No. 12 Steinaubach (stream) between Pfaffendriesch and Reinhards

The feeding habitat is located within the focal area of black stork flight activity (see Map 3). Foraging black storks were confirmed at the site by own observations, as part of the investigations in Hintersteinau, and by third-party observations.

The segment of the Steinaubach stream located between the "Im Pfaffendriesch bei Freiensteinau" nature reserve and the village of Reinhards follows a semi-natural course, contains a range of aquatic and humid habitats, and offers a very good food supply in the form of river trout, European bullheads and brook lampreys.

At its closest point this fish-rich stream is located a mere 300 m from the nest site. The grassland areas on the slopes between the stream and the forest hosting the nest site are also used as feeding grounds (cf. 4.1). A 2016 record was also provided by Karpenstein in Planungsgruppe Grün (2016a) who observed two foraging adult black storks in the Steinaubach valley bottom on 05.08.2016.

Figure 58: Steinaubach valley with aquatic and humid habitats; section of a photograph by the Luftstrom company, Mr. Häußer, looking from the H8 wind turbine towards the forest hosting the nest site on 28.04.2016

No. 13 "Bruchwiesen bei Salz" – Wet meadows at the upper reaches of the Salz

The feeding habitat is located on the periphery of the black storks' focal area of flight activity. There are own observations as well as third-party sightings of foraging black storks.

A number of distance flights target this area and it would appear that there is a flight axis towards the Salz valley bottom.

This feeding habitat is a section of the upper reaches of the Salz which follows a semi-natural course with clear water and a gravel streambed (see Figure 59). The area includes parts of the "Bruchwiesen bei Salz" nature reserve. Given its remote location, at a good distance from built-up areas and primary agricultural and forestry roads, it suffers very low disturbance. It is characterised by strongly aquatic and humid habitats (tall sedge swamps, stream riparian woodlands, spring-outflow streams). Birds are very frequently seen foraging here (pers. comm. agricultural worker at the Heistermühle farm, 22.07.2016). The site hosts brook lampreys, river trout and a number of different amphibian species.

This area is an ideal feeding habitat for black storks. The valuable feeding habitat is located approximately 4 km away from the Atzenstein nest site.

Figure 59: Upper reaches of the Salz in the Heistermühle area, a feeding habitat that hosts European bullheads and river trout and is regularly visited by black storks

No. 14 Steinaubach (stream) below Reinhards

The feeding habitat is located on the periphery of the black storks' focal area of flight activity (see Map 3). There are third-party sightings of foraging black storks (Planungsgruppe Grün 2016a).

In this section the Steinaubach follows a semi-natural course, displays excellent substrate diversity (semi-natural streambed structure, quality grade 1 after GESIS 2013), contains a number of different aquatic and humid habitats (stream riparian woodland, humid grassland, marshy fallow) as well as a very good food supply in the form of river trout and European bullheads.

No. 16 Ürzeller Wasser (stream) and "In den Kehreiswiesen"

The feeding habitat is located on the periphery of the black storks' focal area of flight activity. Flight movements involving behaviour indicative of food searching behaviour were recorded in the area.

The feeding habitat contains a rapidly flowing low mountain stream (Ürzeller Wasser) with sufficient substrate diversity (streambed structure insignificantly altered, quality grade 2 after GESIS 2013) and an adjacent floodplain with periodically wet grassland and stream riparian woodland. It offers fish habitat for river trout, loach and grayling.

No. 29 Wöllbach (stream) at Fleschenbach

The feeding habitat is located on the periphery of the black storks' focal area of flight activity. There are own observations of flight movements as well as third-party sightings of foraging black storks (Planungsgruppe Grün 2016a).

The straightened Wöllbach stream is lined with a continuous strip of riparian woodland which gives cover to the black storks. Small watercourses were created along its upper reaches (see Section 3.2.6). An own site visit on 30.06.2016 confirmed the presence of an ample food supply in the form of smaller fish and amphibians. This site is well suited as a feeding habitat for black storks on account of its shallow water sections and good flight access.

Figure 60: Small watercourse at the Wöllbach stream to the northeast of Fleschenbach

No. 33 Steinaubach (stream) and small valley forest meadows at the Kieselkopf hill

The feeding habitat is located on the periphery of the black storks' focal area of flight activity.

Flight movements towards the area as well as thermaling above the area were observed but it can not be said with sufficient certainty that this site is being utilised as a feeding habitat. It is therefore shown as a potential feeding habitat.

In the area of the "In der Kiesel bei Hintersteinau" nature reserve/SAC the site's quality as a black stork feeding habitat is due to the presence of spring-outflow streams, humid grassland, sedge swamps, marshy fallow and associated species of amphibians, grasshoppers and aquatic insects.

In an easterly direction outside of the nature reserve/SAC the tributary to the Steinaubach follows a semi-natural course and is lined with riparian woody vegetation and both the tributary and this segment of the Steinaubach have varied streambed substrates. The site hosts river trout, European bullheads, loach and grayling as well as amphibians and reptiles.

No. 34 Steinaubach (stream) tributary

The Schwarzellerbach, a tributary to the Steinaubach, is a small semi-natural low mountain stream with high substrate diversity, a meandering course and riparian woody vegetation in a structurally rich grassland floodplain containing humid meadows and alder forest in the area of its spring-outflow. Sections of the stream are lined with woody vegetation offering cover.

Numerous flight movements were recorded above the area but it can not be said with sufficient certainty that this site is being utilised as a feeding habitat. It is therefore shown as a potential feeding habitat.

No. 36 Holzmühl pond at Heiertsborn

The feeding habitat is located within the focal area of black stork flight activity. There are own observations of flight movements involving food searching behaviour.

The pond offers an ample food supply (fish and amphibians). Due to the presence of shallow water areas and good flight access this feeding habitat is well suited for black storks.

Conclusions on the feeding habitats evaluated:

Map 3 references the black storks’ established spatial behaviour in relation to the feeding habitats. Feeding habitats 11, 12, 13, 14, 16, 22, 29, 33, 34, and 36 are located in the area of medium to high spatial use, indicating a preference for these habitats as a broad preliminary trend.

Records show that 16 out of the total of 35 evaluated feeding habitats are evidently being utilised. Given the dense network of watercourses and their surrounding complexes of humid habitats it can reasonably be stated that there is a uniform distribution of good feeding habitats around the nest site in the study area. Man-made ponds predominated in the north and northwest of the study area and these are of greater significance as a food source in springtime due to the amphibian spawning period. This may explain the preference given to these areas during spring (cf. Section 4.6).

Close to the nest site and in the south and southwest of the study area semi-natural watercourses and floodplains predominate which are relevant as a source of fish and invertebrates as food sources. These areas may be more important later in the year and this may explain the preference given to these areas in June and July (cf. Section 4.6). These results must be viewed with reservations as only data from one study year were analysed and the quality of feeding habitats may vary, for example as a result of fluctuations in precipitation events or prey population dynamics.

5 Additional black stork studies

The project remit involved not only the analysis of own research data but also the findings of other suitable studies addressing a variety of issues. The following Figure 61 shows the location of the individual study areas. The studies are focused on the low mountain ranges of the Vogelsberg (Rabenau, Hintersteinau, NABU data), the Westerwald (Alpenrod) and the Fulda-Werra Uplands (Moskau-Kreuzstein). A further study location was in the Stade Geest landscape in the northern German lowlands (Wohnste).

An overview of the studies' approaches to investigation and assessment is given in Section 3.10. A more detailed description is given below for each of the studies.

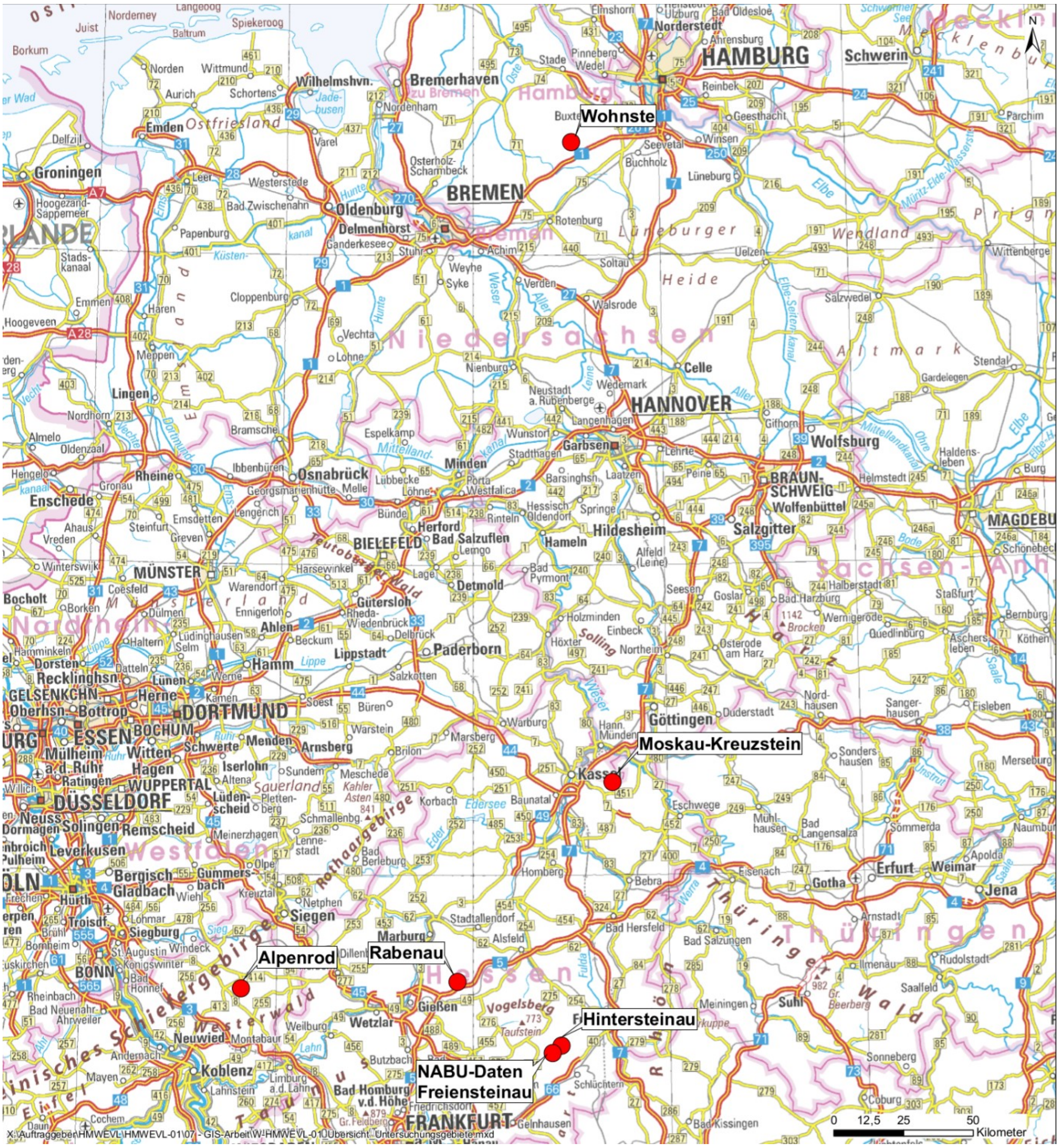

Figure 61: Location of the study areas of studies used for further analysis (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

5.1 Alpenrod wind farm

5.1.1 Alpenrod wind farm, spatial behaviour analysis

The following assessment approach was taken:

- Black stork breeding success
- Flight movements in the vicinity of existing WTs, distance to existing WTs
- Case-by-case assessment of flight movements in the danger zone
- Impact of topography on flight movements/spatial behaviour
- Preferential use of certain land-use types/habitats for overflights

In 2015, the EAM Natur GmbH consultancy commissioned the Büro für ökologische Fachplanungen (BöFa) ecological consultancy to undertake a spatial behaviour analysis of large bird species (black stork and red kite) as part of a planned wind farm development in the Alpenrod municipality, Hachenburg local authority association, Rhineland-Palatinate (Rheinland-Pfalz). The wind farm with five existing WTs considered in the present study is located in spatial proximity to the planned wind farm development that was the subject of the 2015 Alpenrod study. The 2015 study did not focus on the former. The EAM Natur GmbH in Dillenburg was so kind as to make available for analysis the data collected for the planned wind farm development. The study area was defined as a radius of 6 km around the planned wind farm; two occupied black stork nests are located within this area.

Physiographic region

The study area is located in the "Dreifeldener Weiherland" (sub-unit 323.2, LWUG 2011) of the Oberwesterwald physiographic region, situated between the municipalities of Alpenrod, Gehlert, Steinebach an der Wied and Lochum. The study area is comprised of forest areas including some more mature beech forests, a number of different mixed and coniferous forests as well as sites under successional vegetation in the area of existing wind farms. The eastern part of the study area contains some areas of open land, parts of which are used for livestock grazing. In the northeast of the study area the Gehlerter Bach emerges from its spring, with the stream flowing out of the study area in a northerly direction. At a height of 513 m a.s.l. the Gräbersberg is the highest hill in the study area. Other hills within the area are the Schmidtborn and the Schieferkopf. The western half of the study area forms part of the 28,980 ha Westerwald SPA (DE 5312-401). On its western edge, the study area also overlaps with the 4000 ha Westerwälder Seenplatte (Westerwald lakelands) protected landscape (07-LSG-7143-010).

Alpenrod wind farm data

Manufacturer	Enercon
Installation type	E-82
Nominal capacity in MW	2.0
Overall height	149 m
Hub height	108.3 m
Rotor diameter	82 m
Height of rotor tip above ground level	66 m
No. of WTs	5
Operational since	2010

Nest site

The study area for the spatial behaviour analysis contains two black stork nest sites. The nest site at Langenbaum is the one located closest to the existing WT at a mere 550 m distance. Another nest site, one that has been used and known for longer, is located near the village of Gehlert and at a distance of approximately 2.3 km to the north of the nearest WT.

The wind farm in the forest area of Oberholz near Alpenrod became operational in 2010 and a black stork pair first settled in the area in 2014. Fourteen years ago there had also been a black stork breeding attempt near the artificial nest platform (Isselbächer & Hormann 2015). That breeding attempt was abandoned as the nest had been built on an unstable side branch. The platform was not used for a long time thereafter, until 2014.

Despite the close proximity to existing WTs (550 m to the nearest WT) two juvenile storks were successfully raised in 2015 (Fehr 2015). Similarly, the nest site at Langenbaum was once again occupied in 2016 and resulted in a successful hatch (pers. comm. Joachim Kuchinke 2016).

Study type

Method	Spatial behaviour analysis, direct observation
Survey period	Early March to early August 2015
No. of breeding territories	2
Daytime / dusk or dawn survey days	18/2
Survey duration in hrs/day/person	8
Survey hours	308
Altitude categories	no
No. of persons surveying synchronously	2
No. of observation points	4
Nest inspection(s), days	1

The survey was conducted between early March and early August 2015. One recorder was always stationed at observation point 1 at the Gräbersberg viewing tower. This tower has a viewing platform at 34 m above the ground which offers full panoramic visibility over the study area (see Figure 62). This observation point is located at distances of 2.2 km and approximately 2.8 km from the black stork nest sites at Langenbaum and Gehlert respectively. On all survey days this observation point was occupied for an uninterrupted period of eight hours.

The second recorder rotated between the three other observation points which on each of the survey days were occupied for a period of three hours. Observation point 2 was located near the village of Langenbaum and approximately 1 km to the southwest of the nest site. While this observation point was close to the nest site, its viewshed was smaller than that of observation point 1. It did however provide a good view of black storks approaching and departing the site. A further observation point was located to the northeast of Gehlert (3) at a distance of approximately 3.2 km to the nest site. This observation point provided a view of the area around the known nest site to the west of Gehlert (approximately 2 km away). The last observation point (4) was located to the east of the small lake Dreifelder Weiher at a distance of approximately 3.2 km to the nest site. This observation point provided a view of the areas in the vicinity of the Dreifelden golf course.

Figure 62: Viewshed from the observation point on Gräbersberg viewing tower; the five existing E-82 WTs under consideration can be seen in the centre of the image.

Table 28: Overview of survey days for spatial behaviour analysis at Alpenrod wind farm

Date	Duration [h]	Observation period*	No. of recorders
06.03.2015	17	9:00-17:00 or 18:00	2
13.03.2015	17	9:00-17:00 or 18:00	2
18.03.2015	17	9:00-17:00 or 18:00	2
25.03.2015	17	9:00-17:00 or 18:00	2
10.04.2015	17	9:00 or 10:00-18:00	2
20.04.2015	17	9:00-17:00 or 18:00	2
29.04.2015	17	9:00-17:00 or 18:00	2
07.05.2015	17	9:00-17:00 or 18:00	2
13.05.2015	17	9:00-17:00 or 18:00	2
21.05.2015	17	9:00-17:00 or 18:00	2
26.05.2015	17	9:00-17:00 or 18:00	2
03.06.2015	17	9:00-17:00 or 18:00	2
11.06.2015	18	14:00-23:00	2
19.06.2015	17	9:00-17:00 or 18:00	2
25.06.2015	17	9:00-17:00 or 18:00	2
03.07.2015	18	05:00-14:00	2
15.07.2015	17	9:00-17:00 or 18:00	2
04.08.2015	17	9:00-17:00 or 18:00	2
Total	308		

=Dawn/dusk surveys (dusk after sundown, dawn from sunrise at the latest)

* Observation periods differ due to different lengths of stay at the different observation points

A total of 88 black stork flight movements were observed, comprising a total flight distance of approximately 392 km. In contrast to the present Freiensteinau study, the Alpenrod data were recorded as flight movements. It is therefore not possible to distinguish different behaviours or flight events and it must be borne in mind that only limited comparisons can be drawn between these analysis results and the findings of the present study.

Table 29: Overview of flight movements recorded at the Alpenrod wind farm

Flight altitude category	Total number	Flight distance
Below rotor area (<66 m)	25	42,078 m
Within rotor area (66–149 m)	7	21,034 m
Above rotor area (>190 m)	16	96,619 m
Multiple flight altitudes	40	233,051 m
Totals	88	392,782 m
Recording month		
March	18	52,525 m
April	16	59,727 m
May	24	117,127 m
June	18	113,433 m
July	11	47,204 m
August	1	2,765 m
Totals	88	392,782 m

Table 30: Phenological distribution of flight movements

Recording month	**Flight movements**		
	[n]	**[h]**	**[n/h]**
March	18	68	0.26
April	16	51	0.31
May	24	68	0.35
June	18	69	0.26
July	11	35	0.31
August	1	17	0.06
Overall result	**88**	**308**	**0.29**

Flight distances from the nest site

Flight movements commencing or ending in the vicinity (500 m radius) of the nest site were considered. This condition was met by 39 out of the total of 88 recorded flight movements.

Of these, 16 flights (40% of the flights) were at a distance of up to 1000 m around the nest site. A further 15 flights (39%) were located at greater distances of between 1000 and 3000 m. Distances of between 3000 and 6000 m were observed for eight flight movements (21%) out of the 39 flight movements that either started or ended near the nest site (Figure 63).

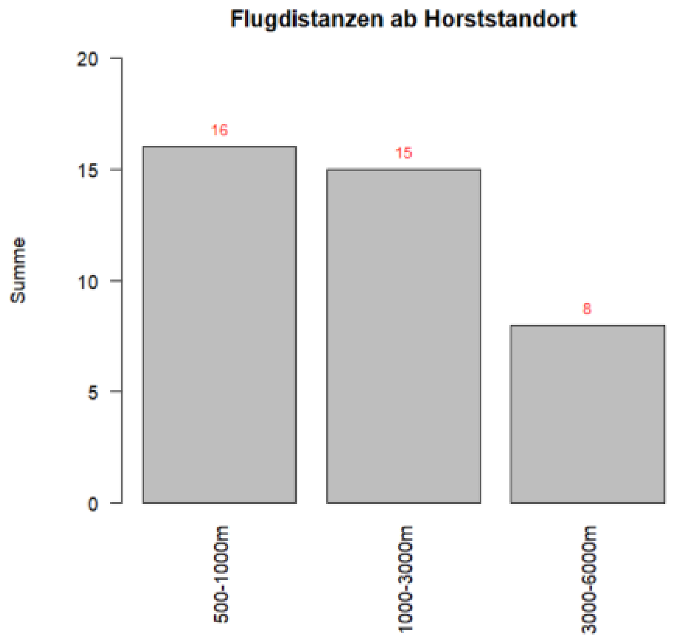

Figure 63: Flight distances from the Langenbaum nest site

Flugdistanzen ab Horststandort	Flight distances from the nest site
Summe	Totals

Flight movements in the vicinity of existing WTs, distance to existing WTs

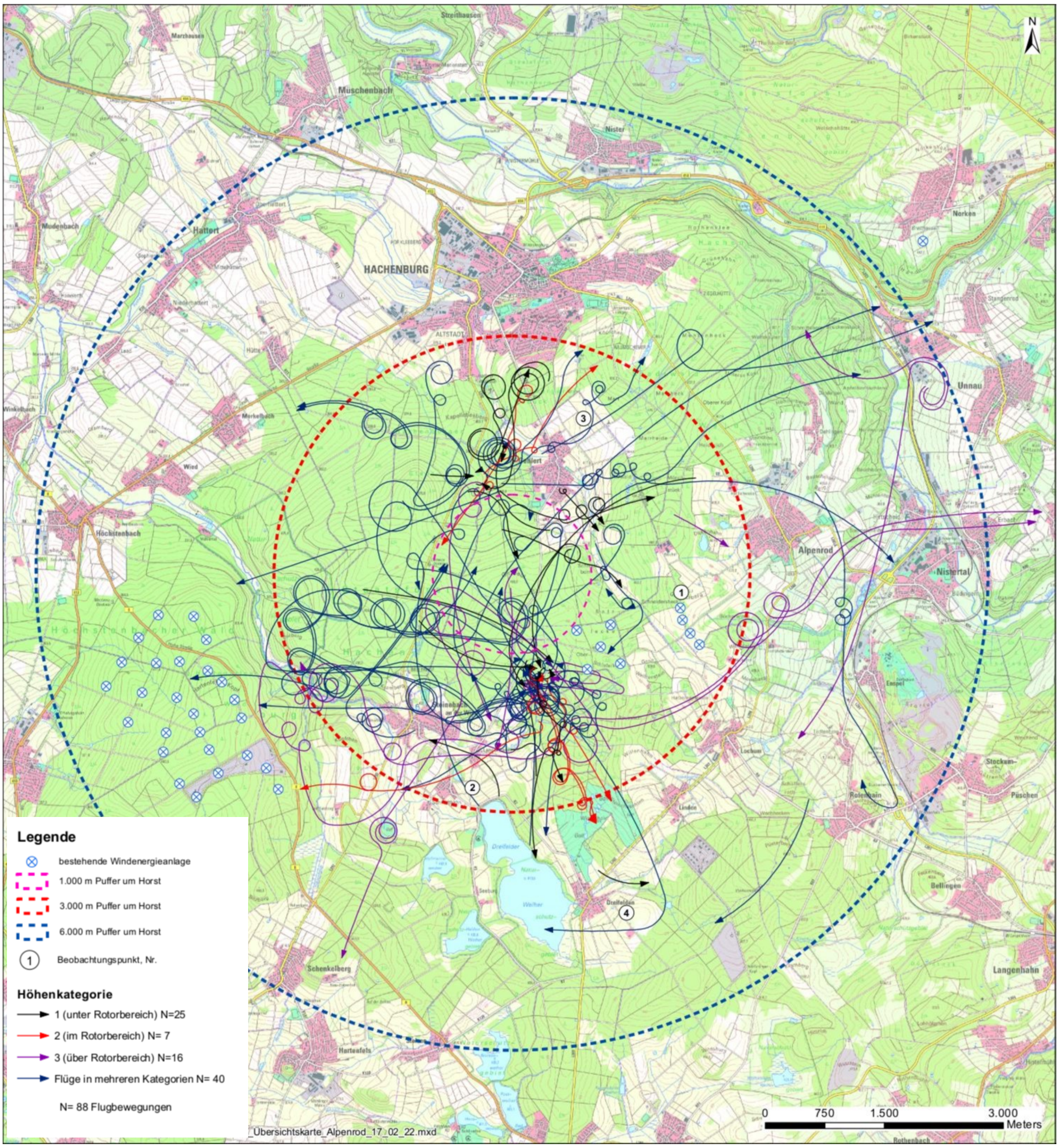

Figure 64: Flight movements/spatial behaviour of black storks in 2015, Alpenrod wind farm (BöFa 2015) (Baseline map: Rhineland-Palatinate state agency for surveying and geoinformation (LVermGeo Rheinland-Pfalz))

	(otherwise as in previous maps)
Höhenkategorie	Altitude categories
1…	1 (below rotor area) N=25
2…	2 (within rotor area) N=7
3…	3 (above rotor area) N=16
Flüge …	Flights in multiple categories N = 40
N = 88…	N=88 flight movements

The documentation of flight movements reveals a focus in the area of the nest locations. Looking at the flight movements to and from the Langenbaum nest site, which is situated close to the wind farm, it is notable that the flight directions run towards the north, west, and south to southeast.

There are hardly any flights in an easterly direction towards the existing wind farm; as in Fehr (2015) the birds fly southward around the wind farm. The non-utilisation of the eastern corridor may also be due to the fact that there are hardly any suitable watercourses for feeding at a short distance of the far side of the wind farm, the only exception being a small spring-outflow stream which is however targeted by the breeding pair at Gehlert.

In terms of spatial behaviour the birds prefer the habitats to the south and west. Strong humid habitat complexes (shallow water zones, large sedge swamps) are located to the south at the Dreifelder Weiher; Kunz (2016) classified these complexes as resting/feeding habitats. In the area to the west, an intricate semi-natural system of watercourses is embedded in a matrix of forest and grassland (Wied, Schimmelbach nature reserve, Viehbach).

Case-by-case assessment of flight movements in the danger zone

Six out of the total of 88 recorded black stork flight movements touched the danger zone of the existing WTs (see Figure 65). Out of these six flights, two were above rotor height, two below and two at rotor height, at an estimated distance of approximately 150 m to the closest WT.

Weather data for the periods in question were sourced for the Bad Marienberg weather station which is located approximately 10 km away and therefore in spatial proximity. The data are available at 60 minute intervals. Additionally, visibility data from the field protocols were taken into consideration for the analysis.

For the remaining 82 flights (93%) the birds maintained greater distances to the existing WTs and flew around the wind farm.

Table 31: Overview of flight movements, spatial behaviour analysis 2015 in the danger zone of the Alpenrod wind farm

Flight_ID	Description of flight movement	Wind speed in m/s	Wind direction in degrees	Precipi-tation	Temper-ature in degrees	Visibility
59	2 black storks circling on 25.03.2015 (15:19 – 15:20 hrs) in the forest area at 100 m altitude, then gliding down to 50 m altitude through the wind farm (below rotor area).	5.3	NW 310	0	4.2	>10 km
73	1 black stork circling on 10.04.2015 (13:30 hrs) above the nest site at more than 200 m altitude (above rotor area).	4.1	S 180	0	18	> 3 km
74	1 black stork flying on 10.04.2015 (14:25 – 14:30 hrs) above the forest area at more than 20 m altitude (above rotor area).	4.1	S 180	0	19.1	> 3 km
129	1 black stork circling on 13.05.2015 at 14:40 hrs above forest hosting nest site; it is attacked by a buzzard and passes within close proximity of the south-western WT at altitudes between 50 and 120 m (within rotor area).	3.0	SSW 200	0	16.7	> 3 km
313	1 black stork departs from nest site, thermaling above the south-eastern forest area on 25.06.2015 between 14:15 and 14:25 hrs at flight altitudes between 50 and 100 m (within rotor area).	2.8	W 250	0	20.4	> 10 km

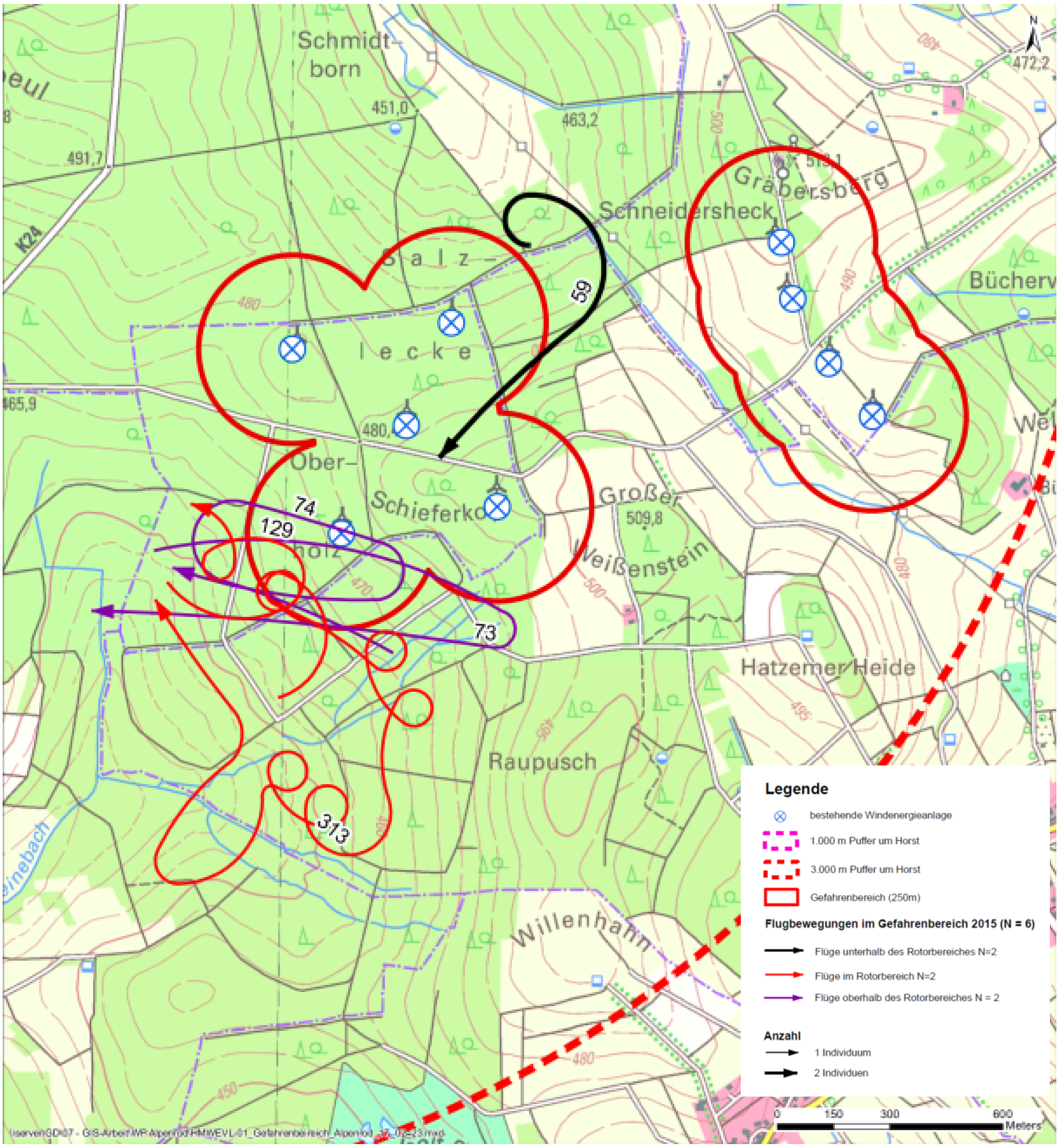

Figure 65: Flight movements in the danger zone, Alpenrod wind farm (Baseline map: Rhineland-Palatinate state agency for surveying and geoinformation (LVermGeo Rheinland-Pfalz))

	(otherwise as in previous maps)
Gefahrenbereich	Danger zone
Flugbewegungen…	**Flight movements in danger zone 2015 N=6**
Flüge unterhalb…	Flights below rotor area N=2
Flüge in …	Flights within rotor area N=2
Flüge oberhalb…	Flights above rotor area N=2
Anzahl	**Number**
1 Individuum	1 individual
2 Individuen	2 individuals

Impact of topography on flight movements/spatial behaviour

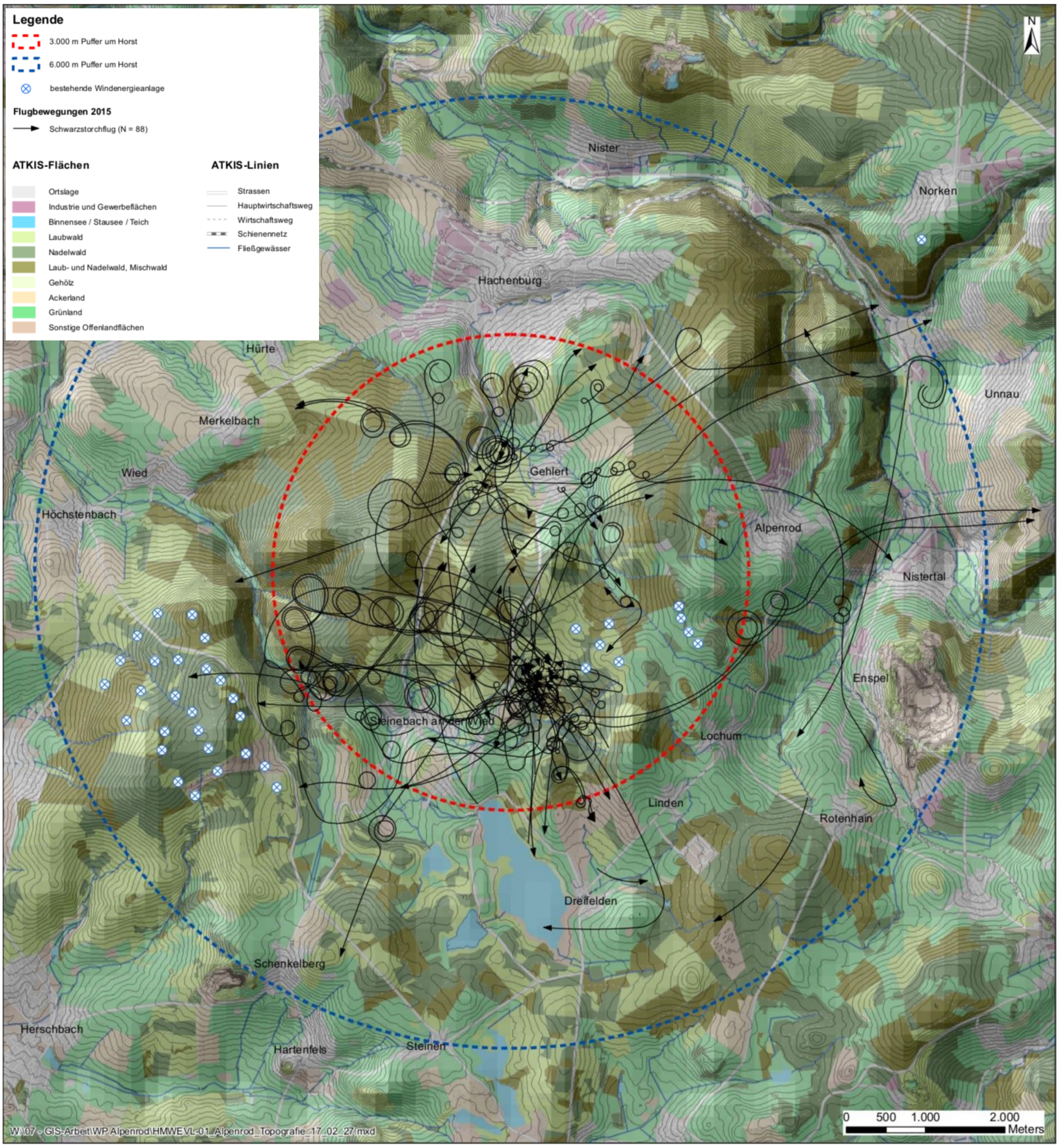

Figure 66: Flight events superimposed on DLM and DTM, Alpenrod wind farm (Baseline map: Rhineland-Palatinate state agency for surveying and geoinformation (LVermGeo Rheinland-Pfalz))

	(key otherwise as in previous maps)
Flugbewegungen 2015	**Flight movements in 2015**
Schwarzstorchflug…	Black stork flight (N=88)
ATKIS Flächen	**ATKIS spatial objects**
Ortslage	Built-up area
Industrie…	Industrial, commercial area
Binnen…	Lake, reservoir, pond
Laub…	Deciduous forest
Nadel…	Coniferous forest
Laub- und Nadel…	Deciduous and coniferous forests, mixed forest
Gehölz	Copse
Ackerland	Arable land
Grünland	Grassland
Sonstige Offen…	Other open land

ATKIS Linien	ATKIS linear objects
Strassen	Roads
Haupt…	Rural hard-surface roads
Wirtschafts…	Rural tracks
Schienennetz	Rail network
Fliessgew…	Watercourses

The study area’s topography does not appear to strongly influence the black storks’ flight behaviour. The birds fly over both hilltops and valley bottoms to a similar extent. The recorded flight movements took place above terrain altitudes of between 280–285 and 500–505 m a.s.l. The black storks only avoided hilltops with existing wind turbines, a notable fact given the small distance to the forest hosting the nest site. The nearest WTs (to the east of the nest site) are located at terrain altitudes of between 480–485 and 500–505 m a.s.l.

Preferential use of certain land-use types/habitats for overflights

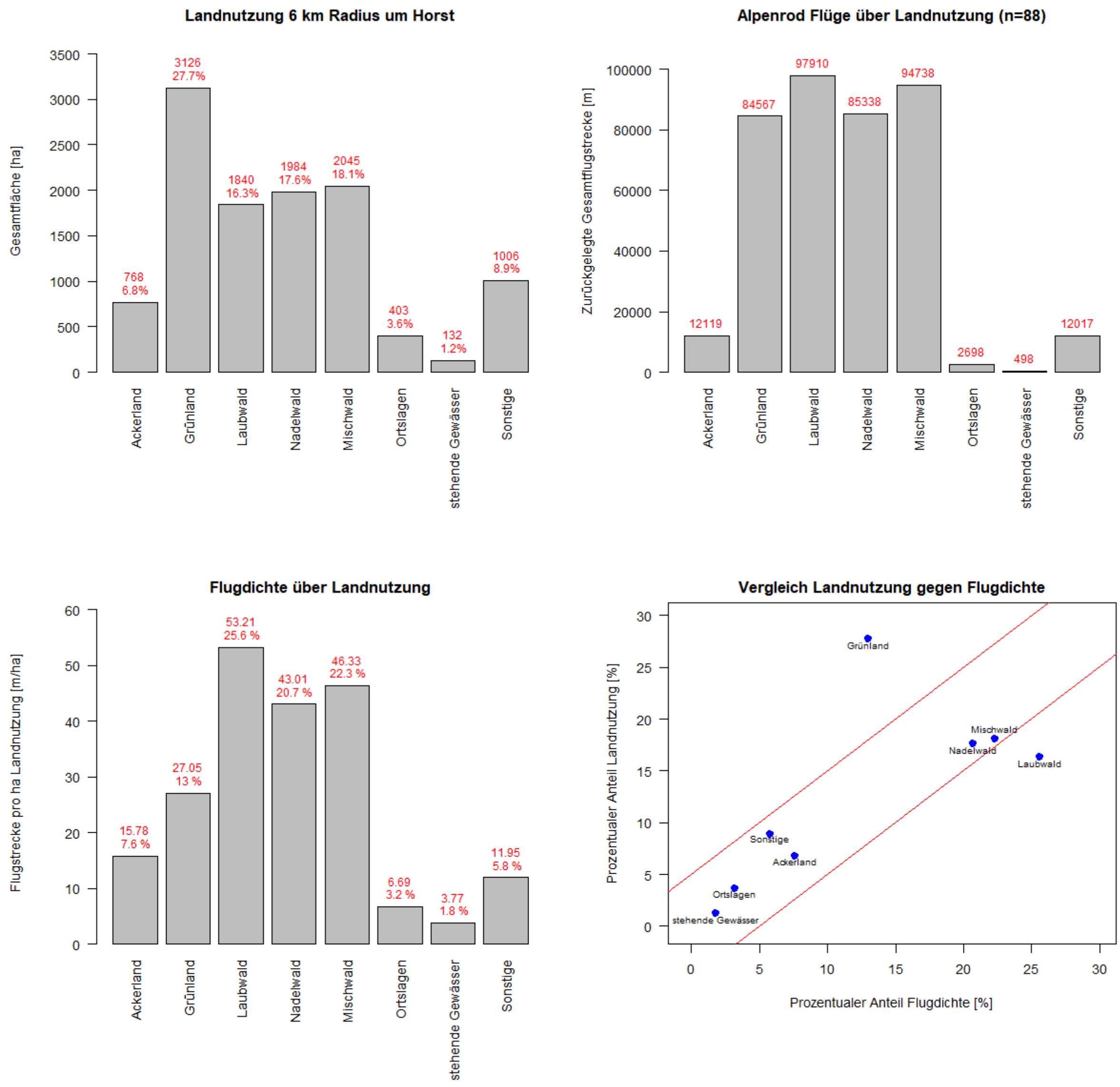

Figure 67: Flight movements by land use at Alpenrod

Alpenrod Flüge über Landnutzung…	Alpenrod flights by land use [n=88]
	Key otherwise identical to Fig. 52

Land use within a 6 km radius around the occupied nest site at Alpenrod is dominated by different types of forest (52%) and different types of open countryside (approximately 35%). However, the flights are concentrated above deciduous forest, with the highest flight densities recorded above such forests.

The flight density is lower only above grassland compared to what would have been expected given the proportional share of grassland in land cover. The predominance of flights over forests can be explained by the location of fish-rich forest streams in the vicinity of the nest site.

5.1.2 Alpenrod wind farm, monitoring

The following assessment approach was taken:

- Flight behaviour in the vicinity of existing WTs, distance to existing WTs

Simultaneous to the spatial behaviour analysis by BöFa (2015), Fehr (2015) conducted a study on behalf of the Alpenrod wind farm operator. The study area, the wind farm, and the focal nest site are identical for the two studies.

Study type

Method	Monitoring, direct observation
Survey period	Early April to early May 2015
No. of nest sites <3 km	2
Daytime / dusk or dawn survey days	5/0
Survey duration in hrs/day	5
Survey hours	50
Altitude categories	no
No. of persons surveying synchronously	2
No. of observation points	2
Nest inspection(s), days	6

Five field visits were undertaken between April and early May 2015 with five hours of recording time each.

The recording days did not coincide with those of the spatial behaviour analysis by BöFa (2015) and therefore help to establish a more complete picture of the breeding pair's spatial behaviour. Seventeen flight movements were recorded from two observation points in the course of the 50 survey hours. As in the BöFa (2015) study, the observation points were located at the Gräbersberg viewing tower and at the location to the northeast of Langenbaum close to the nest site.

Table 32: Overview of survey days at Alpenrod wind farm, monitoring study

Date in 2015	Duration [h]	Observation period*	No. of recorders	No. of flight observations
08.04.2015	5	09:15-14:15	2	3
16.04.2015	5	10:00-15:00	2	9
22.04.2015	5	09:00-14:00	2	3
30.04.2015	5	08:00-13:00	2	0
06.05.2016	5	08:00-13:00	2	2
Totals	**25**			**17**

Flight behaviour in the vicinity of existing WTs, distance to existing WTs

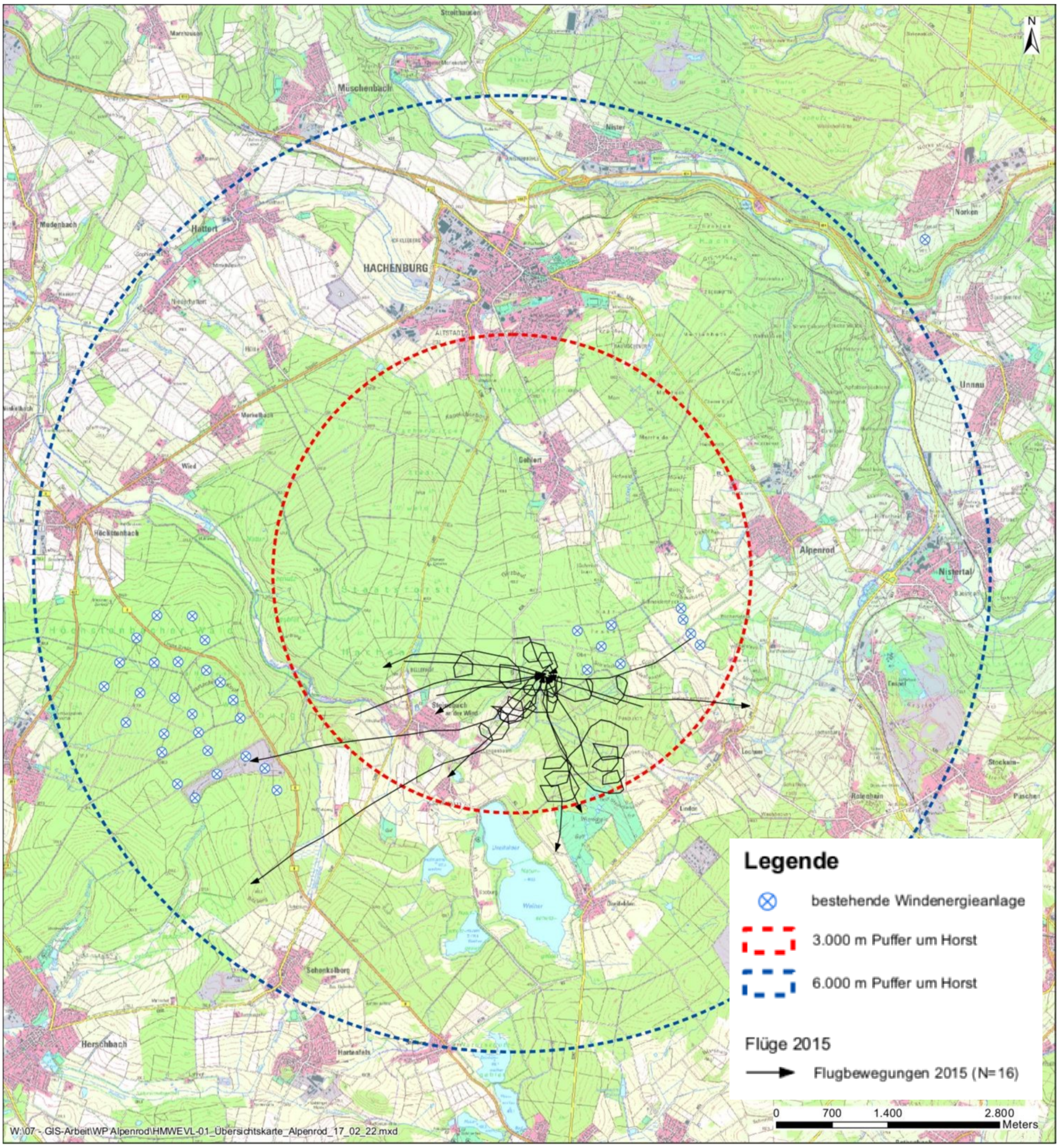

Figure 68: Black stork flight movements in 2015, Alpenrod wind farm (FEHR 2015) (Baseline map: Rhineland-Palatinate state agency for surveying and geoinformation (LVermGeo Rheinland-Pfalz))

	(key otherwise as in previous maps)
Flüge 2015	Flights in 2015
Flugbewegungen 2015	Flight movements in 2015 (N=16)

In his study report, FEHR (2015) describes that the birds fly around the wind farm on its southern side. According to FEHR (2015), the black storks recognise the WTs as an obstacle or dangerous object, as they are familiar with the wind farm and fly around it on its southern side at a distance of 100 m to the installations.

This random sample monitoring of the same wind farm showed two out of 17 flights in the critical danger zone (250 m radius) of the installations (see Table 33).

Table 33: Overview of flight movements, 2015 monitoring in the danger zone of Alpenrod wind farm

Description after FEHR (2015)	Wind speed in m/s	Wind direction in degrees	Precipitation	Temperature in degrees
16.04.2017, 13:40 – 13:55 hrs: Departure of a stork in an easterly direction	3.5	W	0	17.7
06.05.2015, 9:26 – 09:27 hrs: Inward flight of a black stork from an easterly direction, approximately 100 m south of the wind farm.	7.5	SW	0	10.7

Conclusions

1. Black stork breeding success in spatial proximity to WTs

The studies have ascertained that black storks can successfully breed at a spatial proximity of 550 m to a wind farm.

2. Phenology

May is the month with the highest level of flight activity.

3. Flight behaviour in the vicinity of WTs

As part of the spatial behaviour analysis, two black storks were seen to traverse the wind farm below the rotor area. Another four flights approached the existing turbines to the south. Therefore, 6.8% of flights were in the critical zone. The monitoring found two out of 17 flights to be in the critical zone. Given the small sample, the data are combined here. Overall, the proportion of critical flights in all flight movements was 7.6% (cf. Table 34).

Table 34: Flight behaviour in the vicinity of WTs of the Alpenrod wind farm

Type of study	**Total flights**	**Number of flights in danger zone*** **Risky flights**	**Proportion of flights in %**	**Behaviour (vertical)**		**Assessment of conflict situation**
				Flights in danger zone*: Within rotor area	**Flights in danger zone*: Outside of rotor area**	
Alpenrod spatial behaviour analysis	88	6	6.8	-	2 flights at rotor height	conflictual
				-	2 close low-level flights	moderate conflict
				-	2 overflights	little conflict
Alpenrod monitoring	17	2	11.8	-	flight altitude not known	conflictual to little conflict
Overall result	**105**	**8**	**7.6**			**-**

*Danger zone (250 m, horizontal view)

Birds approached existing turbines to within 100–150 m, while the rotor diameter is only 82 m. One pair was seen to traverse the wind farm in favourable weather conditions, passing below the rotor area in the gap between turbines.

4. Flight altitude

The flight category below the rotor area (<66 m) comprised 28% of flight movements. Eight percent of flights were at rotor height and 18% of flights above rotor height. Flights covering multiple altitude categories comprised 46% of all flights and thus predominated.

5. Land use and topography

No preference was shown for certain land-use types or topographical factors. While the WTs were bypassed, they were not bypassed because of their elevation.

5.2 Hintersteinau wind farm

The following assessment approach was taken:

- Flight movements in the vicinity of existing WTs, distance to existing WTs
- Case-by-case assessment of flight movements in the danger zone
- Comparison with own study
- Impact of topography on flight movements/spatial behaviour
- Preferential use of certain land-use types/habitats for overflights

Physiographic region

The Hintersteinau study is situated in the same physiographic region as the own study in Freiensteinau (see Section 3.1). The spatial behaviour analysis was conducted in connection with the planned wind farm development comprising eight WTs at Hintersteinau (Simon & Widdig Gbr – Büro für Landschaftsökologie 2016). The spatial behaviour analysis was conducted in the 2015 survey year in spatial proximity to the own surveys.

The data recorded with respect to the planned wind farm at Hintersteinau are analysed here with respect to the existing Hallo wind farm.

Hallo wind farm data

Manufacturer	Enercon GmbH
Installation type	E-101
Nominal capacity in MW	3
Overall height	186 m
Hub height	135 m
Rotor diameter	101 m
Height of rotor tip above ground level	50.5 m
No. of WTs	7
Operational since	2014

Approval for the Hintersteinau wind farm with eight WTs was granted by the Darmstadt regional council in December 2016.

Nest site

Two black stork nests sites are located in the study area covered by the spatial behaviour analysis. The occupied Atzenstein nest site was inspected in the course of field visits on 25 February and 24 April 2015. It is located at a distance of >2500 m to the planned Hintersteinau wind farm. A second occupied nest site is located to the southeast of Buchenrod at a distance of >2500 m to the planned WTs at Hintersteinau; following its identification it was inspected on 8 May 2015.

Study type

Method	Spatial behaviour analysis, direct observation
Survey period	Late February to mid-August 2015
No. of breeding territories	2
Daytime / dusk or dawn survey days	18/2
Survey duration in hrs/day/person	8
Survey hours	344
Altitude categories	no
No. of persons surveying synchronously	2 to 3
No. of observation points	5
Nest inspection(s), days	2

The spatial functional analysis included 18 survey days. Additionally, black stork flight movements were also recorded as part of the survey of birds of prey. For the purposes of the spatial behaviour analysis, the survey duration was eight hours per day; dawn/dusk surveys were conducted on two of the survey days.

Table 35: Overview of survey days, spatial behaviour analysis for Hintersteinau wind farm

Date in 2015	Duration [h]	Observation period	No. of recorders
25.02.	16	09:00-17:00	2
09.03.	16	09:00-17:00	2
18.03.	16	09:00-17:00	2
30.03.	16	09:00-17:00	2
06.04.	16	07:00-15:00	2
16.04.	16	07:00-15:00	2
28.04.	16	06:00-14:00	2
12.05.	16	12:00-20:00	2
19.05.	16	11:30-19:30	2
28.05.	16	13:30-21:30	2
04.06.	16	12:30-20:30	2
11.06.	24	09:00-17:00	3
23.06.	24	09:00-17:00	3
03.07.	24	05:00-13:00	3
10.07.	24	07:30-15:30 / 08:00-16:00	3
17.07.	24	06:00-14:00	3
22.07.	24	06:00-14:00	3
11.08.	24	12:00-20:00 / 09:00-17:00	3
Total	344		

=Dawn/dusk surveys (dusk after sundown, dawn from sunrise at the latest)

The six observation points were distributed in a circle around the forest area to be observed at the planned Hintersteinau wind farm (see Figure 70). However, the survey visits to the different observation points were not evenly distributed.

Observation point 3 to the east of Reinhards was the one most frequented as it offered good views into the area in a south-westerly direction. Observation point 1 at Magdlos was the second most frequented one, offering good views into the terrain towards Hintersteinau. Flight movements from the nest site at Buchenrod were visible from observation point 5 at Kauppen which was selected on 55% of the survey days.

In contrast, observation point 2 to the north of Hintersteinau, which offered views into the area to the east of the Atzenstein nest site, was visited only on two out of a total of 18 survey days (see Table 36).

Table 36: Distribution of survey days by observation point or combination of observation points

Combinations of observation points	**Number of survey days**	**Observation points**	**Number of survey days**
1 and 3	5	**1 Magdlos**	12
2, 3	1	**2 Hintersteinau**	2
Near to 4 and 5	1	**3 Reinhard**	15
3 and 5	4	**4 Weidenau S**	2
1, 3 and 5	5	**5 Kauppen**	10
1, 4, 6	1	**6 Weidenau SW**	1
1, 2, 7	1	**7 Weidenau N**	1
Totals	18	-	43

The flight altitude categories given in Table 37 are based on the flight altitude categories of the Freiensteinau surveys (see Section 3.4). No flight movements were recorded in flight altitude categories 0 and 3. However, these flight altitudes are represented as part of the flight movements spanning multiple flight altitude categories.

Table 37: Overview of flight movements recorded at Hintersteinau wind farm

Flight altitude categories	Total number	Distance flown
0 (0–25 m)	-	-
1 (25–50 m)	17	34,763 m
2 (50–80 m)	1	874 m
3 (80–190 m)	-	-
4 (>190 m)	18	69,640 m
Multiple flight altitudes	30	106,258 m
Totals	66	211,535 m
Survey month		
March	1	3,693 m
April	20	54,093 m
May	7	30,749 m
June	10	31,826 m
July	27	75,265 m
August	1	15,909 m
Totals	66	211,535 m

Table 38: Phenological distribution of flight movements

Survey month	**Flight movements**		
	[n]	**[h]**	**[n/h]**
February	0	16	0
March	1	48	0.02
April	20	48	0.42
May	7	48	0.15
June	10	64	0.16
July	27	96	0.28
August	1	24	0.04
Overall result	**66**	**344**	**0.19**

Flight distances from the nest site

Flight movements commencing or ending in the vicinity (500 m radius) of the nest site were considered. This condition was met by 26 out of a total of 66 flight movements.

Ten of these flights (38%) took place at a distance of up to 1000 m around the nest site. A further 13 flights (50%) covered longer distances, having been recorded in a 1000–3000 m radius around the nest site. A further 3 flight movements (12%) out of a total of 26 which commenced or ended near the nest site were observed in a 3000–6000 m radius around the nest site (see Figure 22).

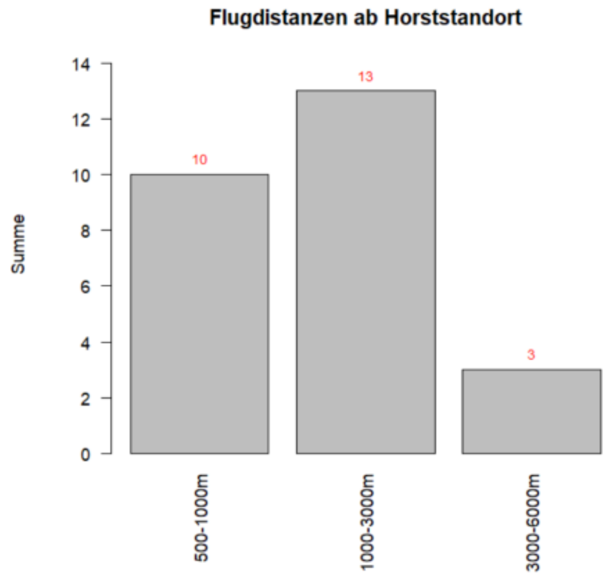

Figure 69: Flight distances from the Atzenstein nest site

Flugdistanzen ab Horststandort	Flight distances from the nest site
Summe	Totals

Flight movements in the vicinity of existing WTs, distance to existing WTs

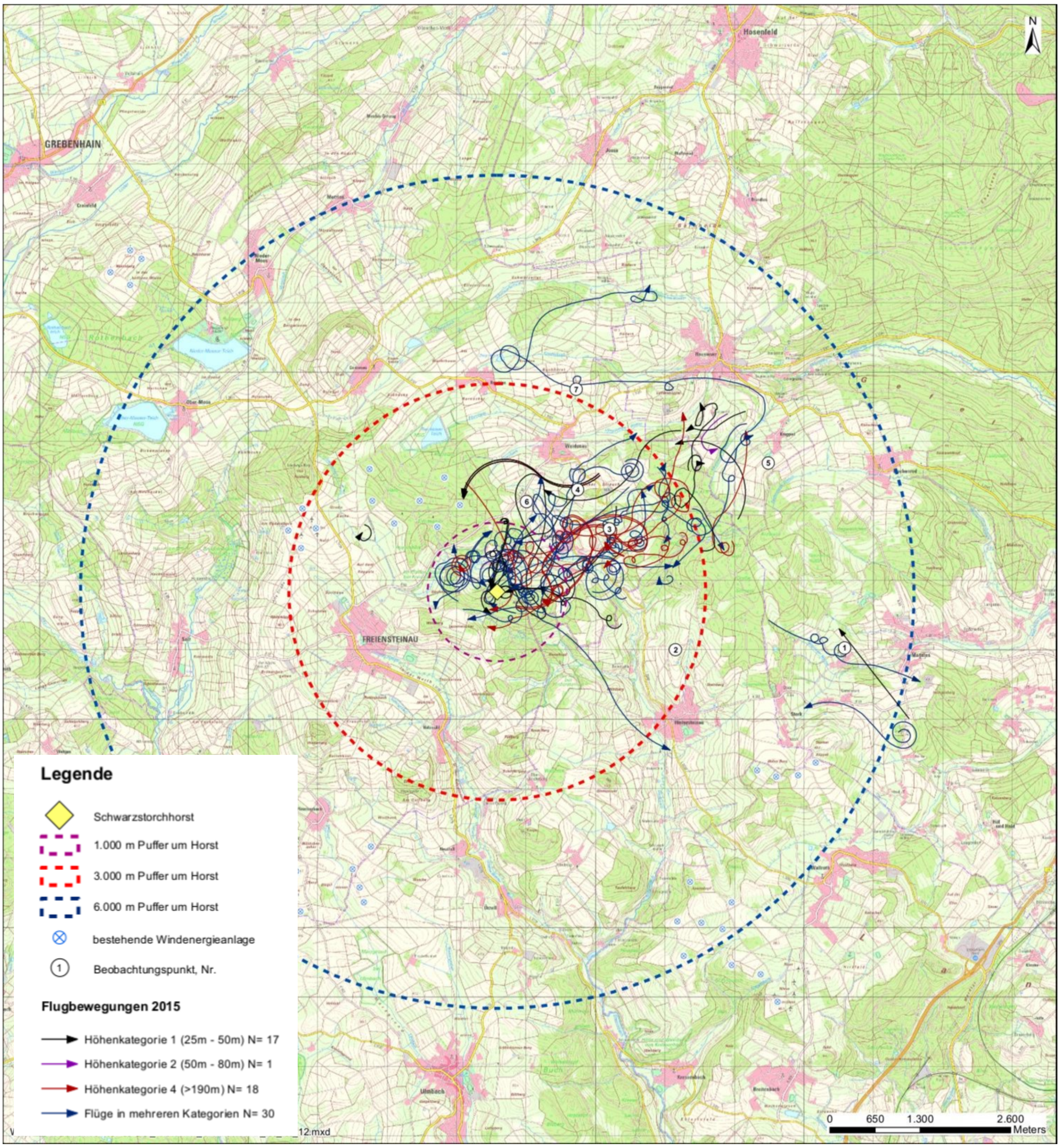

Figure 70: Overview of flight movements recorded for spatial behaviour analysis for the planned Hintersteinau wind farm (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	(key otherwise as in previous maps)
Flugbewegungen 2015	Flight movements in 2015
Hk 1 (25 – 50 m)	Altitude category 1 (25–50 m) N=17
Hk 2 (50 – 80 m)	Altitude category 2 (50–80 m) N=1
Hk 4 (>190 m)	Altitude category 4 (>190 m) N=18
Flüge in mehreren…	Flights in multiple categories N=30

A total of 66 black stork flight movements were observed, comprising a total flight distance of approximately 212 km. The activity focus of flight movements was located between Reinhards and the occupied nest site at the Atzenstein and continues in an easterly direction towards the Kohlwald hill.

Due to significantly longer survey periods at observation point 3 to the east of Reinhards this focal area is overrepresented.

No flight movements were recorded for the second nest site at Buchenrod. Simon & Widdig Gbr – Büro für Landschaftsökologie (2016) speculated that the black storks departed in an easterly direction outside of the viewshed of observation point 5. The surveys recorded a total of two flight movements into the danger zone of a turbine as part of the Hallo wind farm.

Comparison with own study

It is not possible to further analyse the data (e.g. changes in spatial behaviour) in conjunction with the own 2016 survey due to the different position of observation points. Moreover, the methodology chosen – such as the number of field days, distribution of recording periods, recording of flight altitudes and behaviour – strongly diverges from the methodology chosen for the present study.

However, the findings of the 2015 spatial behaviour analysis can be taken into consideration for the viewshed in the southeast of the study area which was underrepresented in the present study.

The superimposition of flight movements from the two studies shows that the 2015 study only captures part of the spatial behaviour recorded in 2016.

With regard to the utilisation of feeding habitats, black storks in search of food were recorded once each in feeding habitats 11 and 12 at the Steinaubach stream.

The chosen observation points 1 (Magdlos), 2 (Hintersteinau) and 3 (Reinhards) did however allow for better views and surveillance of the southeast of the study area compared to the present study.

Mention should be made therefore of the flight movement recorded on 04.06.2015 from the Atzenstein nest site over the hilltop to Hintersteinau into the Steinbachtal valley at a flight altitude of between 100 and 200 m. Additional flight movements in the southeast were recorded at Magdlos and Stork.

Given that the south-eastern part of the present study area would appear to be rarely used as a flight corridor, there is not in fact much of a discrepancy between the two studies.

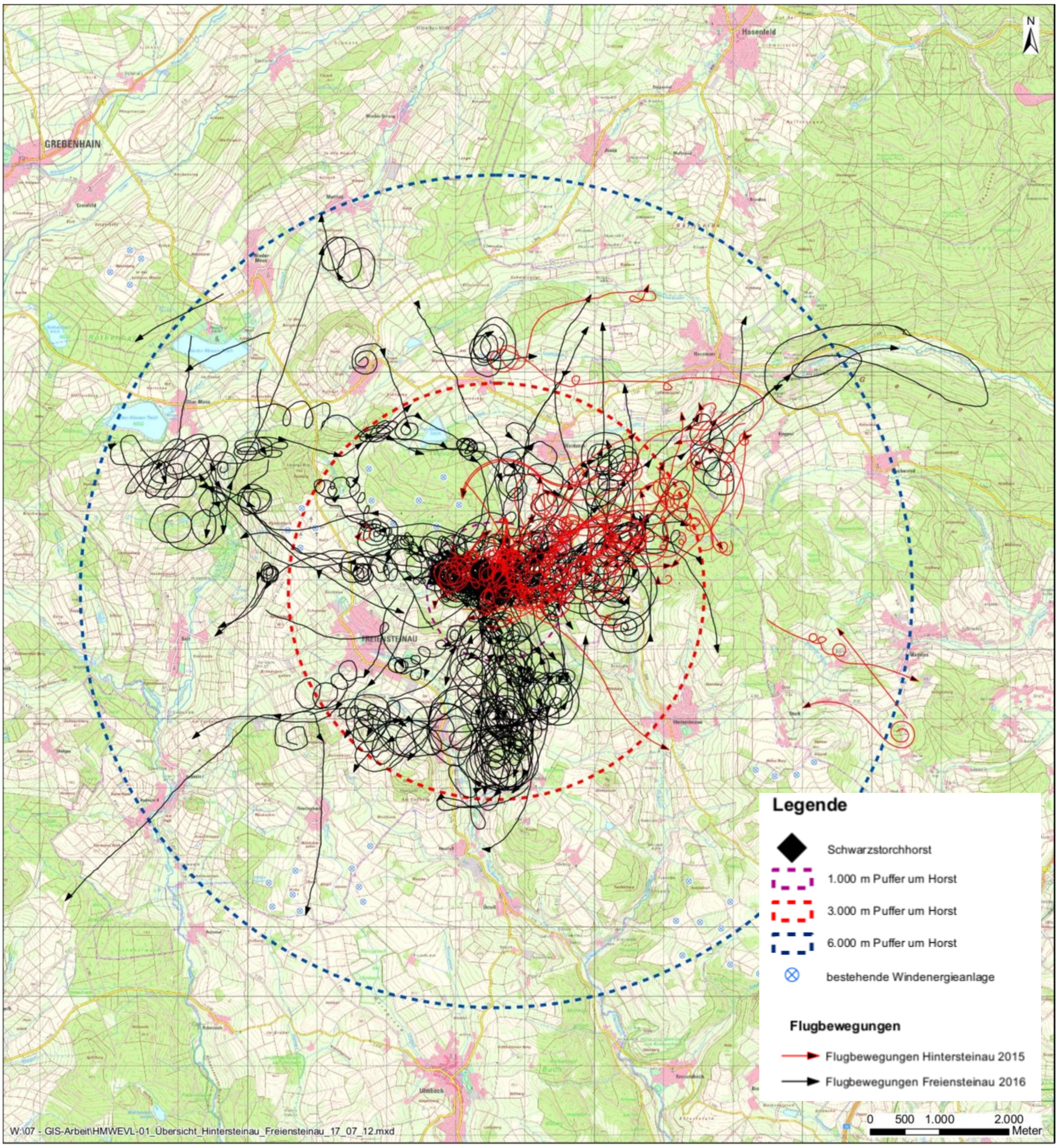

Figure 71: Superimposition of spatial behaviour in 2015 and 2016 respectively (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	(key otherwise as in previous maps)
Flugbewegungen	Flight movements
… 2015	Flight movements Hintersteinau 2015
… 2016	Flight movements Freiensteinau 2016

Case-by-case assessment of flight movements in the danger zone

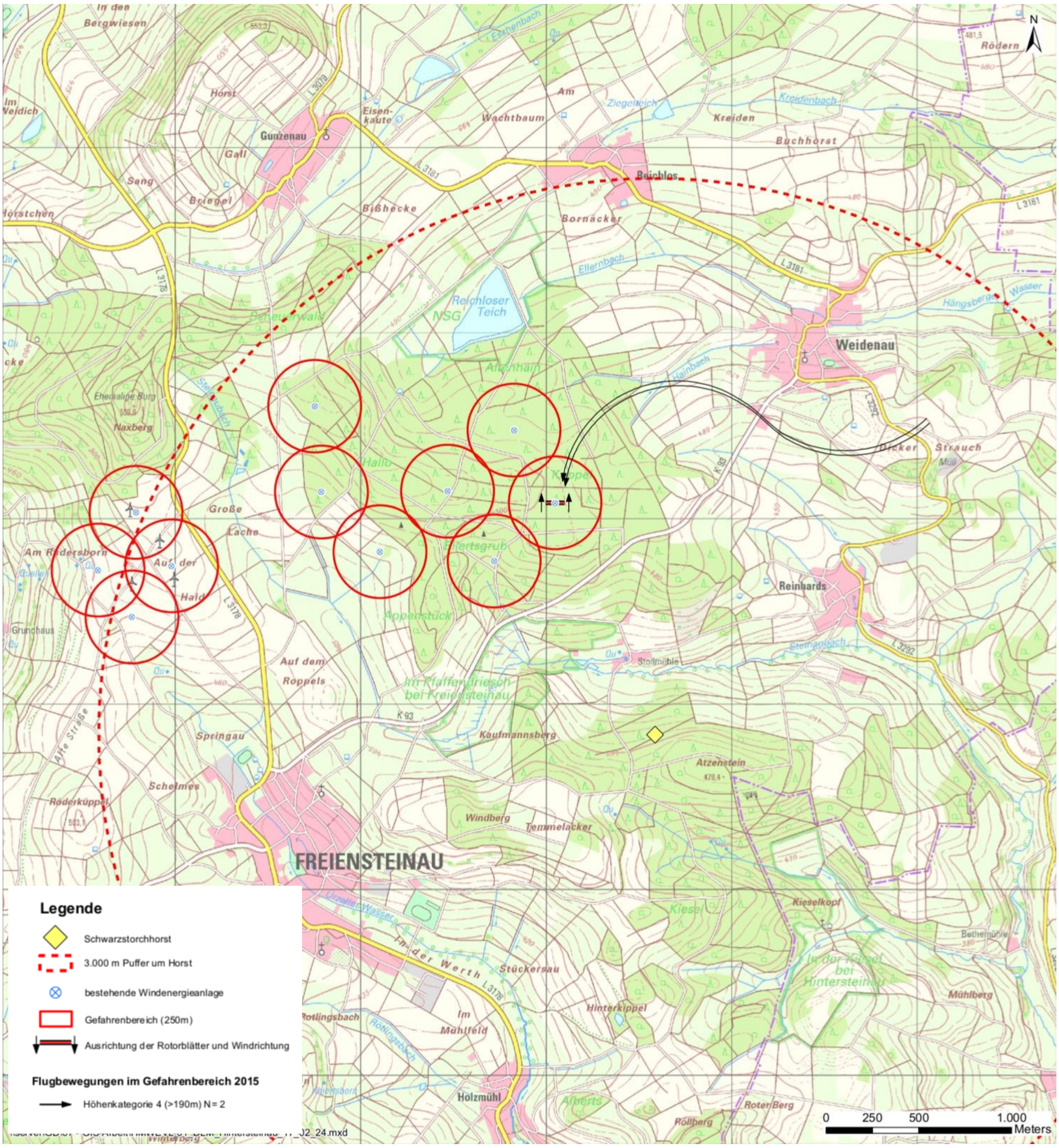

Figure 72: Flight movements in the danger zone, Hintersteinau spatial behaviour analysis 2015 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Ausrichtung …	Alignment of rotor blades and wind direction
Flugbewegungen im…	Flight movements in the danger zone 2015
Hk 4 (>190 m)…	Altitude category 4 (>190 m) N=2

Two out of the total of 66 flight movements recorded touched the wind turbines' danger zone at an altitude of >200 m (see Figure 72). The installations were overflown under conditions of good visibility and low winds. The rotors were aligned perpendicular to the direction of flight.

Table 39: Overview of weather parameters at time of flight movements in the WT danger zone

Date/time	24.04.2015, 10:44 – 10:46 hrs
Observation point	n/a
Flight altitude category/elevation a.s.l. in m	4/>200
Rotor alignment in relation to direction of bird's flight	perpendicular
Wind direction	S
Wind speed in m/s*	5.4
Rotor tip speed* in km/h	156
Visibility in km*	51
Precipitation in mm	0
Flight behaviour	distance flight
Temperature in degrees*	12
Sunshine duration / observation interval in minutes*	10

Land use and topography

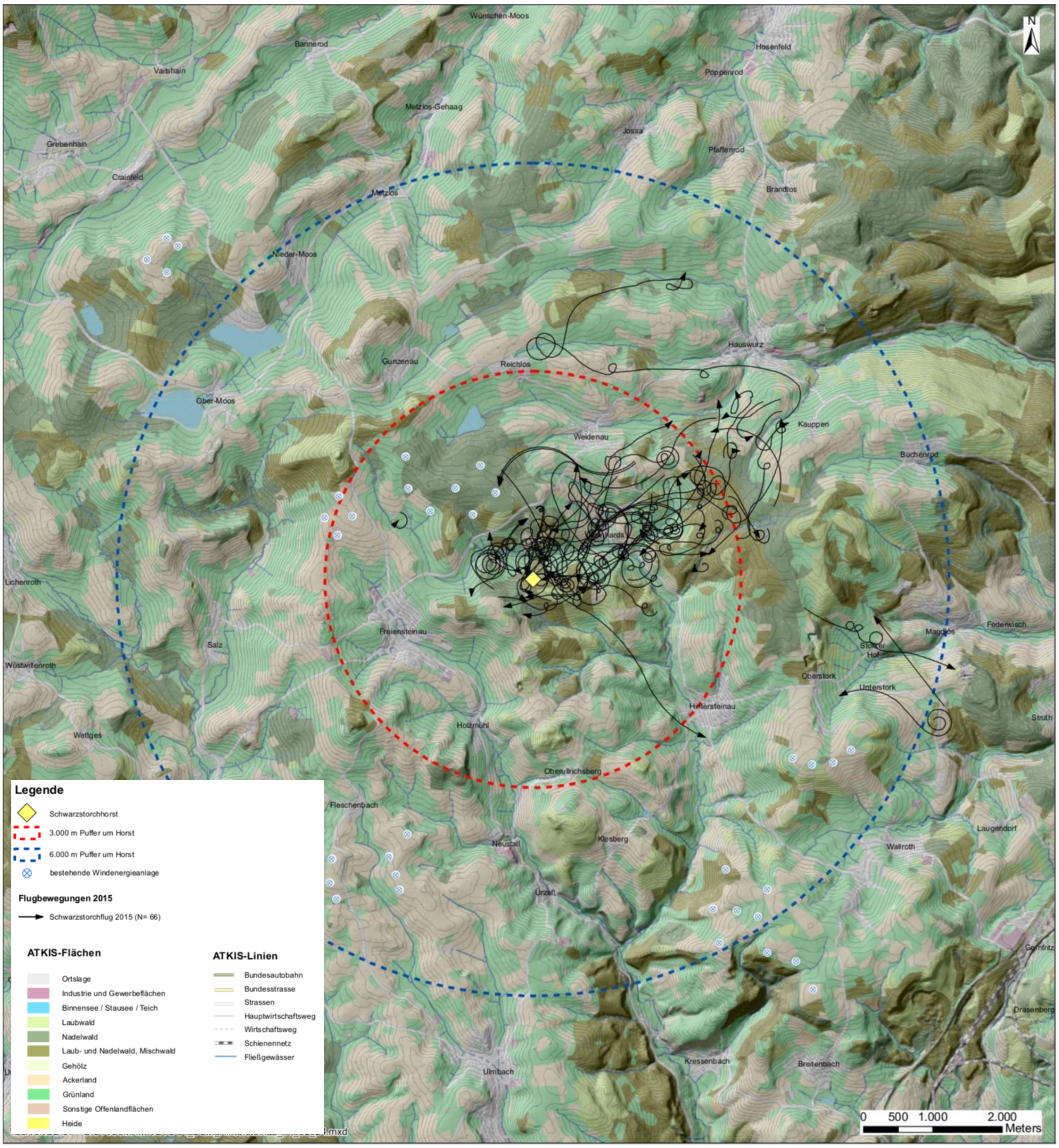

Figure 73: Flight movements superimposed on DLM and DTM, Hintersteinau wind farm 2015 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	(key otherwise as in previous maps)
Flugbewegungen 2015	Flight movements in 2015
Schwarzstorchflug…	Black stork flight (N=66)
	ATKIS categories as in Figs. 37-45

Most of the observed flight movements occurred over flat open land to the northeast of the forest hosting the nest site. The forested slopes and the Atzenstein hilltop at approximately 478 m a.s.l. were overflown by thermaling birds, as were the slopes and hilltop of the Kohlwald at up to 484 m a.s.l.

Overall, the black storks utilised terrain elevations of between 375–380 and 500–505 m a.s.l. There are indications of preference being given to the floodplain and adjacent flat areas near Reinhards.

The distribution of flight movements above the various land-use types is roughly congruent with the distribution of land-use types in the study area. Flights above open land (grassland, arable land) and forests comprise approximately 63% and 33% respectively of the total distance flown. As in the analysis of flight densities in the own 2016 study, it is important to note when analysing flight densities that particularly for land-use types with a small share in land cover even a small number of overflights can result in a high flight density. This is particularly true for industrial and commercial as well as "other" areas. A comparison of their percentage share in land cover and flight density respectively shows these two land-use types to fall significantly outside of the expected range. Looking at flights over mixed forest, it is evident that this land-use type is used significantly more frequently than would be expected based on its proportional share in land cover (see Figure 74).

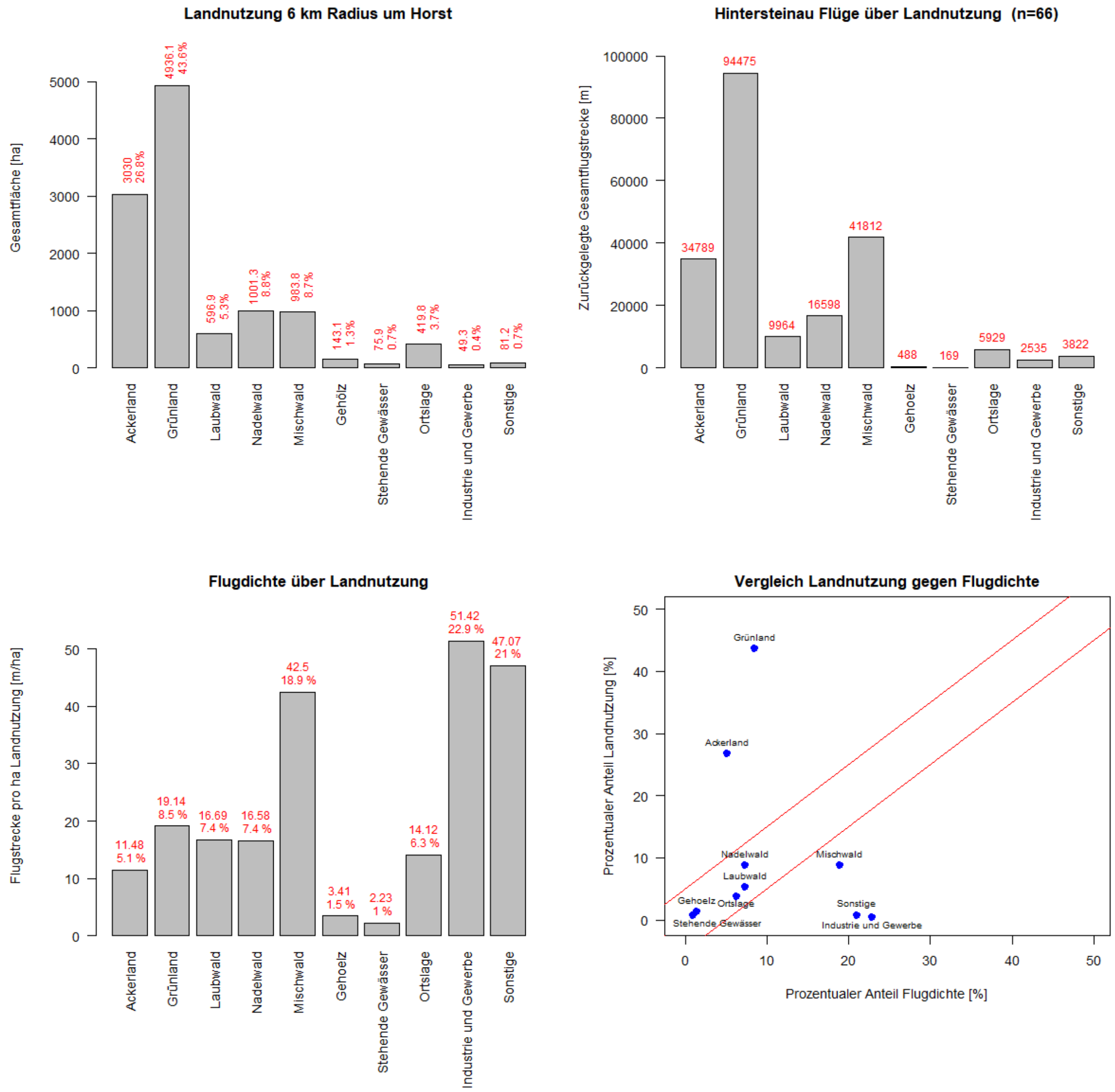

Figure 74: Flight movements by land use in Hintersteinau, in 2015

Hintersteinau Flüge über Landnutzung…	Hintersteinau flights by land use [n=66]
	Key otherwise identical to Fig. 52

Conclusions:

1. Flight behaviour in the vicinity of WTs

Two overflights of the wind farm were recorded under conditions of good visibility and low winds. Overall, 3% of the flight movements were critical flights.

2. Phenology

April is the month with the highest level of flight activity.

3. Flight altitude

The analysis of flight altitudes does not yield any usable result as there were no flights at all in the critical rotor area. Lower altitude flights up to 50 m comprise 27% of total flight movements.

4. Comparison with own study

Due to the different methodologies employed a direct comparison between the 2015 spatial behaviour analysis and the present study is not possible. Flights near to the ground in the southeast of the study area could not be recorded as part of the 2016 survey; flights here could only be recorded at altitudes upwards of 200 m. The analysis of the 2015 data shows that in 2015 the flight activity in this poorly viewable area was not high and it appears that this corridor was not often frequented.

5. Land use and topography

There was a high density of overflights of industrial and commercial areas as well as "other" areas. However, this is due to their small acreage and must not be interpreted as a preference for areas of this type. The predominance of flights over mixed forests is due to the location of the nest site in spatial proximity to mixed forest.

With regard to terrain structure it can be seen that the birds exhibit a preference for the floodplain and adjacent slopes.

5.3 Rabenau wind farm

The following assessment approach was taken:

- Black stork breeding success
- Flight movements in the vicinity of existing WTs, distance to existing WTs
- Comparison of spatial behaviour in wind farm area before and after wind farm construction
- Before-and-after comparison
- Flight movements and topography

Physiographic region

The Rabenau wind farm is located to the east of Geilshausen, a village in the Rabenau municipality, in the area of the former NATO depot and the current composting facility of the Gießen district in the Vorderer Vogelsberg (349) physiographic area after KLAUSING 1988. At 371.1 m a.s.l. the Noll is the highest hilltop in the study area.

Wind farm data

Manufacturer	General Electric
Installation type	GE 2.5-120
Nominal capacity in MW	2.53
Overall height	199 m
Hub height	139 m
Rotor diameter	120 m
Height of rotor tip above ground level	79 m
No. of WTs	6

Following the construction phase in 2014, the Rabenau in farm became operational in July 2015. It consists of six wind turbines of type GE 2.5-120 with a hub height of 139 m, and an overall height of 199 m.

Nest site

The ornithological survey associated with the approval process for the planned wind farm development (2011) found that there was one old black stork nest site (breeding pair 1 – BP1) more than 5 km away in the Eichwald forest of the neighbouring Buseck-Beuern municipality and one new black stork nest site (BP2, known since 2010) at a mere 1.2 km distance to the east of the nearest WT in Grünberg-Weitershain at the Windkopf hill.

BP2 breeding pair at the Windkopf hill

Following the start of construction in the spring of 2014 a pair of ravens drove out the BP2 breeding pair from the nest tree at the Windkopf hill. The storks built a new nest on a hunters' tree stand at a distance of approximately 620 m to the closest WT under construction. The juvenile storks were successfully raised despite the construction phase.

In 2015 there was no breeding activity at the BP2 breeding territory; the consultant ornithologist assumes that one of the partners did not return from the wintering grounds. Only one adult black stork was present in the area.

In 2016 there was a successful hatch with a new partner on one of two newly constructed nest platforms at the Windkopf hill. The nest site is located 1.2 km away from the nearest WT. Two juvenile black storks were successfully raised (Weise 2016a).

In 2017 the birds were in the process of lining the nest with moss between the end of March and early April. However, forestry workers continued to extract timber until the end of March at a distance of approximately 200 to 300 m from the site and removed timber using the forestry track directly adjacent to the nest site which was abandoned as a result (pers. comm. Hormann, 31.03.2017).

Study type

A five-year black stork monitoring was ordered in conjunction with the grant of approval for the wind farm on 06.08.2013 (amendment notice dated 22.10.2014).

In addition, ex-ante mitigation measures were imposed such as the establishment of aquatic feeding habitats, the construction of nest platforms, the establishment of forest set-aside and a scheme designed to avoid losses at an artificial fishpond in the Appenborn valley, i.e. mitigation of black stork disturbance or death. All measures were implemented between 2013 and 2015 before the wind farm became operational (Weise 2016a).

The amendment notice dated 22.10.2014 also established a deterrence measure to be taken at the secondary nest site following the storks' winter migration and, as a compensatory measure, the construction of three nest platforms.

Method	Monitoring, direct observation
Survey period	Early April to early September 2016
No. of breeding territories	2
Daytime / dusk or dawn survey days	42/0
Survey duration in hrs/day/Person	Variable (1 to 5.25)
Survey hours	166
Altitude categories	no
No. of persons surveying synchronously	Variable (1 to 3)
No. of observation points	5
Nest inspection(s), days	11

The spatial behaviour analysis performed as a part of monitoring was conducted over 25 survey days and a total of approximately 166 hours. Recorders worked synchronously and also individually. The selected methodology does not meet the normal standard for spatial behaviour analyses as recommended by the Rhineland Palatinate state guidelines (VSW & LUWG 2012).

Flight altitudes were not recorded and not all flight movements were integrated into the spatial behaviour visualisations.

Five observation points (at Bäune, Grohberg, Melmes, Appenborn valley, and Märzäcker) were located to the north, northwest and west of the forest area. Further observation points were located to the south of the forest area and in the vicinity of the nest site, allowing for observations of the presence of juveniles and adult birds as well as to determine breeding success, the birds' age, and to allow for notifications of disturbances by third parties. This combination provided for a more comprehensive understanding of spatial behaviour.

Table 40: Overview of survey days, Rabenau wind farm, 2016 monitoring

Date in 2016	Duration [h]	Observation period	No. of recorders	Flight observations*
06.04.	15.75	10:00-15:15	3	4
07.04.	1.5	12:00-13:30	1	0
12.04.	1	14:15-15:45	1	0
29.04.	2	12:45-13:45	2	0
05.05.	7	12:00-15:30	2	5
26.05.	10.5	11:00-16:15	2	3
02.06	4.83	12:00-14:25	2	2
10.06.	5	12:00-14:30	2	2
17.06.	6.16	11:40-14:45	2	2
23.06.	10	11:00-16:00	2	5
30.06.	3.33	12:15-15:35	1	0
06.07	10	11:00-16:00	2	3
15.07.	7	12:00-15:30	2	0
20.07.	2.75	12:00-14:45	1	4
22.07.	8.83	10:35-15:00	2	4
27.07.	10	10:30-15:30	2	4
01.08.	2	13:00-15:00	1	0
05.08.	3.25	11:45-15:00	1	1
06.08	1	09:15-10:15	1	2
15.08.	5	14:30-17:30	1	1
17.08.	8	12:15-16:15	2	0
24.08.	9	12:00-15:45	3	3
25.08.	11.75	11:50-15:45	3	3
26.08.	12.5	09:15-15:30	2	2
01.09.	7.84	11:20-15:15	2	0
Totals	165.99			50

* pursuant to the report's text.

Table 41: Overview of flight movements recorded at Rabenau wind farm, 2016 monitoring

Recording month	Number of flight movements	Survey hours, rounded	Activity n/h
April	4	20.25	0.20
May	8	17.50	0.46
June	11	29.32	0.38
July	15	38.58	0.39
August	12	52.50	0.23
September	0	7.84	0
Overall result	50	165.99	0.30

Flight movements in the vicinity of existing WTs, distance to existing WTs

Four flight movements were documented in **April**. These flights consisted of thermaling and subsequent soaring flight. While thermaling the birds reached flight altitudes of 200 m, 300 m and up to 400 m. The spatial focus was on the Lumda floodplain which offers a good food supply.

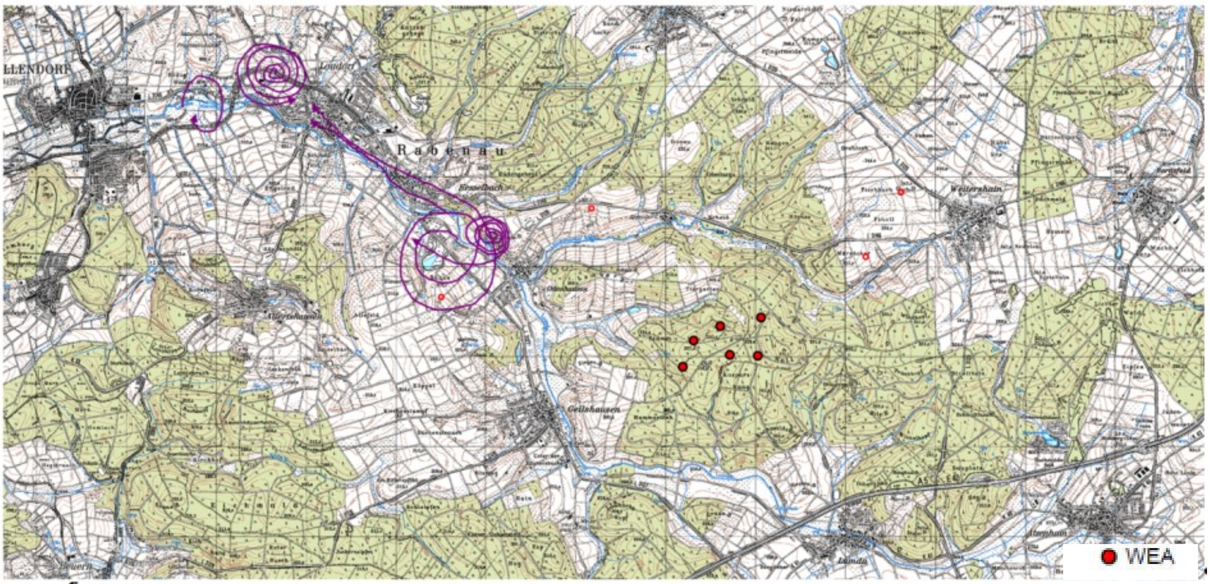

Figure 75: Flight movements in April 2016, Rabenau wind farm, figure by WEISE (2016a)

WEA, Windenergieanlagen	WTs, wind turbines
	Ditto in Figs. 75–78

A total of eight flight movements were recorded in **May**. As part of three of these flight movements, the birds came close to or flew around the wind farm:

1. 05.05.2016, 14:05 – 14:10 hrs: One black stork flies low above Odenhausen and the Lemberg hill towards the WTs, then turns south-eastward and gains altitude (note: within rotor height)
2. 05.05.2016: 14:10 – 14:15 hrs: A further black stork flies at high altitude above Odenhausen and then passes the wind farm as it flies towards the upper Lumda valley (note: above rotor height)

3. 05.05.2016, 15:00 – 15:10 hrs: One black stork flies over the Appenborn valley, spiralling upwards in a south-easterly direction (note: above rotor area)

According to the consultant (Weise pers. comm.), the altitudes of two of the flights are above rotor height while one flight is within rotor height. However, in the latter case the bird avoids the installations; given the difficulty of assessing the distance between bird and turbines it is assumed that the distance was greater than >250–300 m.

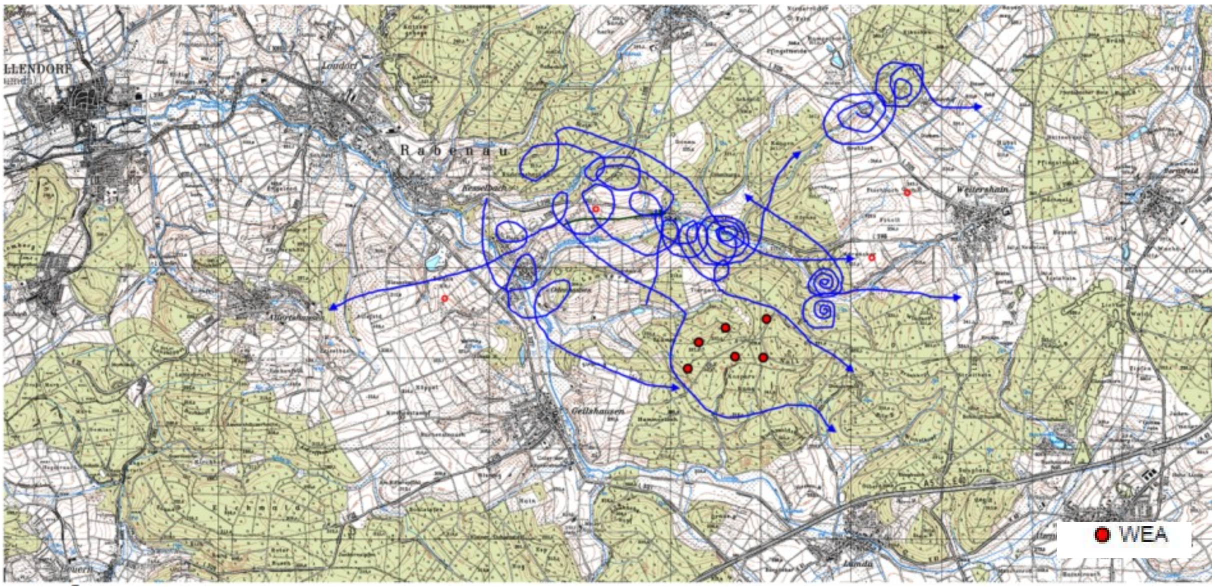

Figure 76: Flight movements in May 2016, Rabenau wind farm, figure by WEISE (2016a)

Eleven flight movements were recorded in **June**. These were characterised by upward circling at the southern slopes of the Appenborn valley and subsequent very long soaring flights to the Lumda valley. The distance covered between the nest site and the feeding habitat was approximately 8 km. In the course of their flights the birds circled upwards to great heights of up to 400 m in flight altitude.

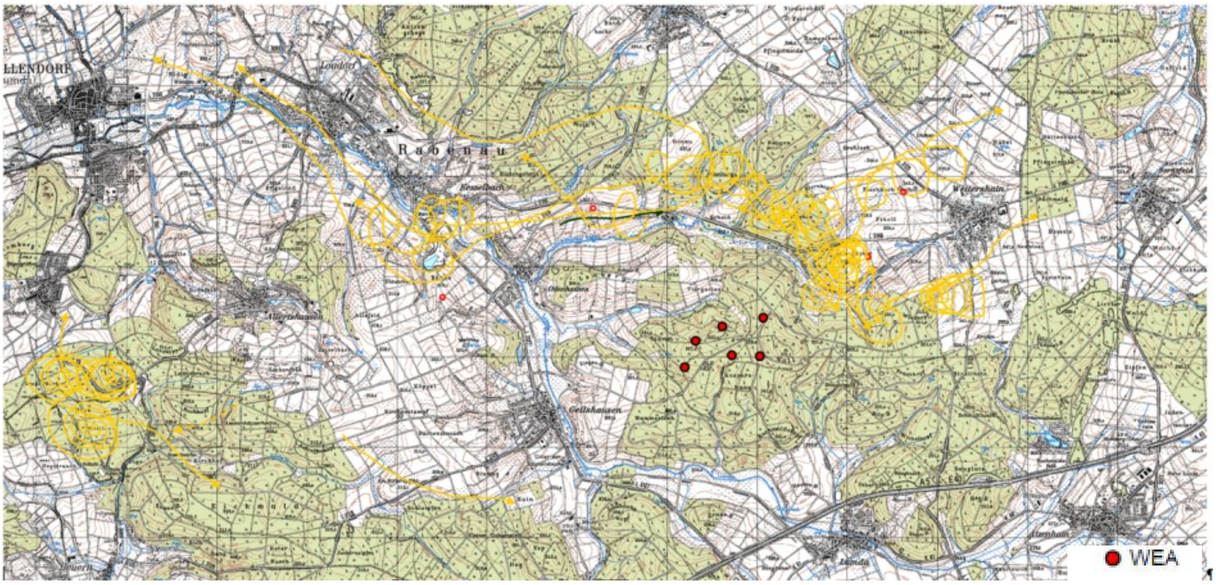

Figure 77: Flight movements in June 2016, Rabenau wind farm, figure by WEISE (2016a)

Fifteen flight movements were recorded in **July**. Three of these flight movements took place in the valley between the Lemberg hilltop and the forest edge at the Noll. The birds used the forest edge for thermaling with a view to reaching the Lumda valley or the Appenborn valley. All flights kept a sufficient distance to the wind farm.

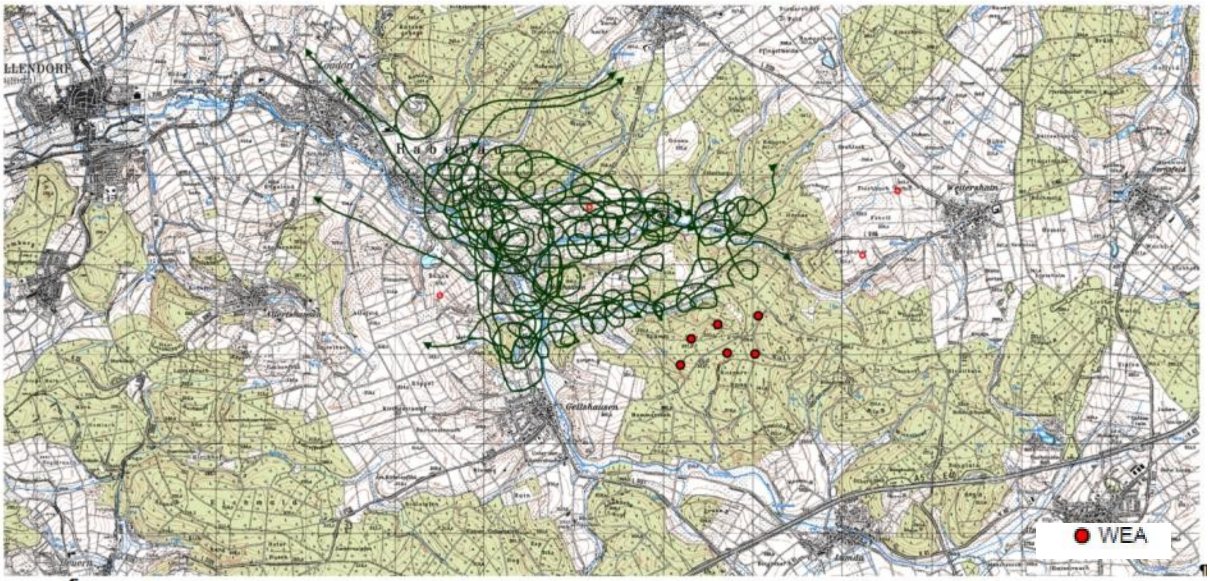

Figure 78: Flight movements in July 2016, Rabenau wind farm, figure by WEISE (2016a)

Twelve flight movements were recorded in **August**, four of which were flights by adult birds as shown in the figure below. None of the flights came into the vicinity of the wind farm.

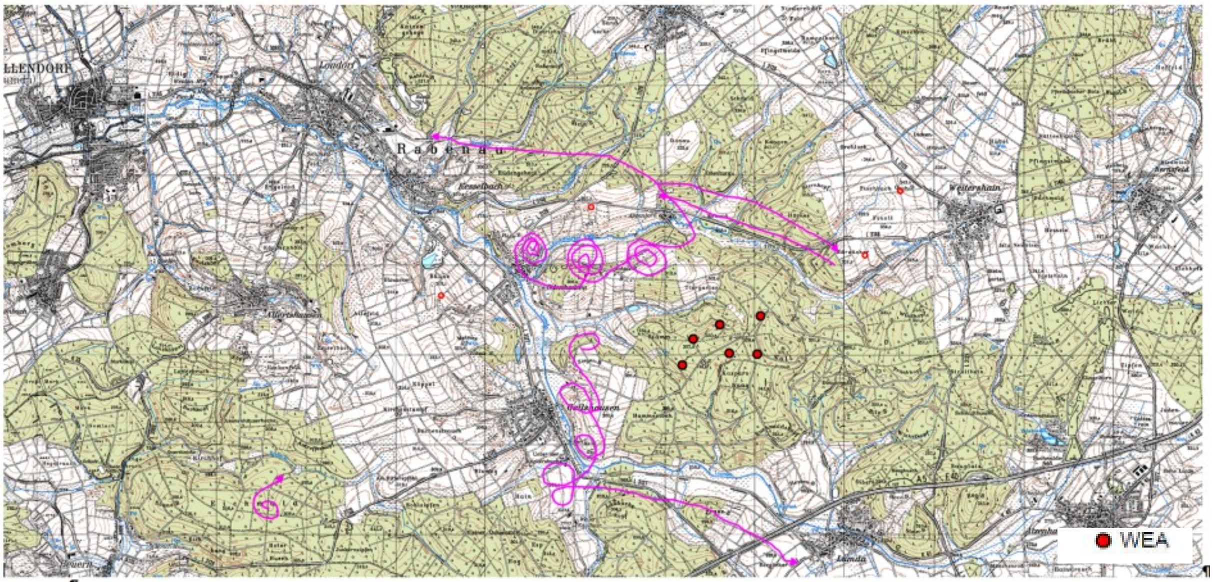

Figure 79: Flight movements by adult birds in August 2016, Rabenau wind farm, figure by WEISE (2016a)

On three survey days (24.08., 25.08., 26.08.) in August, a total of eight flight movements by the two juvenile storks were documented. These included flight movements by juvenile storks on 24 and 26 August which were seen circling predominantly in the Appenborn valley towards Odenhausen and over open land.

On 24 August at 13:40 – 14:10 hrs two juvenile black storks were observed from the Bäune observation point. Coming from the forest hosting the nest site and over the Appenborn valley the juveniles spent a long time on practice flights in the area delineated in Figure 80. Only later they circled upwards and flew in a south-easterly direction over the wind farm. This overflight took place under conditions of good visibility and at altitudes between 100 to 150 m above the installations.

On 25 August at 14:20 – 14:30 hrs a juvenile black stork was observed flying above the nest site, then circling upwards at a relatively fast pace and moving back and forth between the Hörnes forest area and the Noll hill, in part at a small distance to WTs (inside the danger zone and at times at rotor height).

On 26 August at 10:33 – 10:38 hrs a further flight by a juvenile stork was observed from the Birnbaum observation point across from Märzäcker. The juvenile circled back and forth between the Appenborn valley and Märzäcker, in this instance however at a significant distance to the nearest WTs (> 250 m) and below the rotor area.

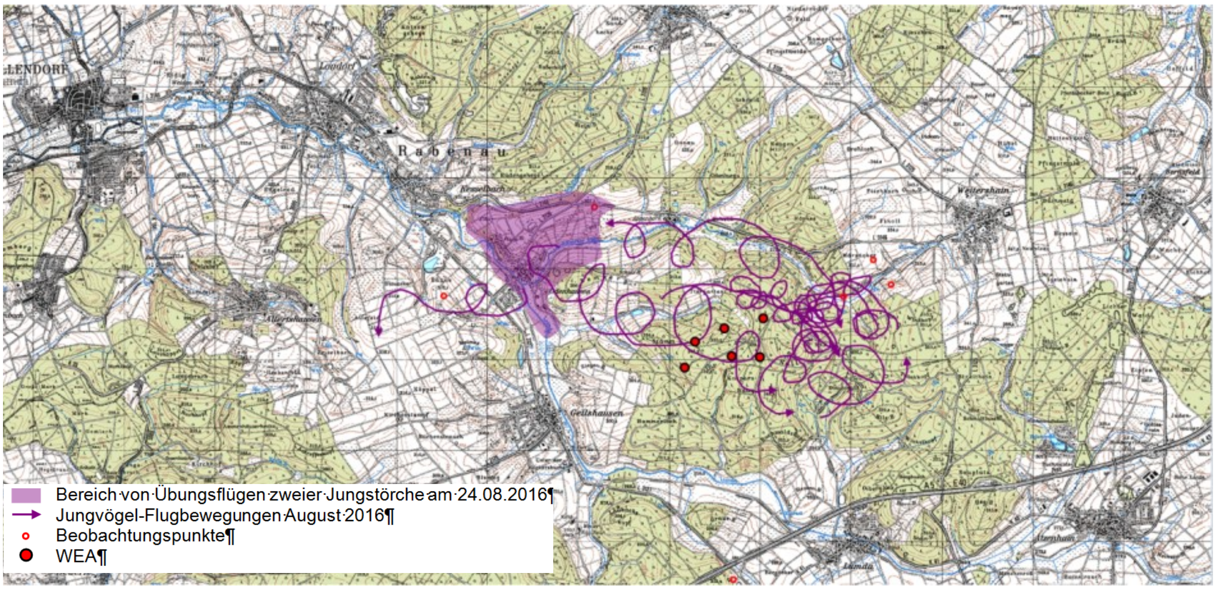

Figure 80: Flight movements of juvenile black storks in August 2016, Rabenau wind farm, figure by WEISE (2016a)

Bereich…	Area used for practice flights by two juvenile storks on 24.08.2016
Jungvögel…	Flight movements by juvenile birds, August 2016
Beobachtungs…	Observation points
WEA	WTs

Comparison of spatial behaviour in the wind farm area before and after wind turbine construction

Black stork spatial behaviour in 2011 and 2014, i.e. prior to the installations' construction, is compared below to the survey years during construction in 2015 and after the wind farm became operational in 2016.

Spatial behaviour in 2011 (prior to construction)

The findings of the 2011 spatial behaviour analysis are shown in Figure 81 in the form of a delineated primary home range, termed "interaction fan" (*Interaktionsfächer*). The survey was conducted on 20 survey days between late March and late August; however, the survey periods were not noted.

The flight movements recorded were documented in daily maps. The combined findings are given in Figure 81. Flight movements were observed above the forest area in which the wind farm is located. The area to the northwest of the nest site along the small tributary valley (primary approach/departure axis) towards the Appenborn valley is one of the regularly used flight corridors; the other consists of the Appenborn valley itself (thicker purple arrows) and the slopes at Kesselbach (Grenz 2011).

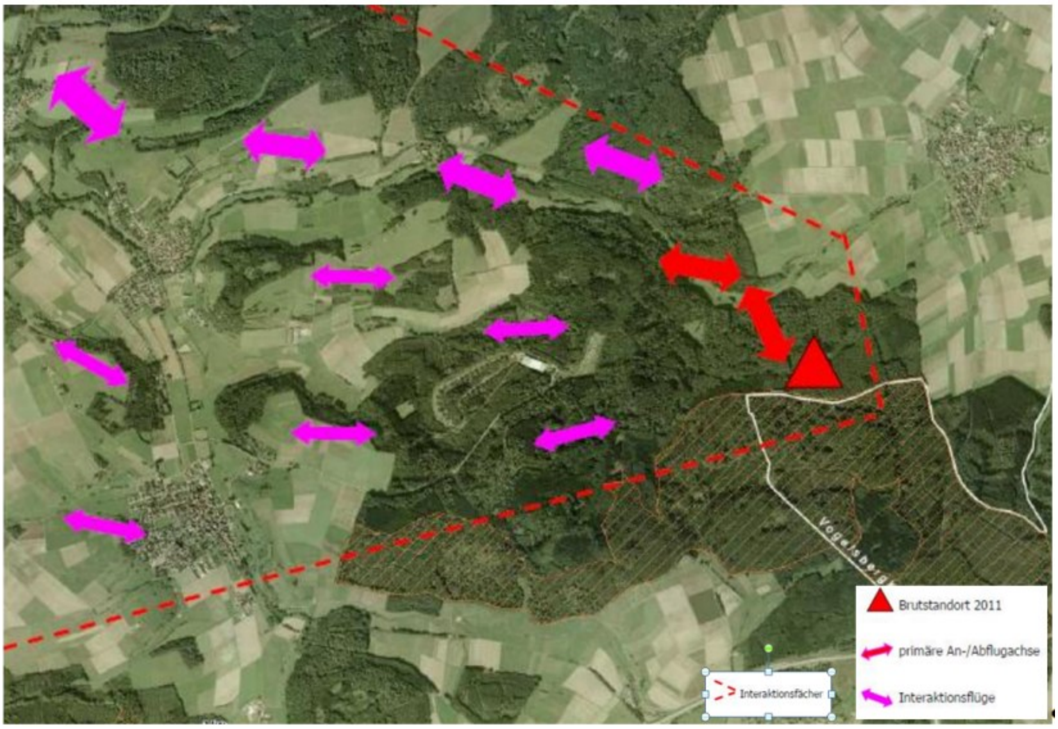

Figure 81: Black stork spatial behaviour in 2011, Rabenau wind farm, figure by WEISE (23.11.2016)

Interaktionsfächer	Interaction fan
Brutstandort 2011	Nest location in 2011
primäre …	primary approach/departure axis
Interaktions…	Interaction flights

Monitoring in 2014 (prior to construction)

Flight movements were recorded in 2014, prior to wind farm construction. The survey period extended from early March to late August and included 34 survey days. According to Weise (2015), in 2014 the black storks utilised a somewhat more narrow home range ("interaction fan") than was observed as part of the spatial behaviour analysis in 2011. According to Weise (2015) the birds overflew the planned wind farm location only on its periphery. An increased density of flights is visible in the vicinity of the nest site (on the hunters' tree stand in 2014) and in the area of the Appenborn valley above Kesselbach.

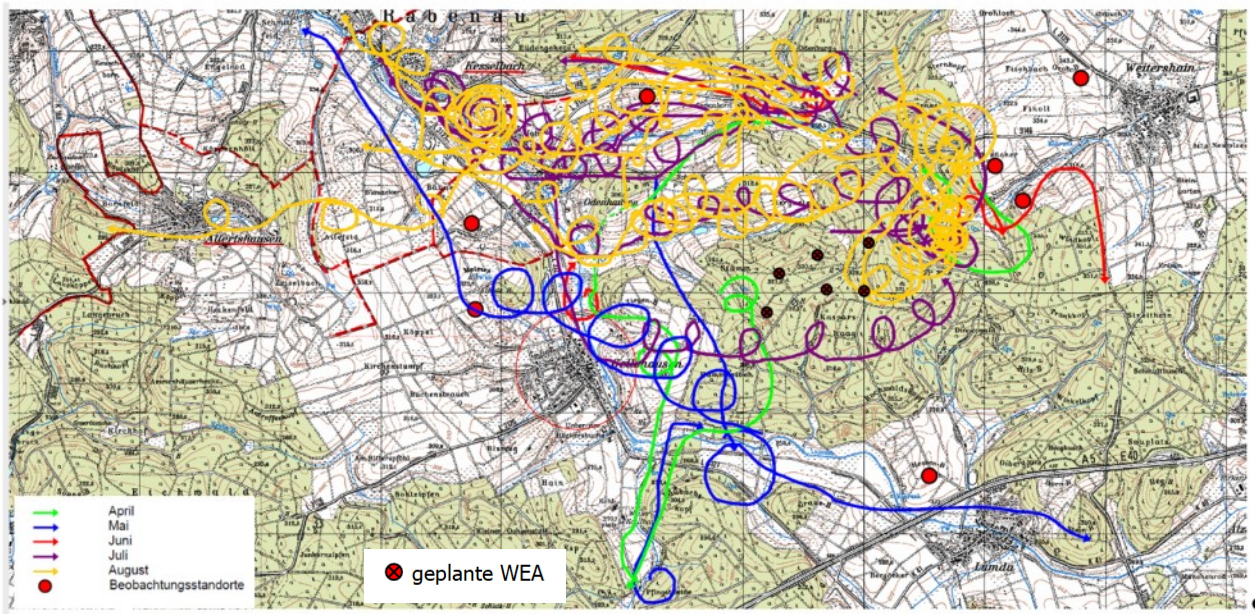

Figure 82: Black stork spatial behaviour in 2014, Rabenau wind farm, figure by WEISE (23.11.2016)

April	April
Mai	May
Juni	June
Juli	July
August	August
Beobachtungstermine	Observation days
WEA	WTs
Geplante WEA	planned WTs

Monitoring 2015 (during construction)

The monitoring conducted in 2015 represents the black storks' spatial behaviour during the wind farm construction phase in 2015. The survey period extended from early March to late August and included 50 survey days. According to WEISE (2016b), the spatial behaviour shown in 2015 differs from the flight behaviour recorded in 2014. The black storks utilised a more narrow "interaction fan" than was observed as part of the spatial functional analysis in 2014. WEISE (2016b) describes that the primary flight corridors continue to be located in the Appenborn valley and the Lumda floodplain; fewer flight movements were however recorded in the vicinity of the wind farm.

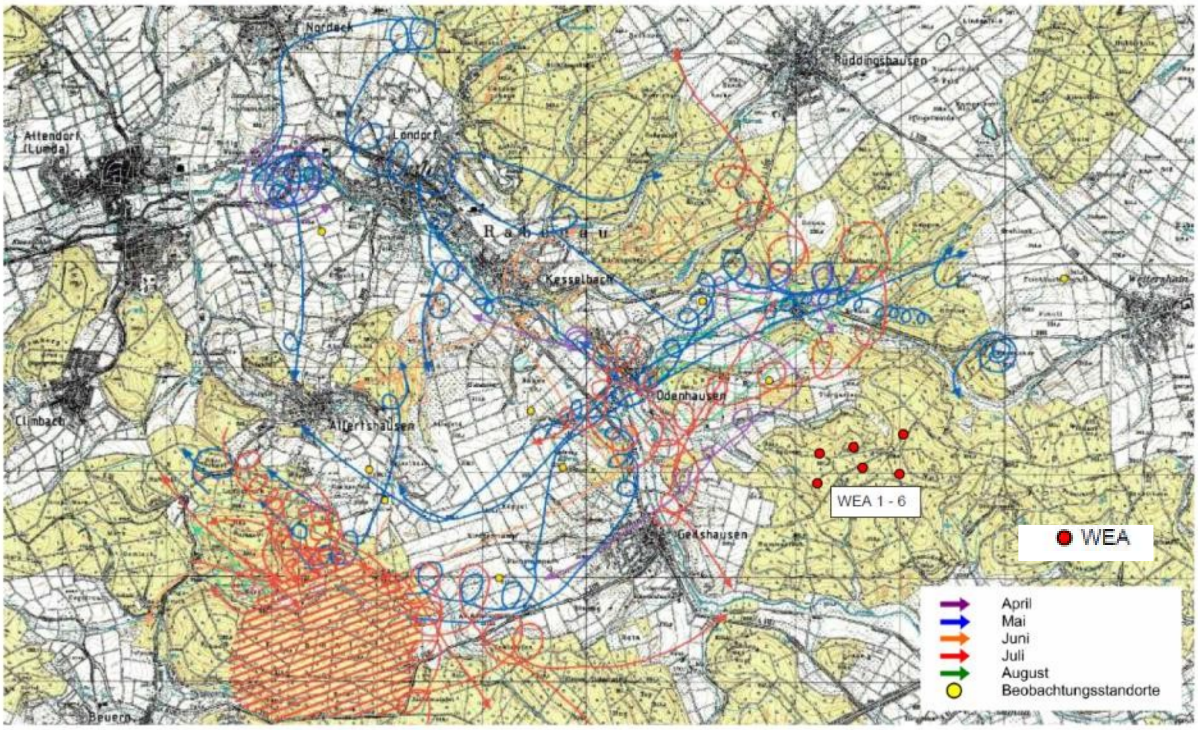

Figure 83: Black stork spatial behaviour in 2015, Rabenau wind farm, figure by WEISE (23.11.2016)

Key as in Fig. 81

Monitoring in 2016 (wind farm operational)

According to WEISE (2016a), the 2016 monitoring showed no significant differences in the adult black storks' spatial behaviour compared to their flight behaviour recorded in 2015. The black storks utilised a more narrow "interaction fan" than prior to the wind farm construction. It appears that the birds fly around the wind farm on its periphery but do not traverse it.

The juvenile storks came into the wind farm's proximity (cf. Figure 80). However, they too appear to fly around the wind farm (Weise 23.11.2016). One overflight of the wind farm was observed; it took place under conditions of good visibility and at a height of 100 to 150 m above the installations (Weise 2016a).

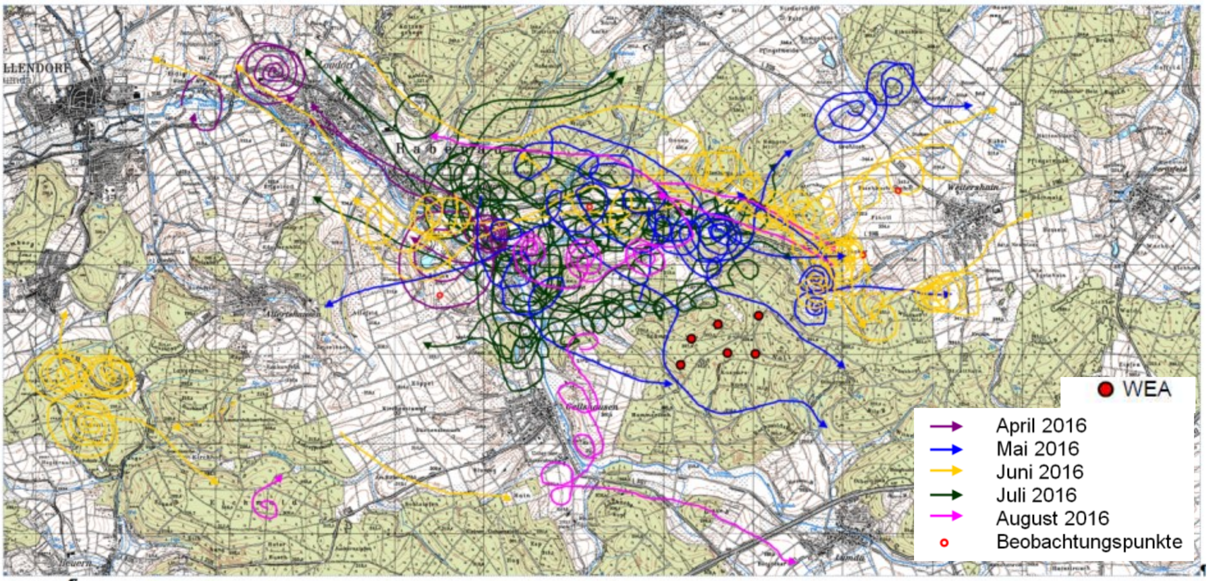

Figure 84: Total flight movements of adult black storks in 2016, Rabenau wind farm, figure by WEISE (2016a)

Key as in Fig. 81

Conclusions:

1. Black stork breeding success in spatial proximity to WTs

The studies have ascertained that black storks can successfully breed in spatial proximity to a wind farm.

2. Spatial behaviour

As part of the monitoring a total number of 50 flights were recorded in the course of 166 survey hours. This is equivalent to 0.30 flights per hour.

2. Phenology

The highest flight activity was recorded in May.

3. Flight behaviour in the vicinity of WTs

Out of a total of 50 flight movements recorded in 2016, three flight movements by adult birds were noted in which the birds flew around the wind farm at a distance of between 250 to 300 m which brought them into the installations' danger zone (250 m radius, horizontal view). During one of the flights in May 2016 it was clearly evident that the black stork in question changed its course so as not to enter the wind farm's danger zone.

A further three flight movements by juvenile birds entered the wind farm's danger zone. Two juvenile storks overflew the wind farm at a height of 100 to 150 m while a further juvenile stork temporarily flew at rotor height within a short range of the WTs.

Overall, out of a total of 50 flight movements, there were three critical flight movements by juvenile storks (6%) which came close to the wind farm.

Table 42: Overview of conflict situation in terms of flights close to WTs

Type of study	**Total flights**	**Number of flights in danger zone*** **Critical flights**	**Proportion of flights in %**	**Behaviour (vertical)**		**Assessment of conflict situation**
				Flights in danger zone*: Within rotor area	**Flights in danger zone*: Outside of rotor area**	
Monitoring Rabenau	50	3	6.0	-	1 flight at rotor height	conflictual
				-	-	moderate conflict
				-	2 overflights	little conflict

*Danger zone (250 m, horizontal view)

4. Before-and-after comparison

A before-and-after comparison shows that there are significant differences in spatial behaviour (cf. 2014 and 2016) in the forested area of the wind farm.

Figure 82 shows that parts of the forest area in which the WTs are located were overflown by the storks prior to the WTs' erection. In Figure 84 the same forested area is now only bypassed on its periphery. The adult black storks do not overfly or traverse this area. The black storks do recognise the wind farm as an obstacle.

In 2015, there is another aspect to the birds' spatial behaviour that strongly diverges from the 2014 behaviour. There are no flight movements in the forest area around the wind farm. This may be due to the fact that the nest site to the east of the wind farm was vacant, thus eliminating any forced ties to the nest site and the need for feeding flights for raising the young.

5. Flight movements and topography

The analysis of the Rabenau wind farm study highlighted a preference for the study area's valleys with regard to the BP2 nest site to the east of the wind farm and associated flight movements. There are clearly identifiable flight corridors along the Appenborn valley and the broad Lumda floodplain.

5.4 Moskau-Kreuzstein wind farm

The following assessment approach was taken:

- Spatial behaviour/phenology
- Impact of topography on flight movements/spatial behaviour
- Preferential use of certain land-use types/habitats for overflights

Physiographic region

The study area is located in the northernmost part of the East Hesse Highlands and physiographically belongs to the forest district Gutsbezirk Kaufunger Wald as part of the Fulda-Werra Uplands. The Kaufungen forest is characterised by a typical low mountain landscape with highly varied relief. The contiguous upland area is completely under forest cover and is dissected by watercourses flowing in narrow V-shaped valleys.

Wind farm

The spatial behaviour analysis was conducted in 2014 in connection with the planned Moskau-Kreuzstein wind farm with its projected eight WTs. No turbines had been erected at the time the study was conducted.

The nearest planned WT was located at a distance of approximately 2 km from the black stork nest site at Nieste. The wind farm development was since granted permission and the installations were erected in 2016.

The Hausfirste wind farm (operational since 2016) is located 4 km to the east of the Nieste nest site and thus in its spatial proximity; it consists of 10 E-115 installations with an overall height of 206.5 m and a rotor diameter of 115 m.

The Stiftswald wind farm consisting of nine E-115 installations (operational since 2016) is located 5.6 km to the southwest, and the Rohrberg wind farm consisting of five E-115 installations (operational since 2015) is located 7 km to the southeast.

All the now completed wind farms, i.e. Hausfirste, Stiftswald and Rohrberg, were in the planning stages at the time the spatial behaviour analysis was conducted.

Nest site

The object of the study is the long established black stork nest site located approximately 2.5 km to the southeast of the Nieste municipality on a north-eastern slope within the more or less contiguous forest area. The nest site has been occupied almost every year since 1993. Over the past 21 years (1993 to 2014) a total of 55 juvenile black storks, or an average of 2.6 juveniles/year, were raised at the site. It is one of the most successful known nest sites in all of northern Hesse (WILKE, pers. comm. 2014 in BÖF 2015). The site was not occupied in 2015 as a raven was breeding 12 m away. The consultants (BÖF 2015) assume that the raven did not tolerate the black stork breeding attempt. In 2016 the nest site was again left vacant; in 2017 another breeding attempt was made, resulting in at least one juvenile; a new nest site was occupied in spatial proximity to the former (written communication by Herzog, 19.07.2017).

Table 43: Black stork breeding success at Niestetal

Nest site	2014	2015	2016	2017
Nieste	3 juveniles	Not occupied	Not occupied	Successful hatch, at least 1 juvenile, new nest site nearby

A further three nest sites are known in the wider area, i.e. one breeding pair between Ziegenhagen and Oberrode (10 km to the north), one pair in the Hopfelde/Küchen area (10 km to the southeast) and one pair in the Söhrewald municipality west of Eschenstruth (8 km to the southwest) (BÖF 2015).

Study type

Method	Spatial behaviour analysis, direct observation
Survey period	mid-March to mid-August 2014
No. of breeding territories	1
Observation days*	78
Survey duration in hrs/day/Person	7.5–8
Survey hours	563
Altitude categories	yes
No. of persons surveying synchronously	2 to 4
No. of observation points	4
Nest inspection(s), days	1

*) in the consultant report (BÖF 2015) this is given not as the number of survey days but as the sum of observation days, i.e. the product of the number of survey days times observation points

Due to the terrain's relief and the complete forest cover there were no observation points offering good panoramic views. The consultants (BÖF 2015) chose four observation points:

- M1 Wickerode, 5.0 km to the south of the nest site with a good view of the planned WT locations
- M2 Niestetal, 1.5 km to the northwest of the nest site with a view of the nest location
- H2 Hausfirste, 4.0 km to the east of the nest site with a view of the planned WT locations
- S2 Nienhagen, 6.5 km to the northwest of the nest site (additional observation point, no views of nest site or planned WTs).

Table 44: Overview of survey days, Moskau-Kreuzstein wind farm, spatial behaviour analysis

2014	**Duration [h]**	**Observation days**
Mid-March to mid-April	~7.5 hrs per day	21
Mid-April to mid-May	~7.5 hrs per day	11
Mid-May to mid-July	~7.5 hrs per day	27
Mid-July to mid-August	~7.5 hrs per day	15
Totals	**563**	**74**

The survey extended from mid-March to mid-August 2015 and included a total of 563 survey hours.

Table 45: Overview of flight movements recorded at Moskau-Kreuzstein wind farm

Flight altitude category*	**Total number**	**Distance flown**
0 (0–25 m)	3	5,259 m
1 (25–50 m)	10	19,903 m
2 (50–80 m)	11	19,844 m
3 (80–190 m)	15	52,739 m
4 (>190 m)	10	26,571 m
Multiple flight altitudes	79	237,818 m
Totals	**128**	**362,134 m**
Survey month		
March	11	19,873 m
April	19	43,884 m
May	35	102,544 m
June	17	50,901 m
July	42	130,247 m
August	4	14,685 m
Totals	**128**	**362,134 m**

*) The flight altitude categories chosen in Table 45 are based on the flight altitude categories of the present study (see Section 3.4).

As part of the survey a total of 128 flight movements were recorded covering a total distance of approximately 362 km.

Table 46: Phenological distribution of flight movements

Period	**Flight movements**		
	[n]	**[h]**	**[n/h]**
Mid-March to mid-April	20	160	0.13
Mid-April to mid-May	20	84	0.24
Mid-May to mid-July	46	205	0.22
Mid-July to mid-August	42	114	0.37
Overall result	**128**	**563**	**0.23**

<u>Flight distances from the nest site and average distance covered</u>

Flight movements commencing or ending in the vicinity (500 m radius) of the nest site were considered. This condition was met by 60 out of a total of 128 recorded flight movements.

Fifteen of these flights (25% of the flights) took place at a distance of up to 1000 m around the nest site. A further 44 flights (73%) covered longer distances, having been recorded in a 1000–3000 m radius around the nest site. Only one flight movement (2%) out of a total of 60 which commenced or ended near the nest site were observed in a 3000–6000 m radius around the nest site.

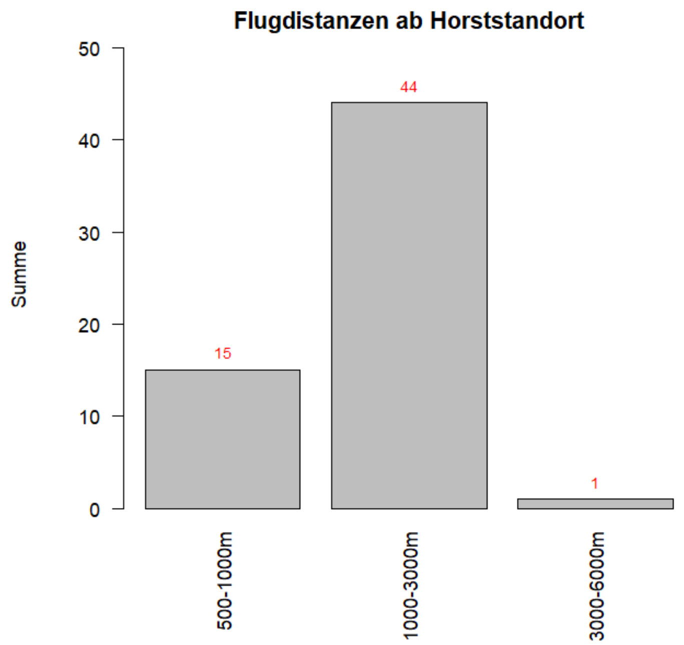

Figure 85: Flight distances from the Nieste nest site

Flugdistanzen ab Horststandort	Flight distances from the nest site
Summe	Totals

Flight movements in the vicinity of existing WTs, distance to existing WTs

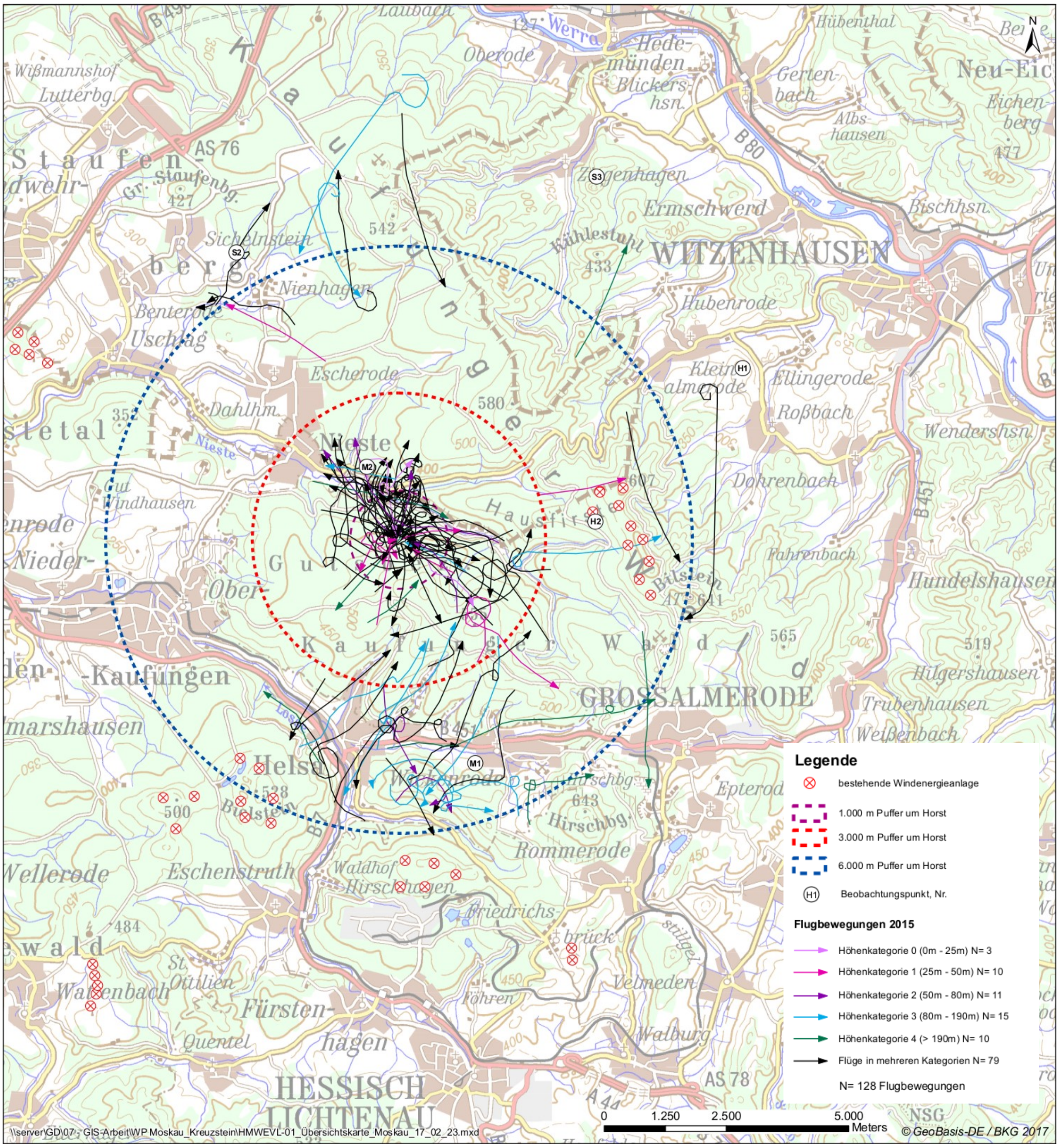

Figure 86: Overview of flight movements recorded at Moskau-Kreuzstein wind farm in 2014

	(otherwise as in previous maps)
Flugbewegungen 2015	Flight movements in 2015
Hk 0 (0 – 25m)	Altitude category 0 (0–25) N=3
Hk 1 (25 – 50 m)	Altitude category 1 (25–50 m) N=10
Hk 2 (50 – 80 m)	Altitude category 2 (50–80 m) N=11
Hk 3 (80 – 190 m)	Altitude category 3 (80–190 m) N=15
Hk 4 (>190 m)	Altitude category 4 (>190 m) N=10
Flüge in mehreren…	Flights in multiple categories N=79
N = …	N = 128 flight movements

Land use and topography

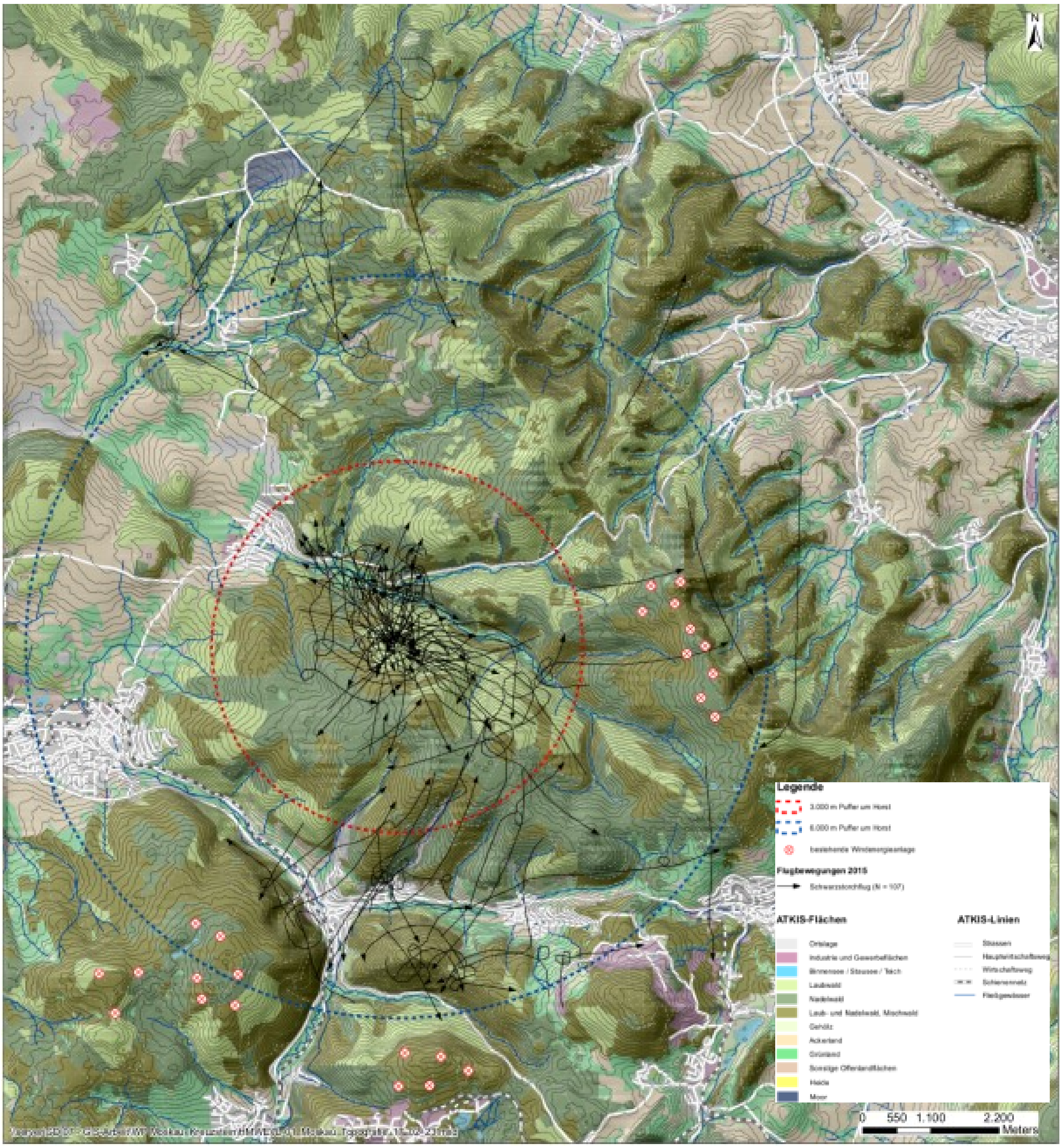

Figure 87: Flight events superimposed on DLM and DTM, Moskau-Kreuzstein wind farm, 2014 (Baseline map: Geodatabase of the Lower Saxony survey and cadastral authority [Niedersächsische Vermessungs- und Katasterverwaltung], Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key as in Fig. 65 with one addition under ATKIS:
Moor	Peatland

The analysis of the area's topography did not reveal a focal preference for certain landforms. The Nieste valley is a very narrow V-shaped valley and is situated at an altitude of 150 m below that of the forest hosting the nest site which is located at 450 m a.s.l. The forests' altitude facilitates overflights of the surrounding uplands. Approximately 2 km away, the nearest WTs (to the east of the nest site) are situated at altitudes of between 540 and 620 m a.s.l.

Overall, flight movements were observed at terrain altitudes of between 250 and 600 m a.s.l. The birds thus span differences in terrain altitude of 350 m.

Land use within a 6 km radius of the occupied Nieste nest site is strongly dominated by forestry, with forests holding a 77% share in land cover; at approximately 18% open land-use types hold a much smaller share (see Figure 88). An analysis of the flight density above the different land-use types show that "Other areas" scores highest on flight density while the overall acreage in this category is very small, consisting of *Außenbereich* developments, i.e. outside of the legally defined built-up area, in the Lautenbach valley (tributary to the Wedemannsbach stream). The southern area offers good feeding habitats and therefore more frequently attracts the birds. The flight density above deciduous forest is almost twice as high as that above coniferous forest; this greater proportion can be explained by the nest site's location in a deciduous forest.

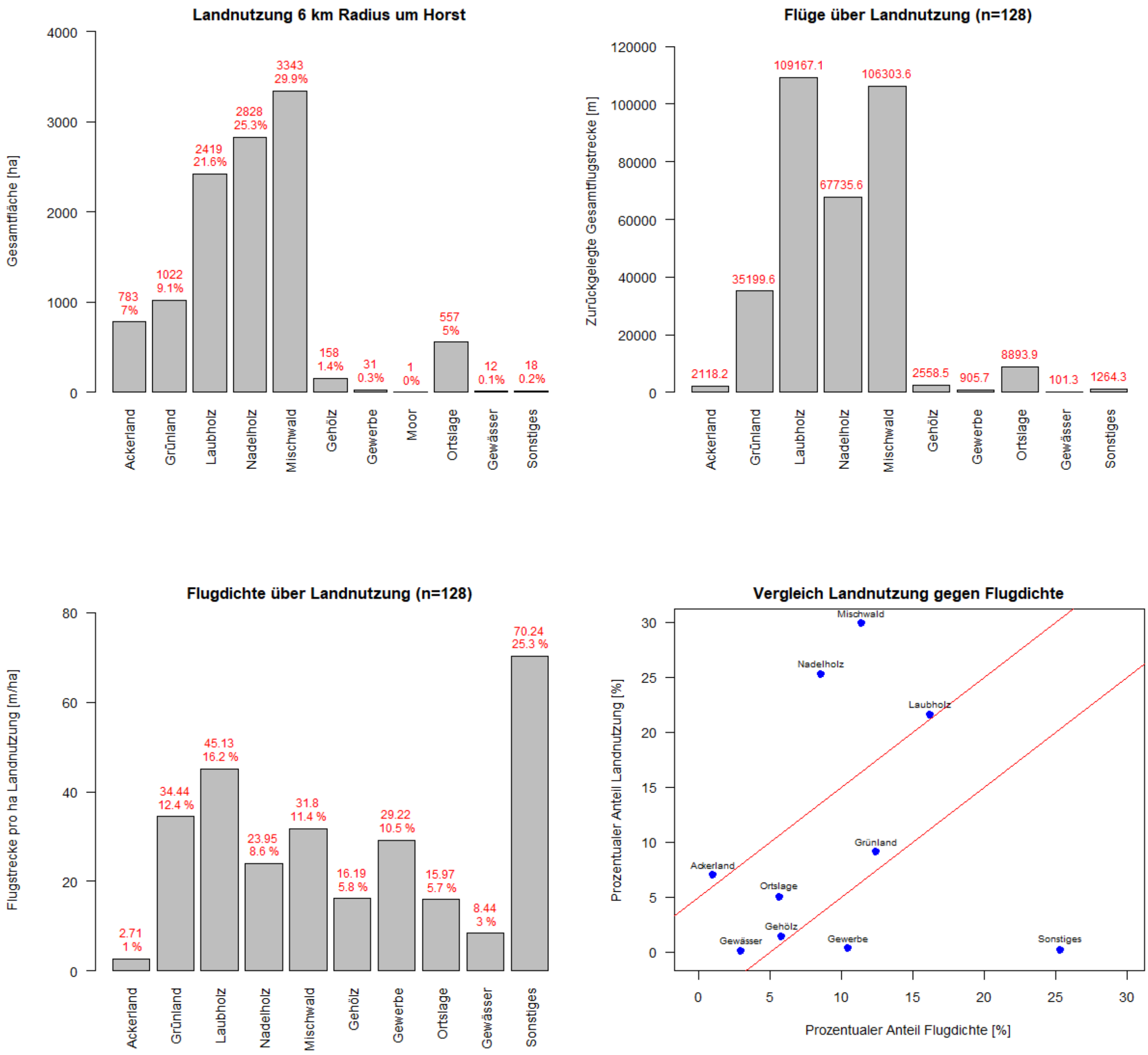

Figure 88: Flight movements by land use; land use within a 6 km radius, Moskau-Kreuzstein wind farm, 2014

Key identical to Fig. 52

Grassland and aquatic systems (watercourses and standing waters) combined account for a greater share in flight density than deciduous forests. This finding is not surprising as the storks fly over these areas in order to reach feeding areas in the Nieste, Schwarzbach, Losse and Wedemannsbach stream and river valleys.

A significantly lower than expected flight density given the proportional share in land cover was found only for mixed and coniferous forests (cf. Figure 88, bottom right).

Conclusions:

1. Spatial behaviour

The spatial behaviour analysis recorded 128 flights in the course of 563 survey hours; this is equivalent to 0.22 flights per hour.

2. Phenology

The highest number of flight movements was recorded in May.

3. Flight altitude

Flights in the critical rotor area comprised 12% of the recorded flights. The majority of flight movements (approximately 62%) could not be assigned to a single altitude category as these flights spanned multiple altitude ranges.

4. Land use and topography

The proportion of overflights of grassland and aquatic systems was somewhat higher than that of deciduous forests, thus revealing a preference for the valley and adjacent slopes.

5.5 Wohnste wind farm

The following assessment approach was taken:

- Breeding success, disturbance
- Flight movements in the vicinity of exsting WTs
- Flight altitude categories

Physiographic region

Physiographically the study area lies in the North German Plain within the Stade Geest landscape and comprises the Wiegerser Forst forest area and adjacent grassland and arable land. The area is characterised by numerous small watercourses such as the Ramme, Tiefenbruchgraben, Viehgraben and Harselahbach. The Ramme stream flows south-eastward through the Wiegerser Forst on a length of more than 4 km. Terrain elevation varies from 35 m to 41 m a.s.l. At 40.3 m a.s.l., the Viertels-Berg hill is the highest elevation in the Wiegerser Forst.

Wind farm data

The study was prompted by the extension of the existing Wohnste wind farm which consists of ten older WTs (overall height: 100 m) to which three or four larger WTs (overall height: up to 150 m) will be added.

Another wind farm, the Ahrenswohlde wind farm with 20 WTs (overall height: 87 m) is immediately adjacent to the Wohnste wind farm. Both wind farms became operational in 2001 (PROPLANTA 2017).

Nest site

Statements on black stork breeding success in the area differ. The PLANUNGSGRUPPE GRÜN (2006b) consultants confirmed a successful hatch in 2006 from their own observations.

However, according to the Lower Saxony ornithological centre (VSW) no successful hatch has been recorded since 1999 (written communication, 03.03.2017). According to the VSW, breeding pairs or individual black storks only enter the study area in search of food. Alfred Nottorf (written communication, 10.04.2017) concurs, stating that the former nest site (presumably this means nest site 1) has been vacant in recent years (2014 to 2016).

These different statements can only be reconciled if in fact they relate to two different nest sites.

Nest site 1 is situated at the southern edge of the forest and, according to the forestry authority (Mr. Haarhaus), it is more than 1 km away from the existing WTs (PLANUNGSGRUPPE GRÜN (2006b)). By 1998 a total of seven hatches had been recorded at this well-known nest site. However, the breeding pair abandoned the site in 1999 as a result of disturbances by prying visitors.

Nest site 2 is situated at the forest's centre. There is no detailed information as to its exact location. The consultants assume that it is located in the vicinity of the Ramme stream – an important feeding habitat. With respect to breeding success, there are two records for this nest site that cannot be pinpointed with any more accuracy. The first record comes from Mr. Haarhaus of the forestry authority (PLANUNGSGRUPPE Grün (2006b)) who stated that as early as the year following the disturbance a breeding pair once again settled in the Wiegerser Forst but that it moved its nest site further into the forest's interior (PLANUNGSGRUPPE GRÜN 2006b). However, this breeding pair which has occupied the nest site every year since only had its first breeding success in 2006. This information is congruent with the consultants' statement that according to their own observations there were two adults with one juvenile in the Wiegerser forest in 2006 (PLANUNGSGRUPPE GRÜN 2006a).

Study type

Method	Spatial behaviour analysis, direct observation
Survey period	early April to mid-August 2006
No. of breeding territories	1
Daytime / dusk or dawn survey days	42/0
Survey duration in hrs/day/Person	7
Survey hours	936
Altitude categories	yes
No. of persons surveying synchronously	2 to 4
No. of observation points	3 to 6
Nest inspection(s), days	0

The spatial behaviour analysis covers the period from early April to mid-August of 2006. The observations were conducted in April and, following a short break, from late May to mid-August 2006. The Ramme stream is mentioned as an important feeding habitat in the forest hosting the nest site; its branching channel dissects the forest on a length of more than 4 km. There are also some small ponds which together with the humid meadows provide ideal feeding habitats.

Flight movements in the vicinity of existing WTs, distance to existing WTs

A total of 39 flight movements were recorded over a period of 935.5 observation hours. The investigations have shown that the birds' focus of spatial behaviour must lie inside the forested areas of the Wiegerser Forst. The black storks utilise the forest edge as a guideline for foraging flights. It is believed that many of the flight movements take place inside the forest or just above the treetops, i.e. in areas that due to the topography are not viewable which means that the flights could not be recorded. In addition to being the breeding habitat, the forest area is also considered an important feeding habitat. It suffers very low disturbance overall as many areas are difficult to access. The forest area is also used by outside storks residing in the wider area.

The most important flight corridor lies along the southern forest edge, connecting the area presumably hosting the nest site with the feeding areas in the southeast (Tiefbruchgraben, Viehgraben). The second flight corridor is located in the northwest of the area.

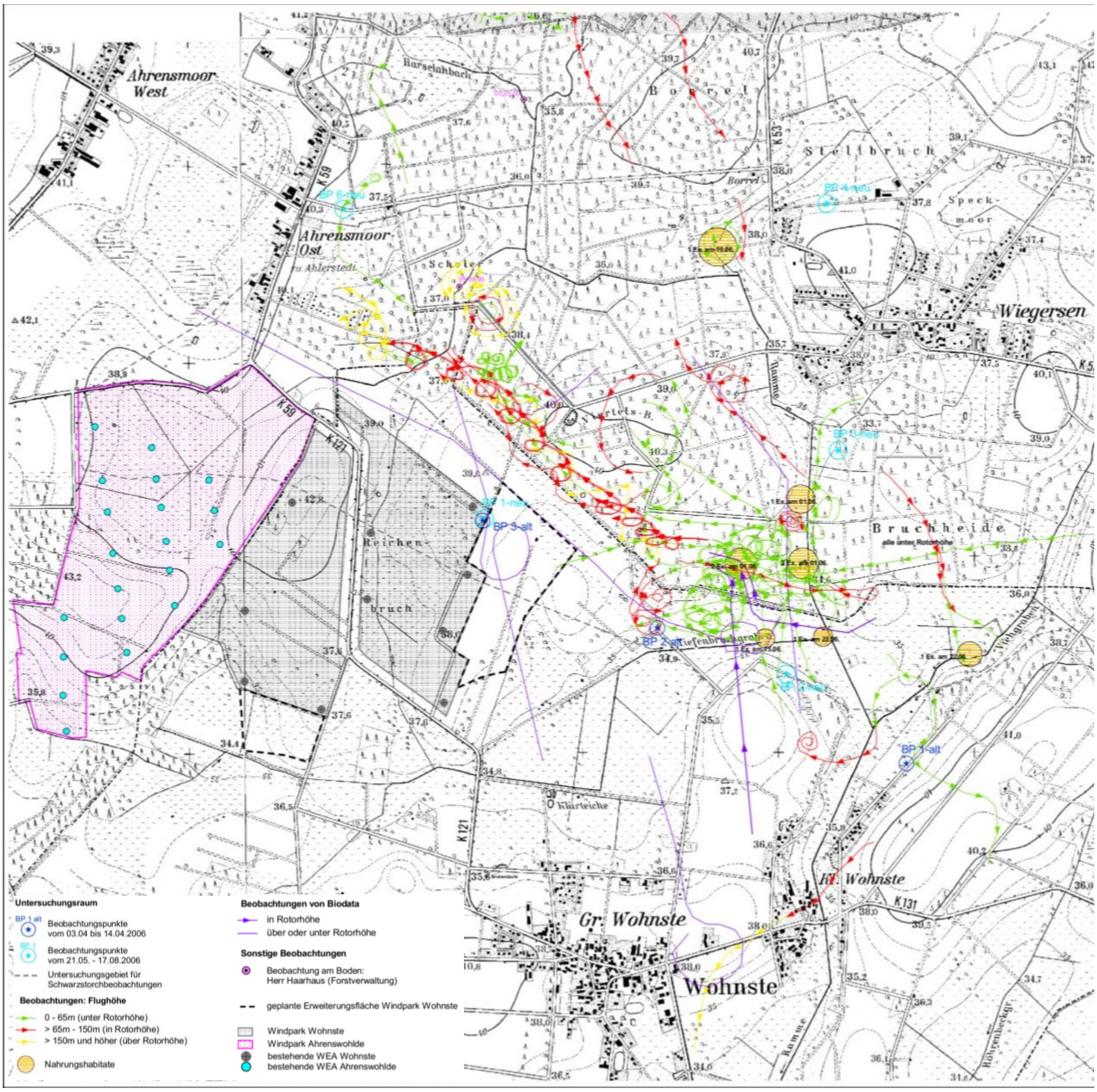

Figure 89: Flight movements, Wohnste wind farm (PLANUNGSGRUPPE GRÜN 2006b)

Untersuchungsraum	**Study area**
…	Observation points 03.04-14.04.2006
	Observation points 21.5.-17.08.2006
	Study area for black stork observations
Beobachtungen: Flughöhe	**Observations: Flight altitude**
…	0–65 m (below rotor height)
	> 65m–150m (at rotor height)
	>150m and higher (above rotor height)
	Feeding habitats
Beobachtungen von Biodata	**Observations by Biodata**
…	at rotor height
	above or below rotor height
Sonstige Beobachtungen	**Other observations**
…	Observations on the ground: Mr. Haarhaus (forestry authority)
	planned expansion of Wohnste wind farm
	Wohnste wind farm
	Ahrenswohlde wind farm
	existing WTs Wohnste
	existing WTs Ahrenswohlde

Records of five flight movements were provided by consultants of the Biodata consultancy (commissioned by the lower nature conservation authority of the Rotenburg/Wümme district), with one of the flight movements very closely passing the periphery of an existing WT, either above or below the rotor (PLANUNGSGRUPPE GRÜN (2006b).

The majority of flights (57% of the observed flight time) occur at low altitude (0–65 m). The birds were often observed just above the treetops. They spent 32% of the flight time at altitudes between 65 and 150 m, with only 11% of flight time spent at very high altitudes (> 150 m).

With respect to phenology, the highest proportion of black stork sightings was recorded in June (see Table 47).

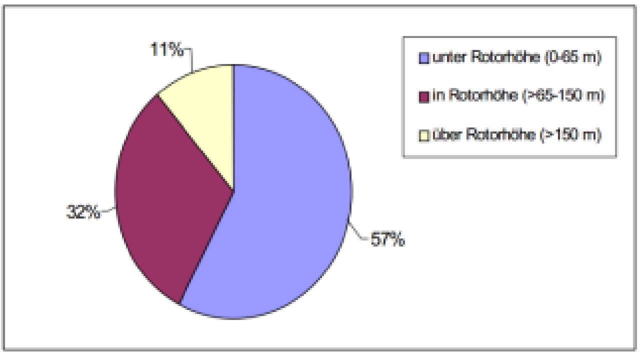

Figure 90: Distribution of altitude categories by total flight time (after PLANUNGSGRUPPE GRÜN 2006b)

unter R...	below rotor height (0-65m)
in R...	at rotor height (>65-150m)
über R...	above rotor height (>150m)

Table 47: Phenological distribution of flight movements, Wohnste

Phase	Flight movements		
	[n]	[h]	[n/h]
April	4	231	0.02
May	6	102.5	0.06
June	17	239	0.07
July	6	194.25	0.03
August	6	168.75	0.04
Totals	**39**	**935.5**	**0.04**

Conclusions

1. Black stork breeding success in spatial vicinity to WTs

Prior to the construction of the wind farm, human disturbance caused the black storks to change their nest site in 1999.

The investigations conducted in 2006 have shown that black storks can successfully breed in spatial proximity to a wind farm. However, it has not been possible to accurately pinpoint the location of the new nest site.

2. Phenology

The highest flight activity was recorded in June.

2. Spatial behaviour

The spatial behaviour analysis recorded 39 flights in the course of 935.5 survey hours, which is equivalent to 0.04 flights per hour. One flight out of a total of 44 flights (39 flights recorded by Planungsgruppe Grün, 5 flights by Biodata consultancy) took place in the danger zone of WTs.

Flight altitude categories

At 57%, the greatest proportion of flight time was spent at altitudes of between 0 and 65 m.

5.6 Data by NABU Hessen

The following assessment approach was taken:

- Utilised feeding habitats
- Case-by-case assessment of flight movements in the danger zone of WTs

Black stork observation data were made available by the conservation NGO NABU Landesverband Hessen e.V. The data concerned are records of flight movements and data on foraging black storks.

The observations of foraging birds and of near ground-level flight movements were integrated into the data analysis on feeding habitats (see Section 4.11).

Table 48: Overview of foraging birds, NABU-Hessen 2016

Date in 2016	Time	Number	Recorder
12.04	12:30	1 adult	Sommerhage
12.05.	16:00	1 adult	Sommerhage
25.05.	08:45	1 adult	Sommerhage
07.06.	15:00	1 adult	Sommerhage
18.06.	10:30	1 hatched 2015	Sommerhage
22.06.	07:30	1 adult	Sommerhage
22.06.	16:00	1 adult	Sommerhage
09.07.	19:00	1	Sommerhage
13.07.	09:00	1 hatched 2015	Sommerhage
20.07.	17:30	2 adults	Sommerhage
27.07.	09:30	2 adults, 1 hatched 2016	Sommerhage
03.08.	20:00	2 adults, 4 hatched 2016	Sommerhage
03.08.	20:45	1 adult	Sommerhage

The 20 flight observations shown in Table 49 are purely random observations and were not collected in adherence to the present study's methodological framework (recording time/day, fixed observation points, synchronous recording, calibration of altitude categories, mapping of the birds' course of flight, logging of behaviour, separation of individual flight events). Three flights out of a total of 20 flight movements were deemed to have occurred in the danger zone.

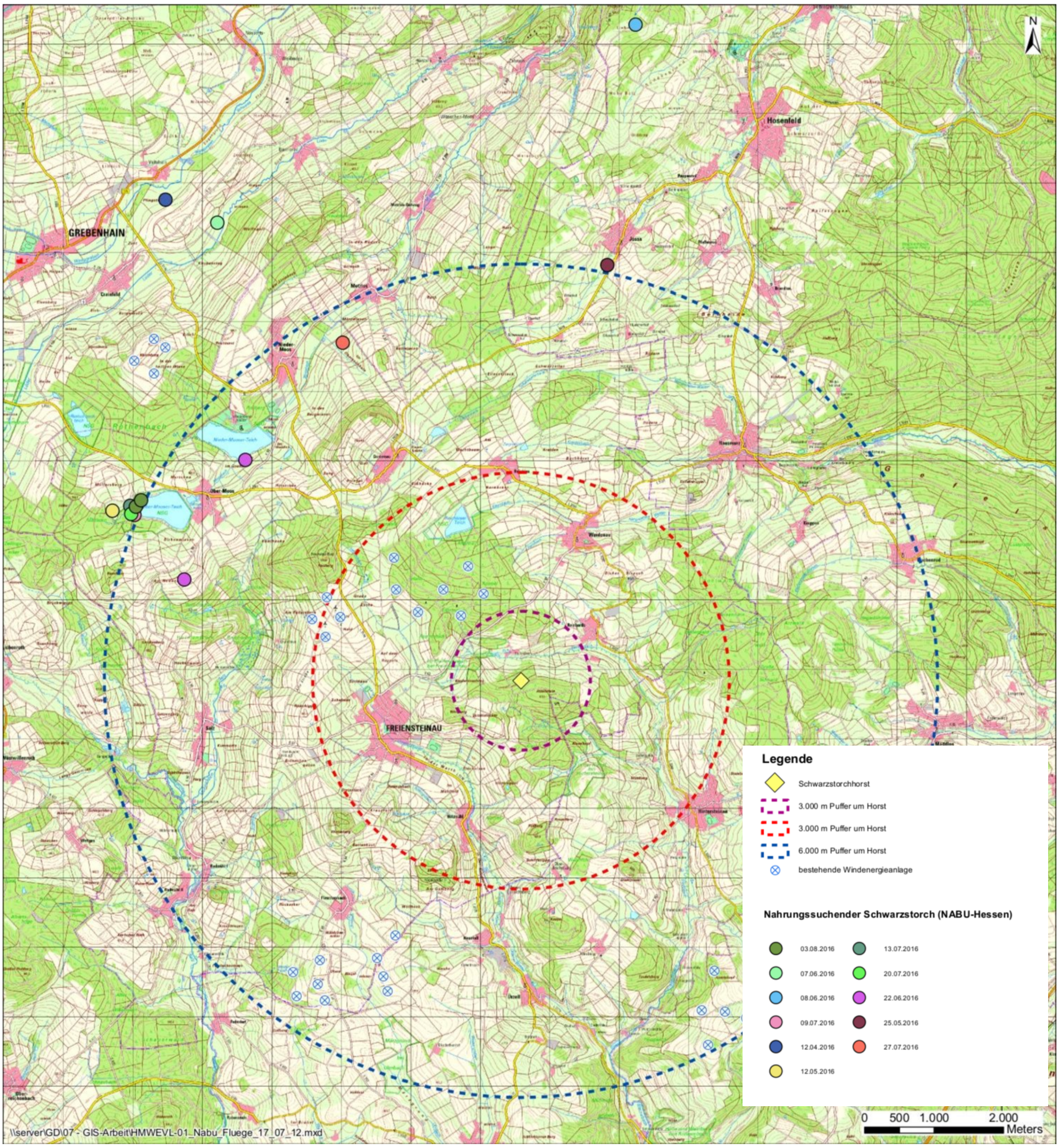

Figure 91: Foraging black storks, data by NABU Hessen 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	(key otherwise as in previous maps)
Nahrungssuchender …	Foraging black stork (NABU-Hessen)

Table 49: Overview of flight movements; records by NABU-Hessen 2016

Date in 2016	Time	Number	Flight altitude category	Recorder
22.03.	11:16	1	Twice tree height	Sommerhage
06.04	09:47	1	Above the rotors	Sommerhage
12.04	15:15	2	Rotor height wind farm	Sommerhage
26.04.	16:00	1	Up to tree height	Sommerhage
12.05.	13:33	1	Up to tree height	Sommerhage
20.05.	11:30	1	Rotor height	Sommerhage
25.05.	8:45	1	Near ground level	Sommerhage
03.06.	10:12	1	Up to tree height	Sommerhage
07.06.	17:27	1	Twice tree height	Sommerhage
16.06.	08:16	1	Up to tree height	Sommerhage
20.06.	18:30	2	Up to tree height	Sommerhage
22.06.	11:00	1	Twice tree height	Sommerhage
08.07.	17:15	1	Up to tree height	Sommerhage
12.07.	08:18	1	Rotor height	Sommerhage
13.07.	10:20	1	Up to twice tree height	Sommerhage
19.07	09:10	2	Above rotor height	Sommerhage
25.07.	20:25	1	Twice tree height	Sommerhage
Totals		20		

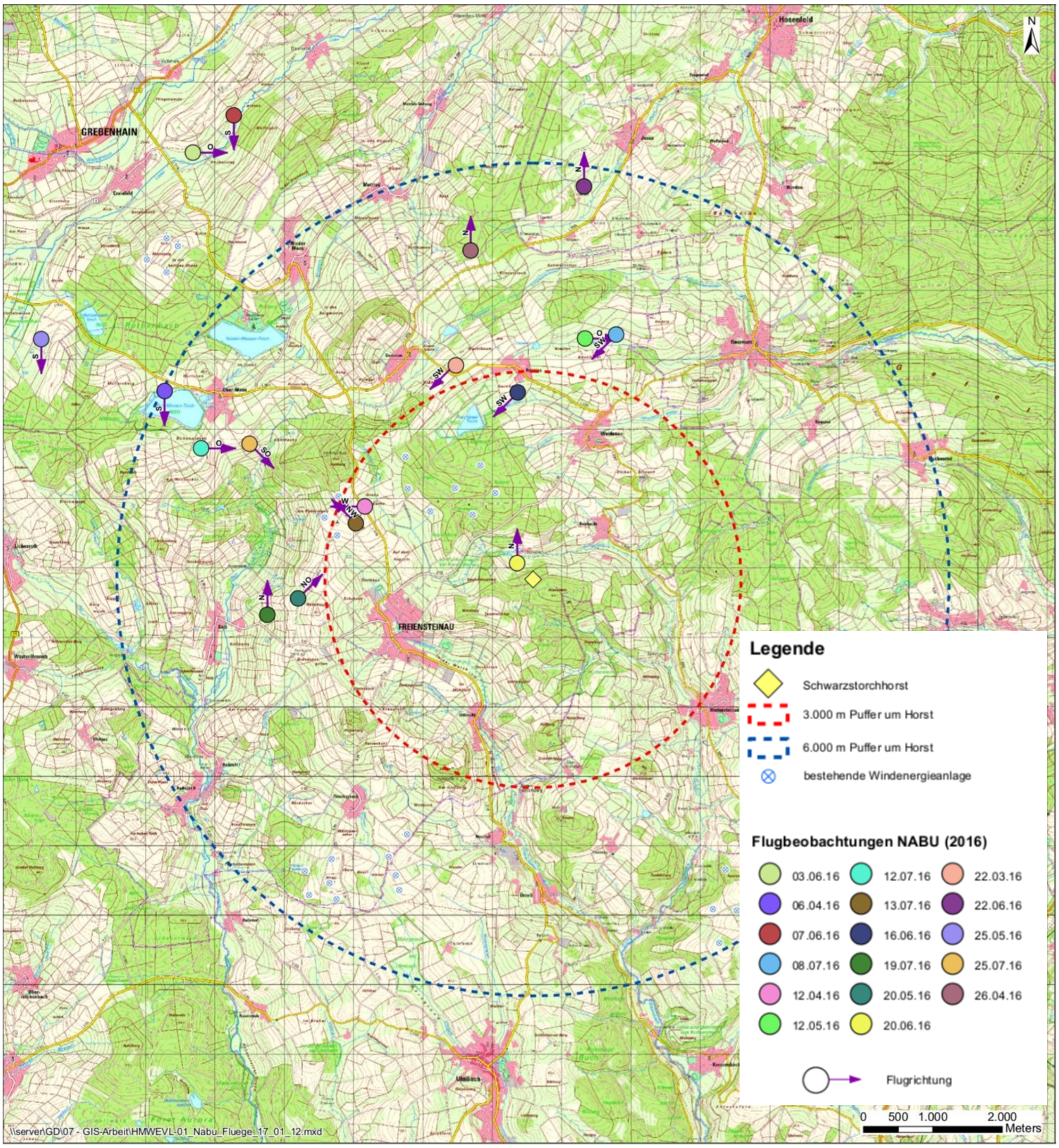

Figure 92: Black stork flight movements in 2016 observed by NABU-Hessen (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	(key otherwise as in previous maps)
Flugbeobachtungen …	Flight observations by NABU (2016)
Flugrichtung	Direction of flight

Case-by-case assessment of flight movements in the danger zone

Closer consideration will be given here to the observations recorded on 12.04.2016 and 13.07.2016. On both days black stork flights were recorded in the area of the Auf der Haid wind farm. One pair was seen flying at rotor height on 12.04.2016 at 15:15 hrs; another flight by a single bird was recorded on 13.07.2016 at 10:20 hrs at a height of up to twice the tree height and thus below the critical area for collisions.

The data show that NABU-Hessen recorded similar flight observations to the flight movement documented on 20.06.2016 (FlightID 91, see 4.9). At that date however the birds flew straight over the wind farm at an altitude of approximately 250 m.

Auf der Haid wind farm, key data

Manufacturer	Enercon GmbH
Installation type	E-101
Nominal capacity in MW	3
Overall height	186 m
Hub height	135 m
Rotor diameter	101 m
Height of rotor tip above ground level	50.5 m
No. of WTs	4

Table 50: Overview of weather data at time of flight movements in danger zone

Date	**12.04.2016**	**13.07.2016**
Time of day	15:15	10:20
Flight altitude category	3	0, 1
Alignment of rotor blades relative to the bird's direction of flight	perpendicular	parallel
Wind direction	S	WNW
Wind speed in m/s	2.9	3.2
Rotor tip speed	102	116
Visibility in km	26	38
Precipitation	0	0
Temperature in degrees	13	17
Sunshine duration / observation interval in minutes	10	3
Conflict situation	conflictual	little conflict
Behaviour	Flying through* the wind farm	Flying through the wind farm

*No evidence of traversing the rotor-swept zone

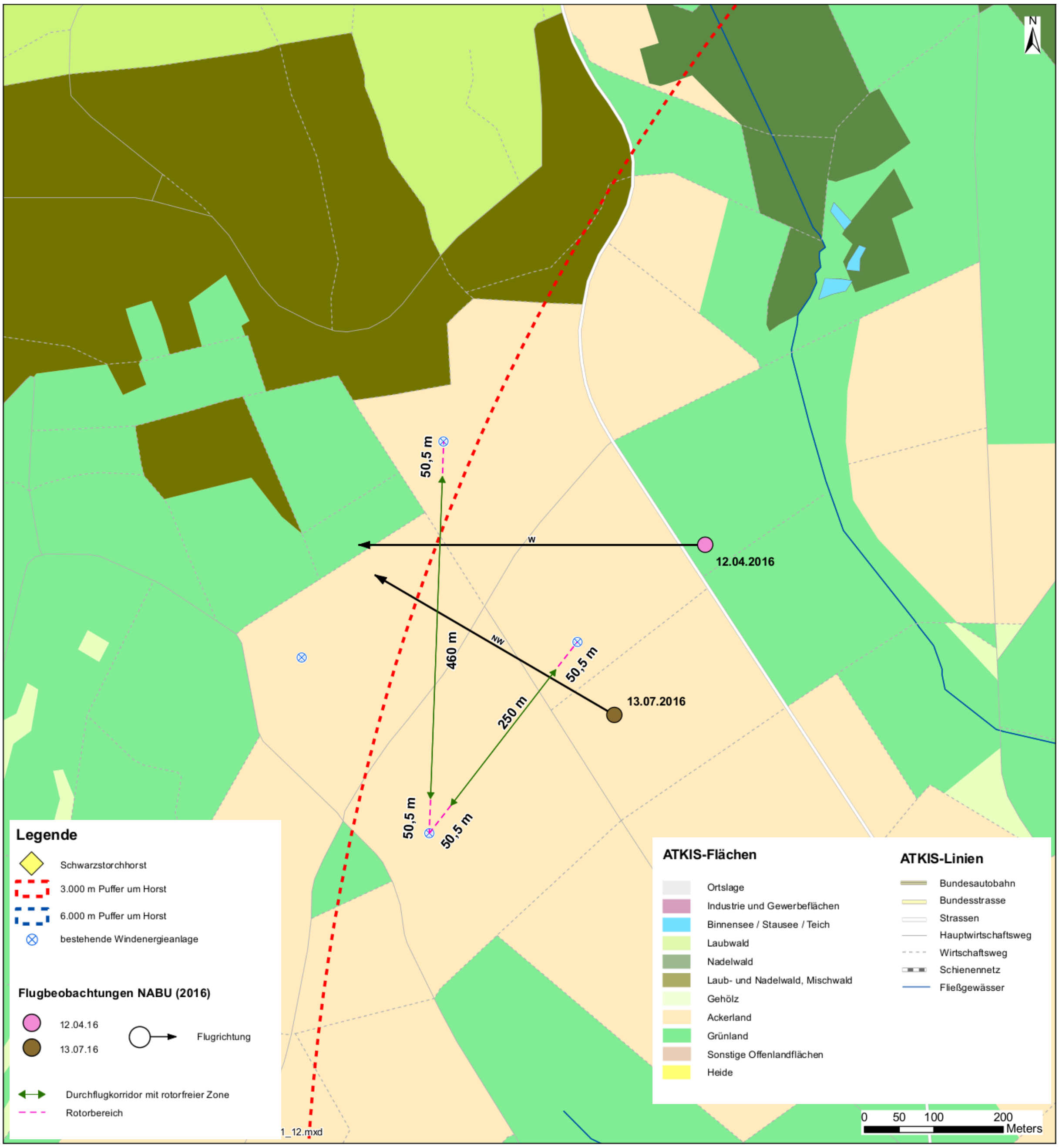

Figure 93: Black stork flights in the danger zone, data by NABU-Hessen 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key
	(otherwise as in previous maps)
Flugbeobachtungen…	Flight observations NABU 2016
Flugrichtung	Direction of flight
Durchflug…	Passage corridor with rotor-free zone
Rotorbereich	Rotor area
ATKIS Flächen	**ATKIS spatial objects**
Ortslage	Built-up area
Industrie…	Industrial, commercial area
Binnen…	Lake, reservoir, pond
Laub…	Deciduous forest
Nadel…	Coniferous forest
Laub- und Nadel…	Deciduous and coniferous forests, mixed forest
Gehölz	Copse
Ackerland	Arable land

Grünland	Grassland
Heide	Heathland
ATKIS Linien	**ATKIS linear objects**
Bundesautobahn	Federal motorway
Bundesstrasse	Federal road
Strassen	Roads
Haupt…	Rural hard-surface roads
Wirtschafts…	Rural tracks
Schienennetz	Rail network
Fliessgew…	Watercourses

Flight movement on 12.04.2016: Mr. Sommerhage (written communication, 8 March 2017) describes the passage through the wind farm by two individuals on 12.04.2016 at 15:15 hrs as a swift and straight paired flight at nacelle height between the WTs in a westerly direction. The WTs are aligned in parallel at a distance of approximately 560 m between the turbine bases. After deduction of the rotor length, a rotor-free zone of approximately 460 m remains as a corridor for passage between turbines.

Flight movements on 13.07.2016: Mr. Sommerhage (written communication, 8 March 2017) describes the passage through the wind farm on 13.07.2016 at 10:20 hrs as a swift and straight flight at a height of at most twice the tree height, and therefore below the critical area for collisions, in a north-westerly direction. The WTs are aligned in parallel at a distance of approximately 350 m between the turbine bases. After deduction of the rotor length, a rotor-free zone of approximately 250 m remains as a corridor for passage between turbines.

<u>Conclusions:</u>

The data analysed provide indications on the utilisation of feeding habitats included in the present study.

Moreover, the records on flight movements show that passages through wind farms are possible and are being undertaken. However, in the cases examined the birds were observed to only traverse wind farms under conditions of low winds and optimum visibility.

5.7 Findings of the additional studies and comparison with the present study

Findings with regard to activity, distance flown

This section will compare the findings of the present study to those of the additional studies. Flight activity varies between 0.32 and 2.4 flights per survey unit (8 hrs). The findings of the present study therefore rank in the mid-range. With respect to the average distance flown, the present study has the highest value compared to the other studies which allowed for distances to be analysed. This can be explained by the fact that a high proportion (67%) of the distance flown was recorded during thermaling. With respect to phenology, the comparison with the other studies confirms the month of May as the period of greatest activity; key periods of activity have however also been recorded in April, June and July–August.

Table 51: Comparison of studies regarding activity, distance flown

Studies of wind farms	Time in h	Total number of flights	Activity Flights/h	Activity Survey unit (8 hrs)	Distance flown in m	∅ Distance flown in m	Phenology Highest activity
Freiensteinau	640	121	0.19	1.52	904,416	7,475	May
Alpenrod	308	88	0.29	2.32	392,782	4,463	May
Hintersteinau	344	66	0.19	1.52	211,535	3,205	April
Rabenau	166	50	0.30	2.40	-	-	May
Moskau-Kreuzstein	563	128	0.23	1.84	362,134	2,829	July to August
Wohnste	936	39	0.04	0.32	-	-	June
Overall result	2.957	492	0.17	1.36	1,870,867	4,642	-

Findings with regard to critical and conflictual flights

With regard to the proportion of critical flights in the danger zone, the findings of the present study are comparable to those of the Alpenrod study. In the other studies the proportion of critical flights is lower.

Combining the findings of all analysed black stork studies conducted near to nest sites at the various wind farms, i.e. Freiensteinau, Alpenrod, Hintersteinau, Rabenau and Wohnste, out of a total of 406 flights there were a total of 27 critical flights (6.7%) in the installations' danger zone (horizontal view). Out of these 27 critical flights, 12 flights must be considered conflictual as they took place at a critical flight altitude at the installations' rotor height (vertical view). Therefore approximately 45% of the critical flights (or 3% of total flights) were conflictual.

Table 52: Critical flights in the danger zone (horizontal and vertical view)

Studies of wind farms	Total number of flights	Number of flights in danger zone** Critical flights	Number of conflictual flights*** at rotor height	Proportion of critical flights (conflictual flights) in %	Behaviour**** (horizontal)
Freiensteinau, own data	121	10	5	8.3 (4.1)	Flying around wind farm on its periphery, slight change in direction
Freiensteinau,* NABU-Hessen data	20	3	2	-*	Traversing the wind farm, sufficiently wide corridor
Alpenrod (spatial behaviour analysis + monitoring)	105	8	4	7.6 (3.8)	Flying around wind farm on its periphery, approaching to 100–150m distance
Hintersteinau	66	2	0	3.0	Overflight
Rabenau	50	3	1	6.0 (2.0)	Approach > 250–300 m
Wohnste	44	1	0	2.3	-
Totals	406	27	12	6.7 (3.0)	

*Random observation, thus not suited to yielding proportional value; **Danger zone: 250 m radius, horizontal view; ***vertical view; **** No evidence of traversing the rotor-swept zone

Findings with regard to altitudinal activity

Twenty-nine percent of the recorded flights were located at altitudes of between 80 and 190 m (rotor height, altitude category 3), i.e. the critical range for collisions with modern WTs. This was the highest proportionate value for flight movements across the five altitude categories. The analysed additional studies concerned with the Alpenrod, Moskau-Kreuzstein, and Wohnste wind farms also show that during the breeding period black storks regularly fly at the WTs' critical altitudes, with values ranging from 8 to 32% of the visually recorded flight movements.

Table 53: Comparison of the studies with respect to altitude categories

Study	Total	Below rotor	At rotor height	Above rotor	Others
Freiensteinau	303	109	88	43	63
Relative proportion	100%	36%	29%	14%	21%
Alpenrod	88	25	7	16	40
Relative proportion	100%	28%	8%	18%	46%
Hintersteinau	66	18	-	18	30
Relative proportion	100%	27%	-	27%	46%
Moskau-Kreuzstein	128	24	15	10	79
Relative proportion	100%	19%	12%	8%	62%
Wohnste	100%	57%	32%	11%	-
Relative proportion					

Findings with regard to the percentage shares of flight distances from the nest site

In the studies analysed, between 79 and 98% of distance flights from the nest site occurred within a range of 3000 m (cf. Table 54). Between 2 and 21% of flights covered greater distances of up to 6000 m from the nest site.

Table 54: Comparison of percentage shares of flight distances from the nest site

Study	Up to 1000 m (1)	Up to 3000 m (2)	Up to 6000 m (3)	Sum of columns (1) + (2)
Freiensteinau	50%	42%	8%	92%
Alpenrod	40%	39%	21%	79%
Hintersteinau	38%	50%	12%	88%
Moskau-Kreuzstein	25%	73%	2%	98%

6 Discussion

Black stork breeding success

Based on multi-annual studies, it is reasonable to assume that there are at least three constantly occupied black stork territories or breeding pairs in the present study area and its surroundings. All three black stork pairs were successful in their breeding efforts in 2016. With a total of eight offspring (2.7 juveniles per territory) the 2016 breeding success can be considered favourable (Janssen et al. 2004).

The Atzenstein nest site has been occupied by a black stork breeding pair for several years and has produced successful hatches despite its proximity to the Hallo and Auf der Haid wind farms (appr. 1.3 km to the nearest wind turbine). The activity radius of the other two successful breeding pairs similarly includes different wind farms (see Table 55).

The other studies also identified successful black stork hatches in spatial proximity to wind turbines (WTs) in recent years. The situation at the Rabenau wind farm is comparable to the present study, as black storks already bred in the area prior to wind farm construction and continued to do so following the wind farms' construction and commissioning. Since the Rabenau wind farm became operational in 2015, one successful hatch each was recorded in 2015 and 2016 at a distance of approximately 1.2 km to the nearest WT (cf. Table 55).

At a distance of 550 m, the black stork nest site at the Alpenrod wind farm is the one located closest to a WT among the various situations studied. The breeding pair produced successful hatches here in 2015 (BÖFA 2015, FEHR 2015) and 2016 (pers. comm. Joachim Kuchinke 2016).

Table 55: Positive breeding success in relation to existing wind turbines

Project	Distance between closest wind farm and black stork nest site studied (m)	Nest site	Recorded breeding success (year, source)
Alpenrod wind farm	550	Langenbaum	2015 (FEHR 2015) 2016 (pers. comm. J. Kuchinke 2016)
Rabenau wind farm	1200	Windkopf	2016 (WEISE 2016a)
Present study of the Hallo and Auf der Haid wind farms	1300	Atzenstein	2015 (written comm. M. Hormann 2016) 2016 (written comm. M. Hormann 2016)
	6600	Buchenrod	2016 (written comm. M. Hormann 2016)
	5600	Sarrod	2015 (written comm. M. Hormann 2016) 2016 (written comm. M. Hormann 2016)

The abandonment of the Holmenstein nest site in 2014 was probably due to regular human disturbance (see 4.1). The singular recorded disturbance by forestry activities at a distance of approximately 150–200 m from the Atzenstein nest site in 2016 (on 02.06.2016) did not result in nest abandonment. It is not feasible to ascertain here at the Atzenstein the degree to which disturbances of this type impact on black stork breeding success. It is however reasonable to assume that disturbance, especially by humans, is a prime factor when it comes to impaired breeding success, as stated by STRAZDS (1995) for Latvia. Similarly, the Hesse black stork species action plan lists human disturbance, especially at the nest site, as a major risk factor (VSW 2012).

At the Wohnste wind farm, an instance of human disturbance prompted the resident black stork pair to change its nest site (PLANUNGSGRUPPE GRÜN 2006b).

At the Rabenau wind farm, the disturbances in 2017 resulting from forestry activities in the immediate vicinity of the nest during the period of nest-site establishment were so significant that breeding efforts were abandoned (pers. comm. Hormann 31.03.2017).

LANGGEMACH & DÜRR (2017) suggest that a black stork pair's breeding failure near Steffenshagen (Prignitz district) may be due to its location at a distance of 1.7 km to a WT. The authors also note that all the hatchlings may have starved to death due to losses of adult birds during the rearing period. However, no detailed records are available.

The data relating to the black stork nest site investigated in the present study as well as the data contained in the other black stork studies considered here (see Chapter 5) show that successful black stork hatches have been recorded in comparable areas and in closer proximity to WTs (≥ 550 m, see Table 55).

ROHDE & GEHLHAR (2011) also studied a number of black stork hatches in spatial proximity to WTs in Mecklenburg-Western Pomerania (2 breeding pairs < 3000 m, 2 breeding pairs 3000–5000 m, 4 breeding pairs 5000–7000 m and 5 breeding pairs at a distance of between 7000 m and 10,000 m to the nearest WT). They were unable to make a connection between breeding failure and proximity to WTs. For many of the black stork territories (a total of 23) the authors name human disturbance at the nest site, e.g. from timber extraction or hunting, as the main shortcoming when it comes to protecting these territories.

The designation of nest protection zones could protect nest sites from the disturbances mentioned above; such zones are proposed in the black stork species action plan for Hesse and are specified in the 2012 conservation guidelines and the 2008 management guidelines for state forests in Hesse (*Naturschutzleitlinie für den Hessischen Staatswald 2012/ Hessische Waldbaufibel 2008*). It would be prudent to halt any silvicultural measures in a 100 m radius around the nest site in order to both avoid disturbances and maintain old-growth trees (see also the proposals in GARNIEL 2014).

Legal protection could also be afforded by designating forest nature reserves (*Schutzwald* pursuant to Article 12 of the Federal Forestry Act *BWaldG*) or by means of legal provisions in state forestry legislation or in state laws implementing the Federal Nature Conservation Act such as that in force in Mecklenburg-Western Pomerania (e.g. Art. 23(4) NatSchAG M-V).

In addition to disturbance by humans there are other issues that can adversely impact on nest sites, such as increasing stand density in the immediate vicinity of the nest (VSW 2012). The nest site at the Atzenstein for example is rather unfavourable given the strong undergrowth of ash and young beech trees. The undergrowth makes it very difficult for the juvenile black storks to find some open ground in the immediate vicinity of the nest where they can undertake their first practice flights and foraging attempts while being safe from predators. This is an area where it would be feasible to enhance the nest site by removing young undergrowth (VSW 2012). An alternative would be the construction of a new nest platform in the neighbouring beech wood section with a view to safeguarding the black stork pair's breeding success.

Phenology of activity, spatial behaviour, and distances covered

As part of the present study a total of 0.19 flights per hour of observation or 1.52 flights per recording unit (8 hours) were recorded (121 plausible flights, two observers, cf. Table 51). In general, the probability of observing black stork flights increases with a focus on periods of particularly high flight activity (see Table in Appendix, Figure 104), on favourable weather conditions (no precipitation, no fog) and on observation points that are suited to the study area's topography.

For the other studies analysed here, the flights per hour similarly vary between 0.04 and 0.3 while the flights per recording unit (8 hours) vary from 0.32 to 2.4. At 0.3 flights per hour, the highest activity in terms of flight movements was recorded as part of the spatial behaviour analysis at Rabenau. The spatial behaviour analysis at Moskau-Kreuzstein recorded 128 flights by the resident black stork pair, which equates to 0.23 flights per hour. The investigations at the Wohnste wind farm recorded as little as 39 flight movements in 935.5 hours (0.04 flights per hour). The very low number of recorded flight movements at Wohnste is very likely due to the poor visibility in the area (lowlands). Moreover, according to the authors the black storks at Wohnste regularly fly at a very low altitude as optimal feeding habitats are located in the immediate vicinity of the nest site.

The spatial behaviour analyses for the Alpenrod and Hintersteinau wind farms recorded 88 flight movements (0.29 flights per hour) and 66 flights (0.19 flights per hour) respectively. These figures are congruent with the published figures for patterns of nest relief. According to the figures compiled in JANSSEN et al. (2004), values for nest relief during incubation vary from 2.5 to 9 hours during the incubation period. This would equate to 0.9 to 3.2 flights per recording unit (8 hours) or 0.1 to 0.4 flights per hour to the nest.

ROHDE 2016 notes that experts record up to 140 flights in 18 survey days (0.97 flights per hour and observation point or 7.8 flights per recording unit). While in the context of spatial behaviour surveys of successfully breeding black storks this would appear to be possible, it would not appear to be the norm.

A high number of flights per hour can more likely be recorded only during the nestling phase during which both partners need to transport great quantities of feed to the nest. The information by ROHDE (2016) for the expected figure of 90 to 110 flights in 18 survey days per observation point (0.63 to 0.76 flights or 5 to 6 flights per recording unit) to be recorded by contracted ecological consultancies would also appear to be unrealistic in light of the investigations conducted and analysed here.

Based on the studies analysed, therefore a figure of 0.17 black stork flights per hour is realistic for surveys generally involving two recorders working synchronously and 18 survey days at 8 hours survey time per recorder. This is equivalent to an average of approximately 1.4 flights per recording unit (cf. Table 51).

In the study area, the data analysis shows a focus of flight movements at 0.3 flights per hour in the month of May (see Table 17, Table 51). The additionally analysed studies at Rabenau and Alpenrod similarly show the highest activity in May. The highest activity of the black stork pair at the Atzenstein in 2015 was recorded as part of the Hintersteinau study in April. Generally the highest level of activity would be expected during the advanced nestling phase (June/July) as this phase can in individual cases involve up to 14 feedings per day by the two adult storks (JANSSEN et al. 2004). The highest recorded level during the advanced nestling phase was found as part of the Moskau-Kreuzstein and Wohnste studies, albeit not at such a high level of intensity.

The focus of flight movements during the incubation and nestling phase (April/May) can primarily be explained by the recording methodology. It is in this phase of activity that the striking courtship flights (SACKL 2000, JANSSEN et al. 2004, SÜDBECK et al. 2005) and the territorial and patrol flights take place (pers. comm. Lorgé 31.03.2017) which makes it easier for the black storks to be recorded.

The change in the activity range was also recorded during the 2016 survey of the Atzenstein black stork pair. In terms of flight distance covered, during the months of April and May there was a clear focus on the north of the study area. In the course of the season the focus changed to the southern part. This can be explained by the different preferences for feeding habitats. In the northern part of the study area ponds dominate which offer a higher food supply during spring as a result of the amphibian spawning period. In contrast, during the summer the storks more frequently visited the stream systems and floodplains (cf. Sections 4.6 and 4.11).

Overall, at 4650 ha (46.5 km^2) the activity range determined in Freiensteinau would appear to be relatively small. Figures in the literature range from approximately 100 to 150 km^2 for activity ranges determined by direct observation (FLADE 1994, SCHRÖDER & BURMEISTER 1974 cited in JANSSEN et al. 2004.).

However, the spatial use by the Atzenstein black stork pair as determined by the present study does not fully equate to the pair's range in the study area.

Three reasons account for this discrepancy. Firstly, due to the observation points' locations and the in part unfavourable topography certain flight movements from the nest site could not be viewed from all the locations. Secondly, the recording effort (in hours) was not evenly divided between the observation points. Thirdly, the observation points' locations were selected with a focus on flight movements in the vicinity of the WTs near to the nest site and on flight movements between the nest, WTs and feeding habitats.

As a result, some of the flight routes were initially underrepresented in the results (grid analysis), e.g. in the south-eastern part of the study area. For the grid analysis to take into consideration the issues set out above, a weighted grid was modelled that takes survey effort into account (see Map 1). Implausible flights had already been excluded prior to data analysis (Section 3.9). This allowed for the establishment, in an iterative manner, of a more complete picture of the black stork pair's spatial behaviour. However, particularly long-distance and high altitude flights are not included in the analysis, meaning that the survey methodology renders the perceived activity range smaller than the actual activity range.

The actual spatial behaviour by black storks can only be determined by means of telemetry which is onerous and involves direct disturbance of the birds. Earlier telemetry data are available from JIGUET & VILLARUBIAS (2004) who studied seven black stork pairs during the breeding period. The authors found that both non-breeders and breeders used an average of approximately 54,000 ha for food prospecting during this period. The territories varied in size from 16,832 ha (168.32 km^2) to 112,360 ha (1,123.60 km^2). The authors did however suspect that activity ranges were smaller when feeding habitats were available that offered ample food supplies.

ROHDE & GEHLHAR (2011) give similar sizes for essential feeding habitats as found in the Freiensteinau study (standing waters ≥120 ha plus watercourses ≥ 25 km in length) which must be safeguarded in order to ensure continuous territory occupancy by black storks in Mecklenburg-Western Pomerania.

In order to minimise inaccuracies within spatial behaviour analyses by means of direct observation, it is essential to conduct a detailed investigation of essential feeding habitats (ROHDE 2016), to carry out viewshed modelling, and to evenly implement the spatial behaviour analysis (number and location of observation points, uniform recording effort).

In the 2016 study, the flight axes ran towards the south, west, northwest, northeast and east. The north and southeast were hardly used for flight routes.

The south-eastern part of the study area was not well visible in 2016 due to the location of the observation points. For this reason the data of the Hintersteinau study (2015) were analysed as the location of its observation points differed and provided a better view of the south-eastern area. However, the Hintersteinau study found that only a small number of flight movements took place in this corridor.

In the studies analysed, distance flights from the nest comprise 79–98% of flights at distances of up to 3000 m (cf. Table 54). Between 2% and 21% of flights covered greater distances of up to 6000 m from the nest site. This distribution is comparable to that found by SACKL (1993), who determined that 76% of flights in Styria (Austria) took place within a 3000 m radius. The majority of flights take place within a 3000 m radius.

With regard to the average flight distance covered, the findings in the different studies vary from 2829 to 7475 m (see Table 51), giving a mean value of 4642 m for four analysed studies with a total of 403 recorded flights and a total of 1871 km of distance flown. These figures are quite congruent with the information given by ROHDE 2009, who found that 53% of the similarly visually recorded flights totalling 3420 km were between 3 and 7 km in length.

Land use and topography

With respect to black stork flights, no particular preference could be detected for any land-use type in Freiensteinau or in the other analysed studies. The distribution of flights above the different land-use types did not match the distribution of land use in the study area. At Freiensteinau, the different forest types were overflown significantly more frequently than arable land or grassland, even though open countryside constitutes a significantly higher proportion of land cover than forests.

In the analysed studies, flight movements were recorded above all the landscape elements contained in the black stock pairs' activity ranges, regardless of land-use configuration (different forest and open land-use types). The decisive factor was the land-use type in which the nest site and the utilised feeding habitats were located as well as the land-use types the birds had to fly over from the nest site to the feeding habitats. In the studies analysed, there was thus no discernible impact of land use on the spatial distribution of black stork flight activity.

Within the German low mountain landscapes, topography does not appear to influence black stork spatial behaviour. Areas at different altitudes – with or without WTs – were overflown in the same way. The highest WT as part of the Hallo wind farm is located at an altitude of 510–515 m a.s.l. A total of ten flight events above an altitude of 510–525 m a.s.l. were recorded in the entire study area, with the black stork nest site being located at an altitude of approximately 460 m a.s.l. In the study on the Alpenrod wind farm the nearest WTs are at an altitude of 480–485 m a.s.l. The resident black stork pair similarly undertook flights at this altitude and at higher altitudes of 500–505 m a.s.l.

Black storks generally do not avoid but overfly hilltop locations in German low mountain ranges. It is therefore reasonable to conclude that the areas containing wind farms are not avoided on account of their altitudinal location.

The black stork studies at Hintersteinau, Moskau-Kreuzstein and Rabenau indicated a slight trend towards watercourses. Especially floodplains that either serve as or lead to feeding habitats are visited in flight or utilised as flight corridors somewhat more frequently than other landscape elements. This may indicate that black storks use distinctive valleys for orientation and that valleys also more frequently serve as flight corridors – as long as they lead towards the birds' essential feeding habitats.

In the present study however the target location (e.g. the feeding habitat or nest) dictated the black storks' flight route.

Landscape elements have different thermal characteristics. Open areas that are impermeable to water, such as rocks, heat up more quickly in morning to midday, thus giving rise to thermal columns which can be utilised by the black storks. Dark landscape elements, such as forests, can provide favourable thermal conditions in the evening hours when these heat stores release their heat into the cooler environment. Different structures can thus be utilised at different points in time, e.g. for thermaling flight.

There also appears to be an element of seasonality when it comes to the utilisation of feeding habitats. The present study documented a shift in flights to feeding habitats from a use during springtime of the feeding habitats located to the north of the nest site (predominantly ponds) to a use in the summertime of the feeding habitats located to the south (semi-natural aquatic habitats and floodplains), e.g. the Ürzeller Wasser (feeding habitat No. 16). The greater abundance of amphibians in the feeding habitats located in the northern and north-western parts of the study area may explain the preference given to these areas during springtime (cf. Section 4.6).

Feeding habitat No. 11, which was classified as a preferred feeding habitat based on the findings by IBU 2012 in KARL (2012), is aligned north-south between the two existing wind farms.

The present study conducted in 2016 recorded one black stork flight movement (searching for food, 50–80 m) towards this feeding habitat as well as a random observation of a prospecting flight movement from 2015.

However, a field visit on 22.07.2016 showed that food availability was good and disturbance was low. In conclusion it can therefore be said that the importance of feeding habitats varies not only by season but also between years.

The flight route to feeding habitat No. 13 (wet meadows to the northeast of Salz) differs in its course. The birds here do not flight due west but choose a corridor along the periphery of the Auf der Haid wind farm or traverse the wind farm as the NABU data show. Similarly there is no evidence of straight-line flight axes above the Hallo wind farm.

The Obermoos and Reichlos ponds (feeding habitats No. 9 and No. 6 respectively) as part of the SAC 5522-304 "Vogelsbergteiche und Lüderaue bei Grebenhain" are located in the study area. Both of these ponds were used for fish production in past centuries and are characterised by extensive shallow riparian zones with aquatic vegetation, riparian reedbeds and perennial tall herb communities, tall sedge swarms and fish populations (e.g. Misgurnus) as well as the presence of a variety of amphibian species (common toad, common water frog, marsh frog, common frog, alpine newt, smooth newt). Both ponds are ideal feeding habitats for black storks, as confirmed by the 2016 study.

In conclusion it can be said that while valleys can serve as guides, flights take place above all landscape elements. In addition, it is important for black storks to have available a complex network of feeding habitats free of disturbances which can be utilised flexibly in the course of the year.

Flight altitude

In 2016, 16.2% of the recorded black stork flight movements were at flight altitudes of up to 50 m (altitude categories 0 and 1). A total of 29% of the recorded flights were in the 80–190 m category (rotor height, altitude category 3) which is a critical height for collisions with modern WTs. This percentage constituted the largest proportion of flight movements in the five altitude categories.

It should be noted in this context that altitude category 3 comprises a 90 m span in altitude while the lower altitude categories cover smaller spans. As a result, it was to be expected that a greater number of flight movements would be recorded in altitude category 3.

Moreover, given the topography and the presence of trees and shrubs it was not always possible to observe the black storks' flights close to the ground. It is therefore possible that flights in the higher altitude categories are overrepresented. However, a relatively high number of flight movements took place in the danger zone of modern wind turbines. The other analysed studies have also shown that during the breeding period black storks regularly fly through the danger zones of WTs. The proportion of flight movements recorded at critical altitudes range from 8% to 32% among the various studies (Table 53).

However, it should be noted in this regard that none of the studies was able to record the entirety of flight movements; the percentage figures therefore are approximate values. Only telemetry data including altitude data can provide comprehensive percentages of the total of flights. Nonetheless it is reasonable to assume that given their special flight behaviour black storks in their breeding areas regularly fly at critical altitudes of modern WTs.

The present study could not confirm the view by ROHDE 2009 who stated that flight altitudes are generally underestimated. Prior to calibration, the recorders rather overestimated the drones' flight altitudes (12.2%). Similarly, flight altitudes were overestimated (24%) in the PROGRESS study by GRÜNKORN et al. (2016).

Flight altitudes in breeding territories may depend on the distances to feeding habitats. According to JANSSEN et al. (2004), the black storks use spiralling upward flight and thermal soaring to cover average distances of between 1 and 8 km to their feeding habitats. GARNIEL (2014) similarly suspects "that the combination of thermaling flight and subsequent gliding (…) is particularly effective in low mountain landscapes (…) and is therefore frequently used" (translation from the German-language paper).

This hypothesis is further strengthened by the study by PLANUNGSGRUPPE GRÜN (2006b) which found that black storks primarily (57%) flew at altitudes of up to 65 m. This may be explained by the complex network of feeding habitats within the forest hosting the site, thus eliminating the need for high altitude distance flights.

A very high flight altitude at 1279 m a.s.l. as part of a migration of several hundred kilometres was recorded for the black stork Thibaut who had been fitted with a transmitter (satellite telemetry) (HEYNE 2013). RÖHL (2015) fitted three juvenile black storks with transmitters and recorded a median altitude during the autumn migration of 541.68 m, with a maximum altitude of 2529.2 m above the terrain, and generally long-distance movements.

However, these extreme altitudes appear to only be reached in the course of long-distance flights and therefore do not serve well as a comparison for flight distances and flight altitudes in the breeding territory.

The present study did not find that the distance flown (within a 6 km radius) had a direct influence on flight altitude. This supports the hypothesis by ROHDE (2009) that there are "no significant values that unambiguously point at a significant correlation between flight altitude and distance to the nest site up to a distance of 7 km" (translation from the German-language paper). However, for the values obtained as part of the present study it is not clear whether weather parameters are crucial in this respect, as described by ROHDE.

Impact of weather conditions on black stork flight altitude

ROHDE (2009) postulates that flight altitude is dependent on local weather conditions, naming the five parameters wind direction, wind speed, air currents, air temperature, and precipitation.

The present study could not infer a statistically supported model that would explain the probability of the occurrence of flights in the altitude category covering the rotor blades. Following a correlation assessment of the available weather parameters, the following parameters were used for further statistical analysis: wind speed, nacelle alignment (wind direction), visibility, temperature, sunshine duration, precipitation and air pressure. Further parameters were discarded due to their correlation with other parameters. However, in the course of statistical analysis it became apparent that sunshine duration was often statistically significant. Despite the unfavourable R-squared values of the respective underlying binomial Generalised Linear Models (GLM) this may point towards sunshine duration having a certain impact on black stork flight altitudes. Further more comprehensive studies, especially studies using telemetry data, could provide further insights in this respect.

In addition, only a single flight event was recorded during rainfall. This was a flight event recorded on 16.06.2016 at 14:42 hrs involving both the adult birds which were flying back to the nest carrying food from the stream at Stollmühle located at a distance of approximately 380 m from the nest site.

This may indicate that black storks avoid long distance flights in search of food during inclement weather. The black stork pair (both had full beaks on their way back to the nest site) flew at an altitude of between 5 and 10 m. Given the small sample, an impact of precipitation on black stork flight altitude cannot be directly inferred.

The literature contains descriptions of migrations by small birds where the birds wait out precipitation events and tend to rest rather than fly during rainy periods (GÄTKE 1900, RICHARDSON 1978, THIELEN & HÜPPOP 2010), thus – following biological principles – spending as little energy as possible. In contrast, breeding birds cannot wait out persistent periods of inclement weather as they need to feed their young. During precipitation events, black storks can rarely make use of updrafts or thermals in order to cover distances in passive flight. ROHDE (2009) assumes that in suddenly occurring inclement weather, such as rain or headwind, black storks fly lower than normal as they are surprised by the rain. Only telemetry data would provide relevant insights in this respect.

CORSO (2001) similarly describes that for birds of prey and storks the shortest and lowest-altitude flight paths have been recorded during cold and rainy weather.

According to ELKINS (2004), three factors play a decisive role in bird flight behaviour and in particular in flight altitude. The author first names convection. Solar insolation produces upcurrents of air, commonly termed thermals. Independent of solar insolation, however, birds can also utilise other parameters in order to gain altitude and fly with minimal expenditure of energy. Orography, the second factor, is significant in this regard. In low and high mountain areas, horizontal air currents encounter these mountains and are forced upwards. Turbulence is a third category of rising airflow. This type of airflow is generated in eddies when the airflow meets an obstacle such as, for example, a building.

Black storks can therefore gain altitude independent of thermals (rising air due to solar insolation) and glide over long distances with minimal expenditure of energy.

The fact that the present study could not infer a statistically supported model that would explain the flights at rotor height (category 3) may be explained by the small sample size of one breeding pair in one year, or it could mean that the parameters tested do not play a decisive role in breeding territories. Account must also be taken of the fact that the breakdown into flight altitude categories was based on the WTs in the local area. This breakdown of the airspace into different flight altitude ranges is not based on black stork behavioural biology demanding certain behavioural responses. It serves to classify flight events into units that lend themselves to analysis. The limitations of the survey methodology must also be taken into account in this regard.

In a more comprehensive study on buzzard and swift migrations, SHAMOUN-BARANES et al. (2006) were able to show that flight altitudes increase with a combination of increasing temperature, decreasing relative humidity, decreasing cloud cover, and increasing atmospheric instability. For migrating white storks (*Ciconia ciconia)* SHAMOUN-BARANES et al. (2003b) found a significant positive correlation between flight altitudes and thermal convection. Moreover, SHAMOUN-BARANES et al. (2003a) found that in addition to meteorological factors, maximum flight altitude is impacted by topography. Cloud cover, increasing rain duration and wind speed also appear to influence flight altitude and/or landing behaviour during adverse weather events in songbird migrations (THIELEN & HÜPPOP 2010). Weather parameters may play a more important role in black stork long-distance migrations than within food-rich breeding territories

In conclusion it can be said that thermals are highly likely to influence black stork flight altitudes. However, this is a conclusion that could not be drawn with certainty as part of the present study. Thermals probably play a role in flight altitude, in particular for very long-distance flights. Furthermore, it may reasonably be assumed that in inclement weather black storks fly at lower altitudes and primarily utilise feeding habitats in the vicinity of the nest site.

Flight behaviour in the vicinity of wind turbines

In the course of the present study conducted in 2016, on ten out of 121 flights (8.3%) black storks approached WTs to a degree that brought them into the danger zone (250 m radius around the WT; horizontal view). Of these, five flights were at a critical altitude in close proximity to the installations. Some individual flights were recorded in the area between the Hallo and Auf der Haid wind farms which, at their smallest distance, are located approximately 876 m apart. During one of the critical flights (FlightID 100) on 30.06.2016, a black stork that was circling along the forest edge approached three WTs at a critical flight altitude (90 m). At the time, the turbines were moving, the rotors were all aligned parallel to the direction of flight, winds were moderate and visibility was optimal. During a further critical flight recorded on 18.07.2016 (FlightID 125) a black stork flew around the perimeter of the Auf der Haid wind farm while slightly changing its flight direction. At the time, the turbines were moving, the rotors were all aligned perpendicular to the direction of flight, winds were low and visibility was optimal.

A similar situation was observed by Mr. Sommerhage (NABU) on 12.04.2016, also under conditions of low winds and optimum visibility, when a black stork pair utilised the 460 m wide, and apparently sufficiently wide, corridor between two installations. During this conflictual flight by the black stork pair the rotors were aligned perpendicular to the birds' flight path. On 13.07.2016 Mr. Sommerhage also observed a black stork traversing the wind farm in low-altitude flight under favourable weather conditions. At the time, the rotors were aligned parallel to the bird's flight path.

These findings show that conflictual flights only occurred under favourable weather conditions, with rotors aligned either parallel or perpendicular to the direction of flight. The black storks flew around the installations on their perimeter or traversed the wind farms if a sufficiently wide corridor was available. It appears therefore that the black storks studied were able to recognise the installations as obstacles, allowing them to fly around them, provided there was good visibility.

There were no observations of flights in the danger zone in the immediate vicinity of the rotors (i.e. outside of free corridors between the individual installations).

The number of flights recorded in the danger zone of the installations as part of the Alpenrod wind farm study was in the same order of magnitude as that recorded in Freiensteinau. Out of a total of 88 flights, six flights (6.8%) took place in the danger zone (BÖFA 2015). Two out of these six flights must be categorised as conflictual. Again, these flights took place under relatively favourable weather conditions (low wind speeds, good visibility and no precipitation).

The random sample monitoring of the same wind farm showed two out of 17 flights (11.7%) in the critical zone (250 m radius) of the installations (FEHR 2015). This figure must however be interpreted with caution as it is based on a small sample. Given that the monitoring surveys refer to the same year and the same location, the flight movements can be considered together: Out of a total of 105 recorded flights, eight (7.6%) took place in the turbines' danger zone.

A more or less similar picture emerges from the studies at the Rabenau wind farm (WEISE 2016a). Out of a total of 50 flight movements, three flight movements (6%) brought the birds into the installations' danger zone. During one of the flights in May 2016 it was clearly evident that the black stork in question changed its course at a distance of 250 to 300 m from the installations so as not to enter the wind farm.

The published risk index, according to which 27.3% of flights occur at a critical distance to WTs (LEKUONA & URSUA 2007, LEKUONA & URSUA), could not be confirmed by the present study, also taking into account the review of other studies.

The overflight of an 85 m high WT by a satellite-tracked juvenile stork during the autumn migration (21 August) in the Upper Palatinate did not lead to a hazardous situation. At its closest proximity, the bird was 323 metres away from the installations. Further approaches by the same bird to a 135 m high WT came as close as 369 m and 579 m respectively (RÖHL 2015).

Looking at the combined results of the reviewed studies on black storks breeding near wind farms at Freiensteinau, Alpenrod, Hintersteinau, Rabenau and Wohnste respectively, a total of 6.7% (horizontal view) or 3% (additional vertical view) of flights were observed in the turbines' danger zone. These figures are significantly lower than the calculations presented earlier, representing only ¼ or 1/10 respectively of the risk index based on the findings by LEKUONA & URSUA (2007) in Spain.

Overall, it can be seen that despite the in part only short distances between nest sites and the nearest wind turbine (550 m to 1300 m) only a very small proportion of total flights must be regarded as conflictual. In all those instances the storks managed to fly around the wind farms or fly through them if there was a sufficiently wide corridor; no collisions were observed. Moreover, none of the adult birds went missing in the course of the surveys, which means that there were no collisions during the study period.

Methodology

The methodology used in the present study for data acquisition, i.e. visual observation of black storks by two recorders working synchronously, offers multiple advantages: the methodology is easy to implement and can flexibly respond to potential changes. Moreover, the animals are not disturbed and no catches of adults or juveniles are necessary. Flight movements in the observer's field of view can continuously be recorded while additional important information is also recorded in parallel, such as behaviours.

The given viewsheds place limits on observations which are dependent on the location of the observation point selected, on topography, and on landscape elements such as trees and/or houses. Occasionally, it may happen that low altitude flights in forests, for example, or landings in feeding habitats are not always visible to the observer (cf. ROHDE (2009)). Flight altitude categories representing the flight altitudes near ground level, i.e. categories 0 (0–25 m) und 1 (25–50 m), as well as certain behaviours such as foraging or approaches and departures may therefore be under-represented (in turn over-representing other categories). Moreover, for visual observations the positional accuracy of flight movements is significantly worse than for analysed telemetry studies. Experiences as part of the present study have shown, for example, that with increasing distance from the observer circling flight movements are recorded with increasingly and significantly overestimated radii. Estimates of distances, including distances to WTs should therefore always be interpreted with caution (JANSSEN 1988).

Other methods, such as data collection using GPS tracking and telemetry, provide the bird's exact position in space at certain intervals; while this allows for observations over much larger areas it is not exact at the small-scale (MEYBURG & MEYBURG 2013). The latter depends on both the tracking interval and the transmitter equipment, both of which are constantly advancing. A five-minute tracking interval is recommended for high-resolution data. The different methods therefore offer different benefits and disadvantages.

As set out in the introduction, the aim of the present study was to investigate black stork flights in the immediate vicinity of wind turbines. The nest site had to be in spatial proximity to the WTs so as to ensure that a sufficiently high number of flight movements could be recorded and in order to allow for the best possible estimates to be made of the distances between flight events and WTs.

The methodology was selected accordingly, allowing for the issue at hand to be addressed. Moreover, it should be noted that these findings must not be generalised since they relate to a single black stork pair in a single year. Additional studies were analysed in order to gain a deeper understanding of the issue.

The present study at Freiensteinau in conjunction with the additional analysed studies may provide an initial indication of the ability of black storks to recognise and actively avoid wind turbines.

In order to deepen the analysis presented above further studies should be conducted (telemetry of birds breeding in proximity of WTs), especially studies utilising new GPS transmitters that collect altitude data. In addition, such data should be collected from multiple black stork individuals over multiple breeding periods.

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8 Appendix

8.1 Flight behaviour

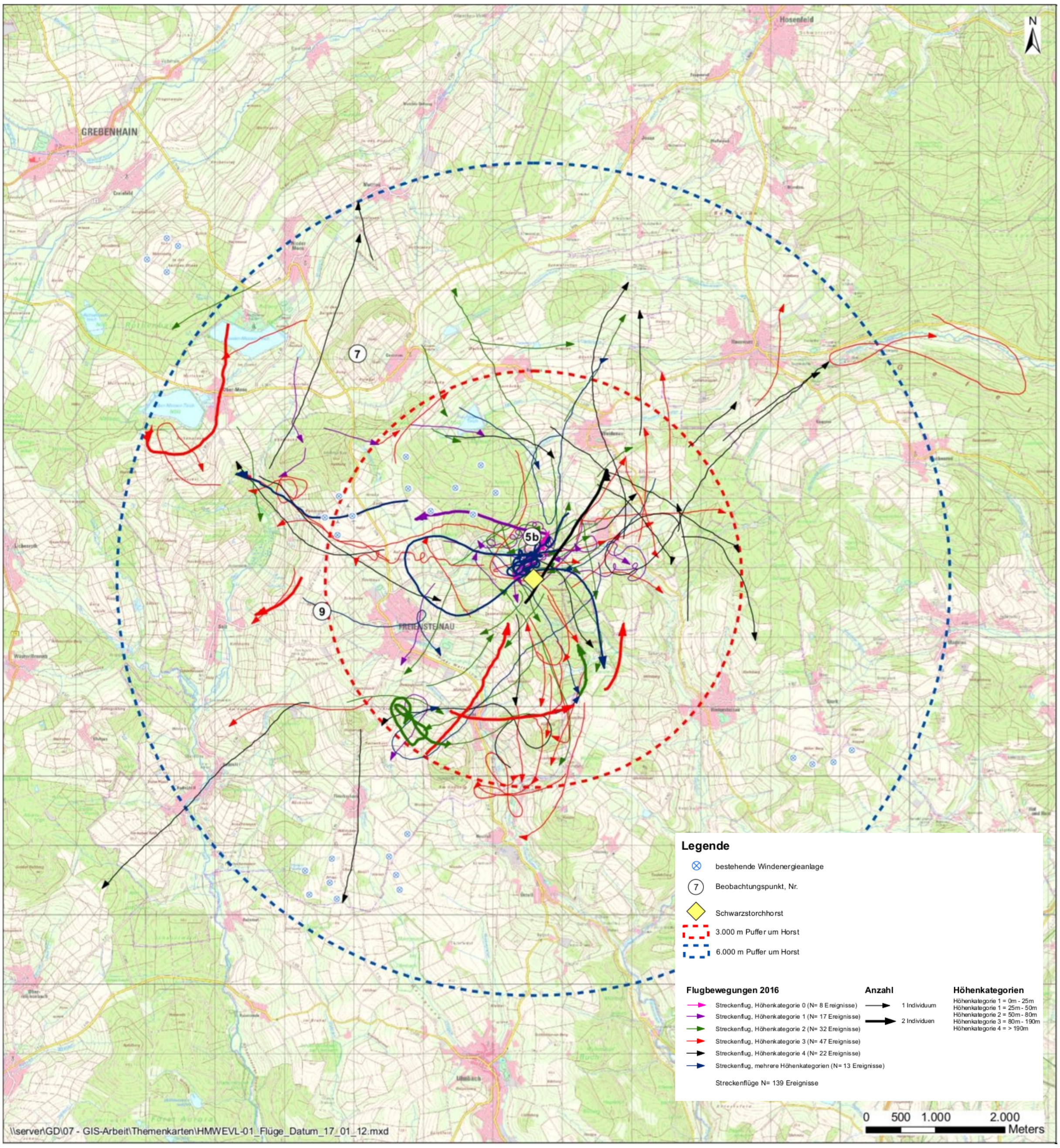

Figure 94: Flight behaviour distance flight (N=139/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key
	(otherwise as in previous maps)
Flugbewegungen 2016	**Flight movements in 2016**
Streckenflug, Höhenkategorie	Distance flight, altitude category
Streckenflug, mehrere Höhenkategorien	Distance flight, multiple altitude categories
Streckenflüge	Distance flights
Ereignisse	events
Anzahl	**Number**
Individuum	individual
Individuen	individuals
Höhenkategorien	**Altitude categories**
Höhenkategorie	Altitude category

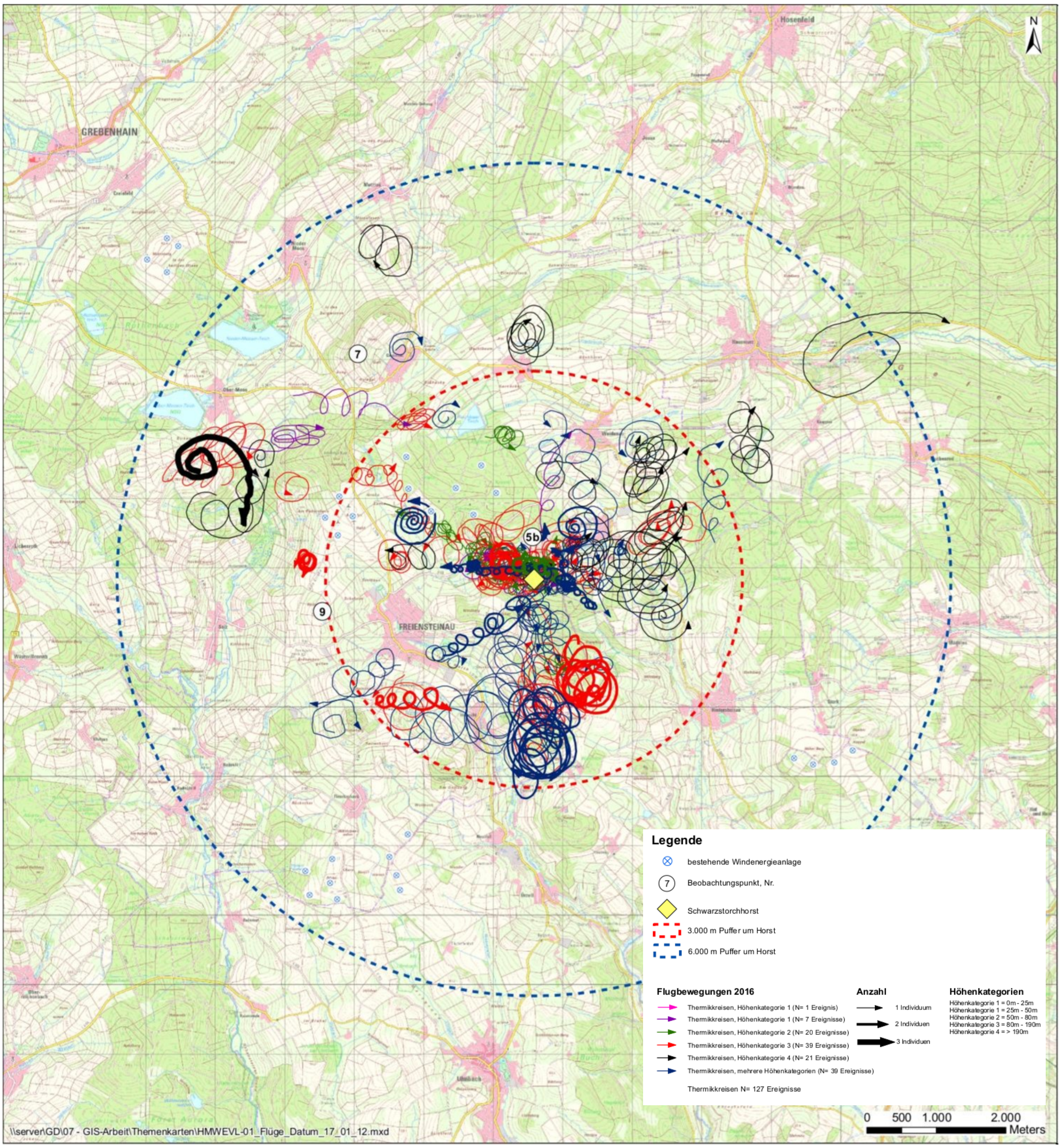

Figure 95: Flight behaviour thermaling flight (N=127/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

Thermikkreisen	Thermaling
	Key otherwise identical to Fig. 93

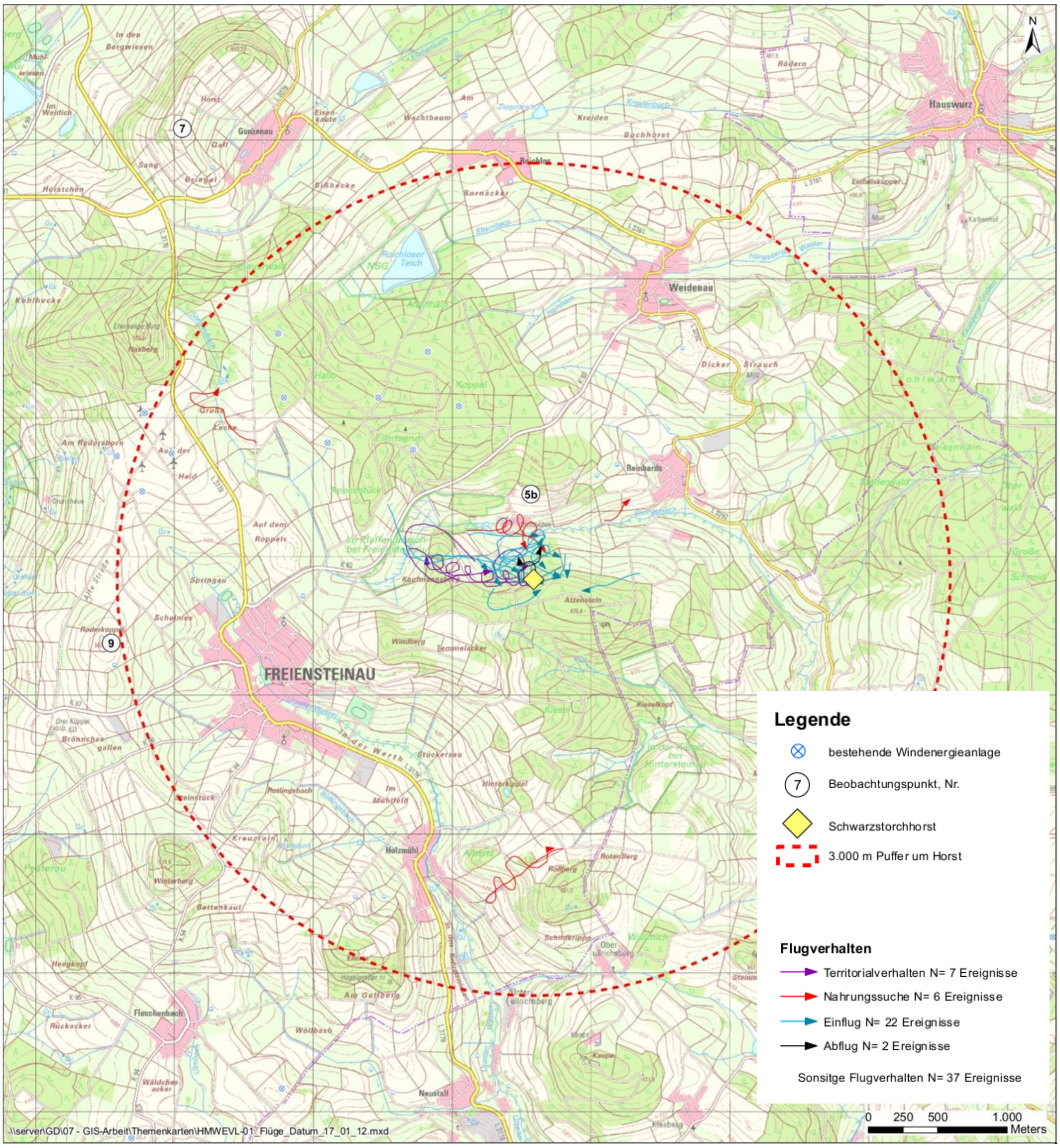

Figure 96: Other flight behaviour (N=37/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key
	(otherwise as in previous maps)
Territorialverhalten	Territorial behaviour
Nahrungssuche	Foraging
Ereignisse	events
Einflug	Approach
Abflug	Departure
Sonstige Flugverhalten	Other flight behaviour

8.2 Flight movements by observation point

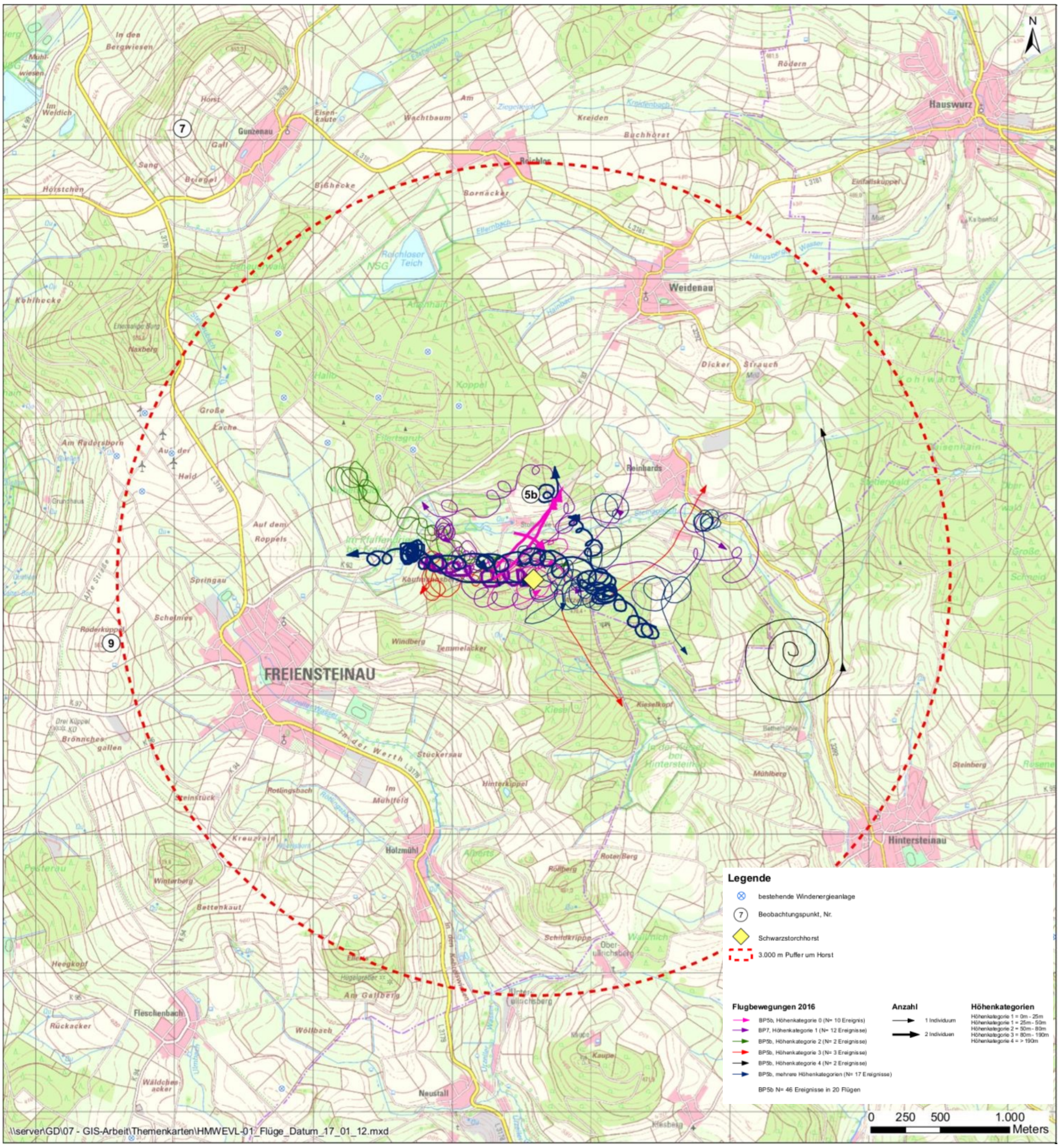

Figure 97: Flight movements recorded from observation point 5b (N= 46/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key
	(otherwise as in previous maps)
Flugbewegungen 2016	**Flight movements in 2016**
BP x	OP x
Höhenkategorie	altitude category
Ereignisse	events
mehrere Höhenkategorien	multiple altitude categories
BP 5b N=46 Ereignisse in 20 Flügen	OP 5b N=46 events as part of 20 flights
Anzahl	**Number**
Individuum	individual
Individuen	individuals
Höhenkategorien	**Altitude categories**
Höhenkategorie	Altitude category

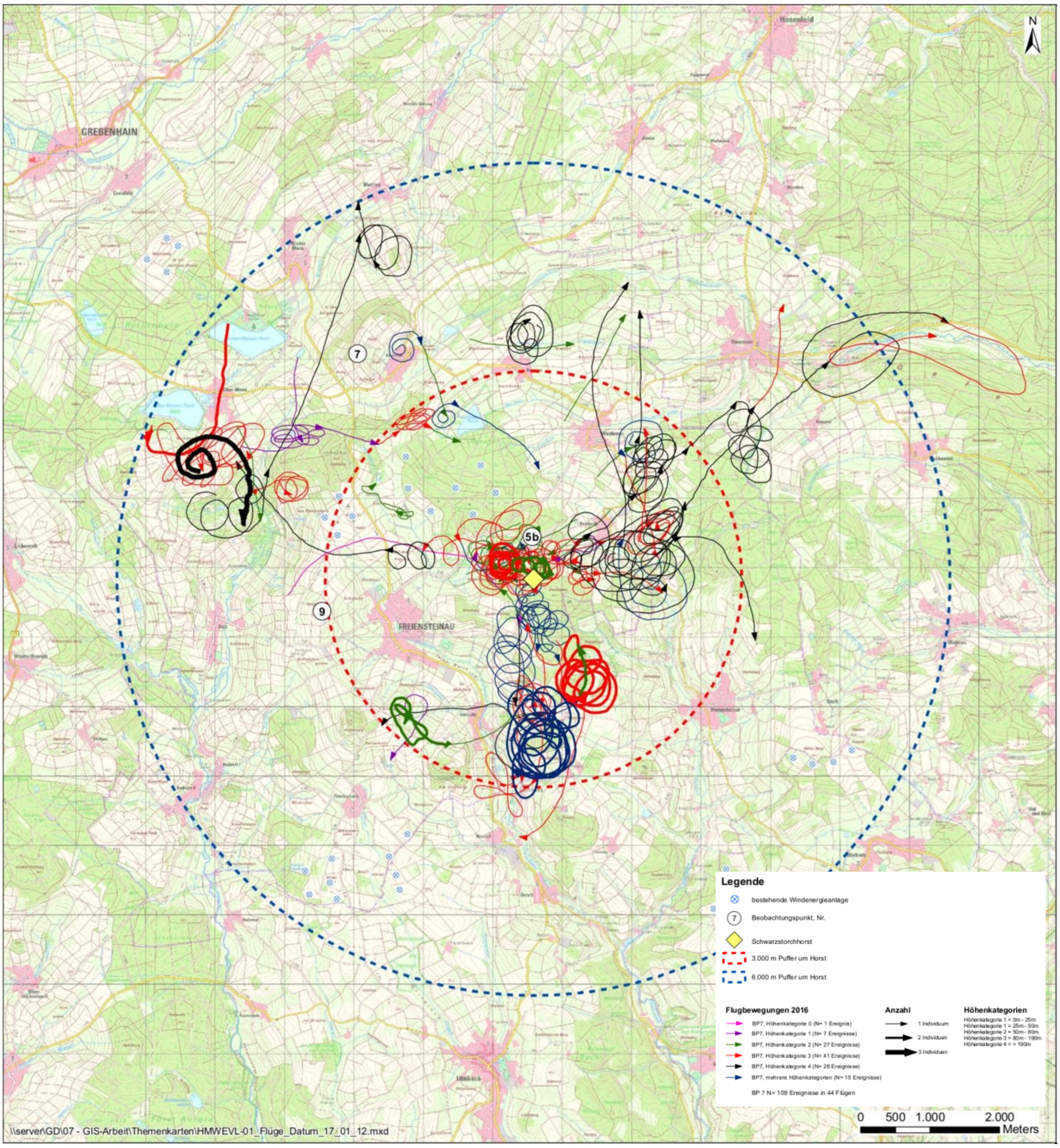

Figure 98: Flight movements recorded from observation point 7 (N= 109/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key as in Fig. 96 (except for N values)
BP 7 N=109 Ereignisse in 44 Flügen	OP 7 N=109 events as part of 44 flights

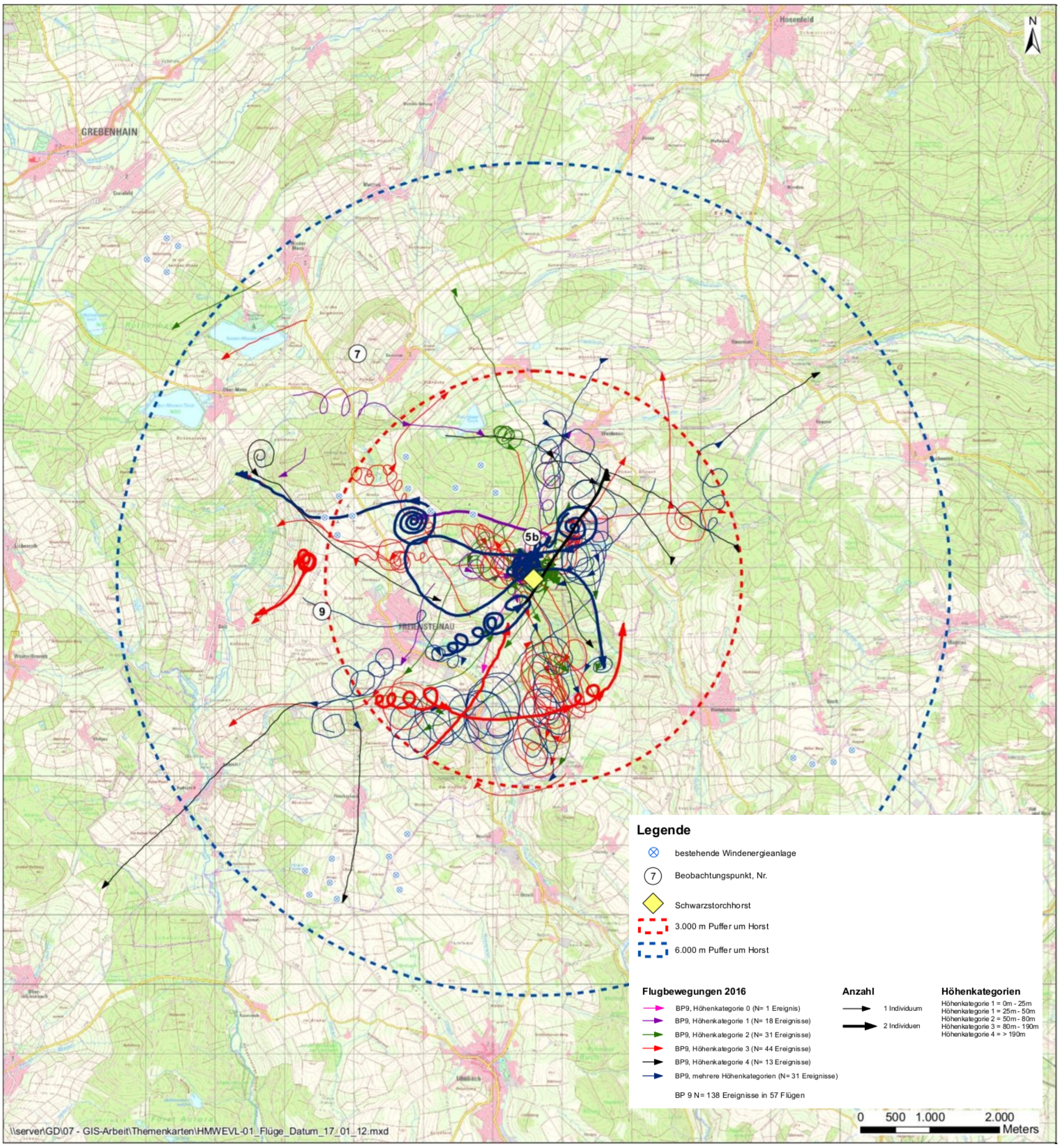

Figure 99: Flight movements recorded from observation point 9 (N= 138/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key as in Fig. 96 (except for N values)
BP 9 N=138 Ereignisse in 57 Flügen	OP 9 N=138 events as part of 57 flights

8.3 Phenological distribution of flight movements

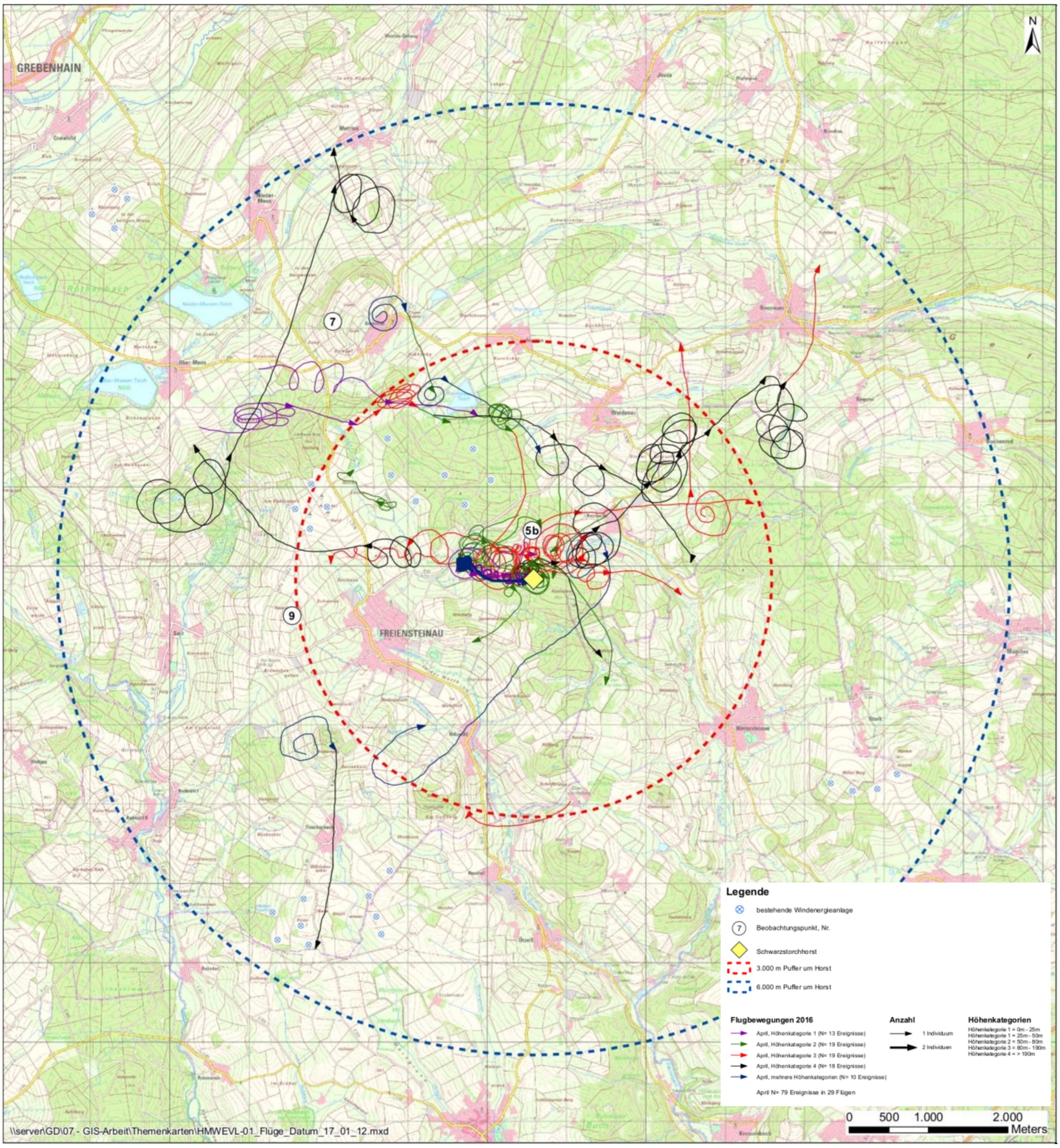

Figure 100: Flight events in the month of April (N=79/304) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key as in Fig. 96 (except for N values)
April N=79 Ereignisse in 29 Flügen	April N=79 events as part of 29 flights

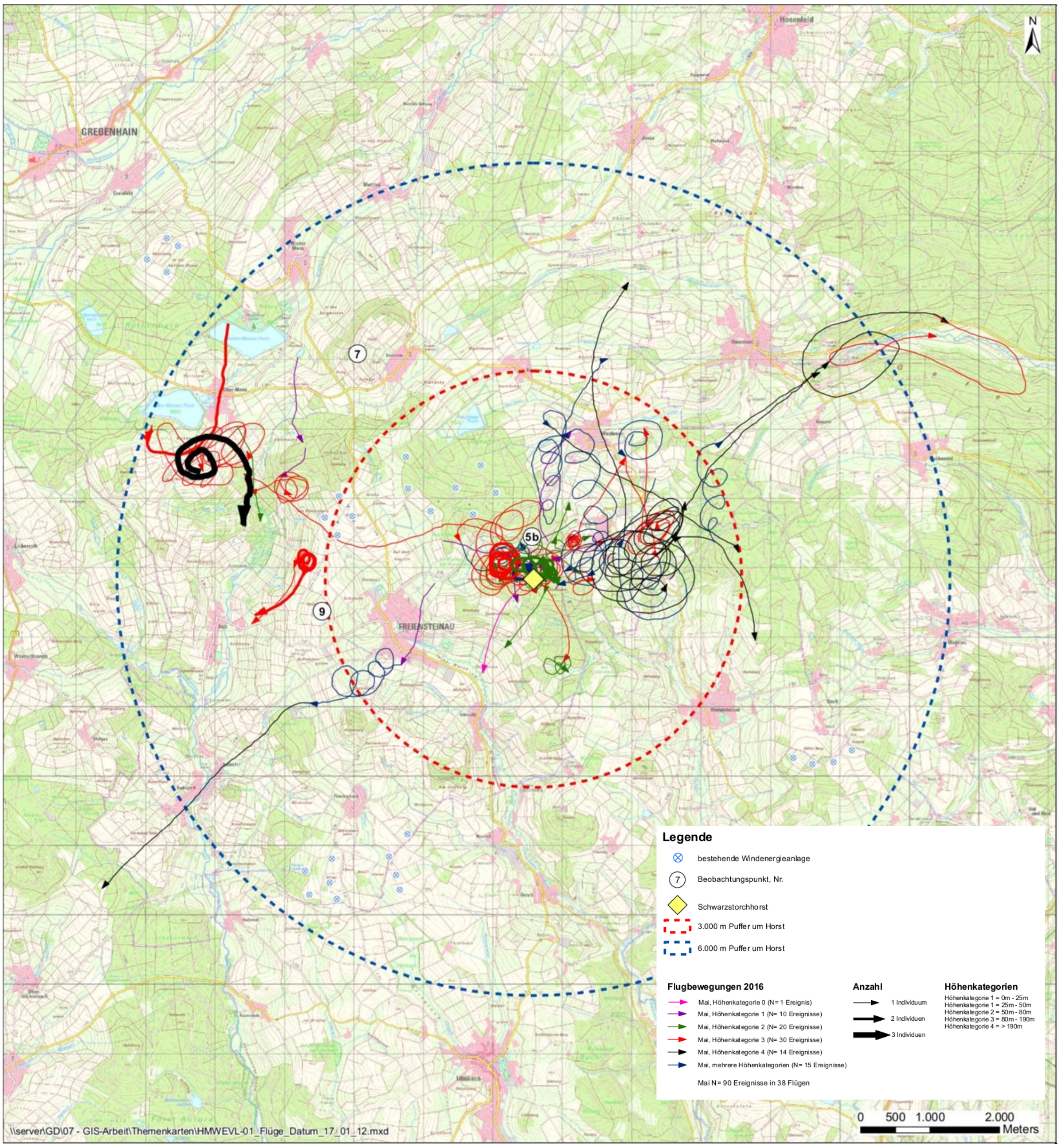

Figure 101: Flight events in the month of May (N=90/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key as in Fig. 96 (except for N values)
Mai	May
Mai N=90 Ereignisse in 38 Flügen	May N=90 events as part of 38 flights

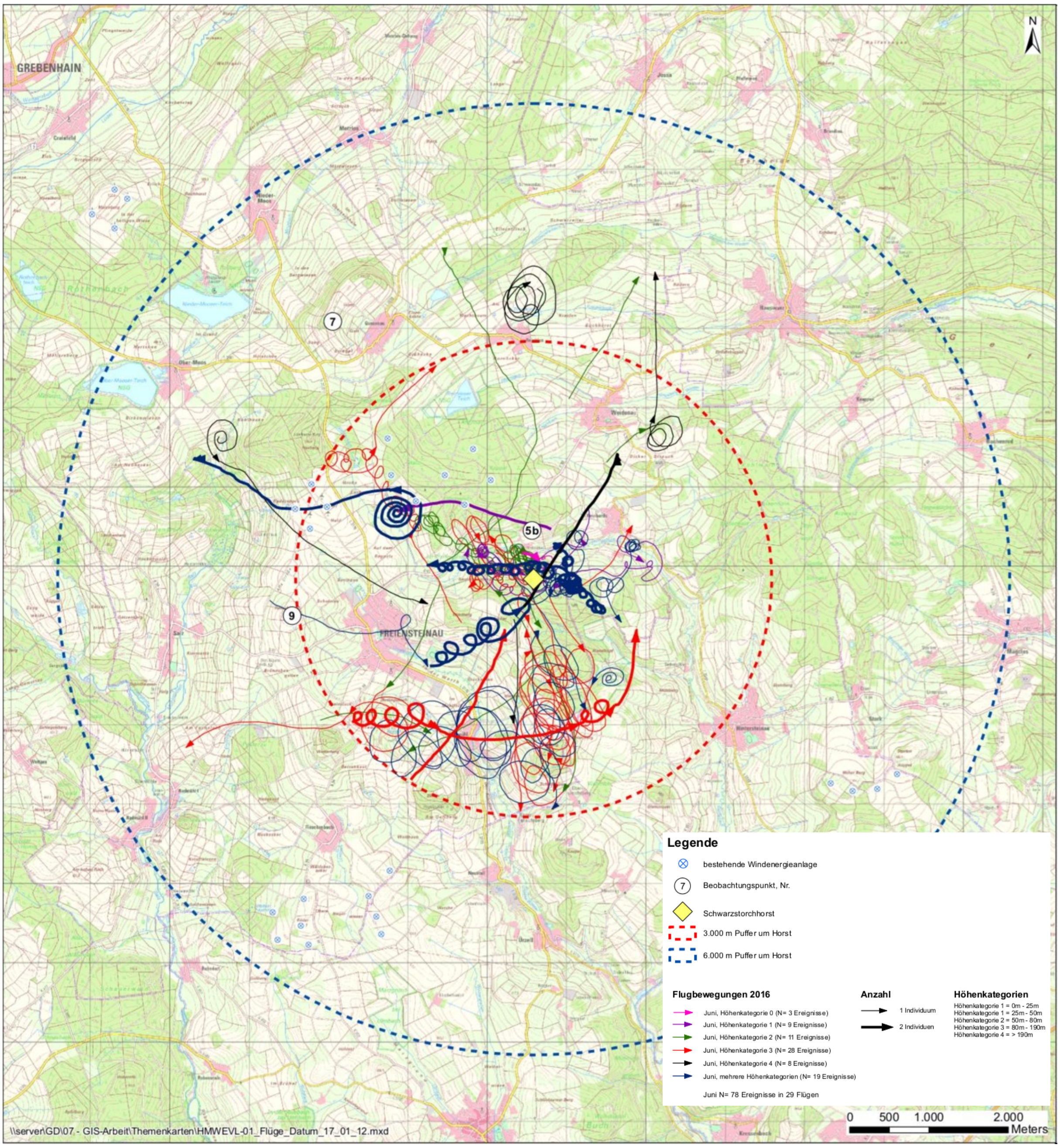

Figure 102: Flight events in the month of June (N=78/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key as in Fig. 96 (except for N values)
Juni	June
Juni N=78 Ereignisse in 29 Flügen	June N=78 events as part of 29 flights

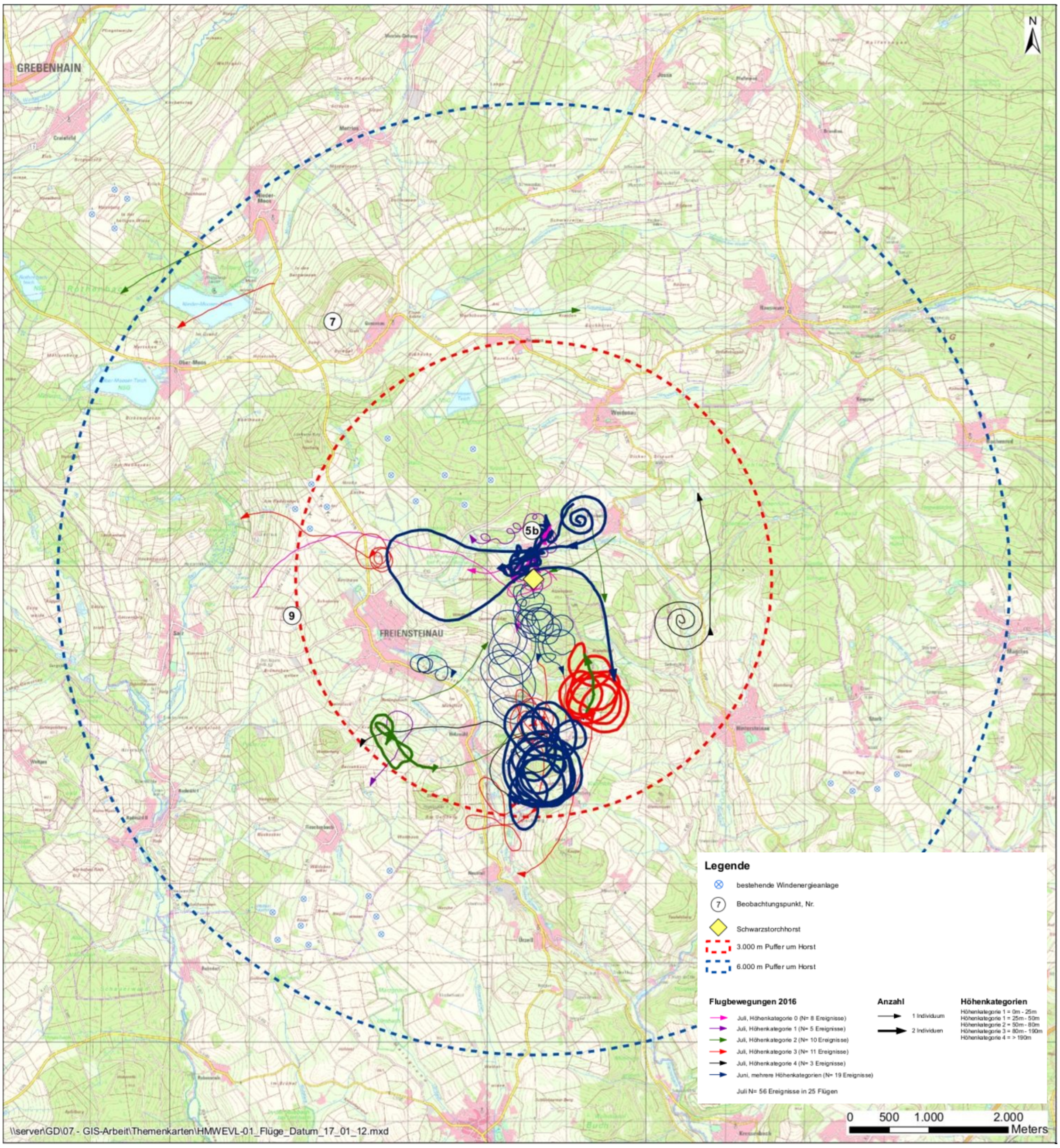

Figure 103: Flight events in the month of July (N=56/303) in Freiensteinau 2016 (Baseline map: Hessian Administration for Land Management and Geoinformation, HVBG)

	Map key as in Fig. 96 (except for N values)
Juli	July
Juli N=56 Ereignisse in 25 Flügen	July N=56 events as part of 25 flights

8.4 Activities by time of day

Analysis of activities (N=457) by time of day recorded as part of the studies at the Alpenrod, Hintersteinau and Freiensteinau wind farms.

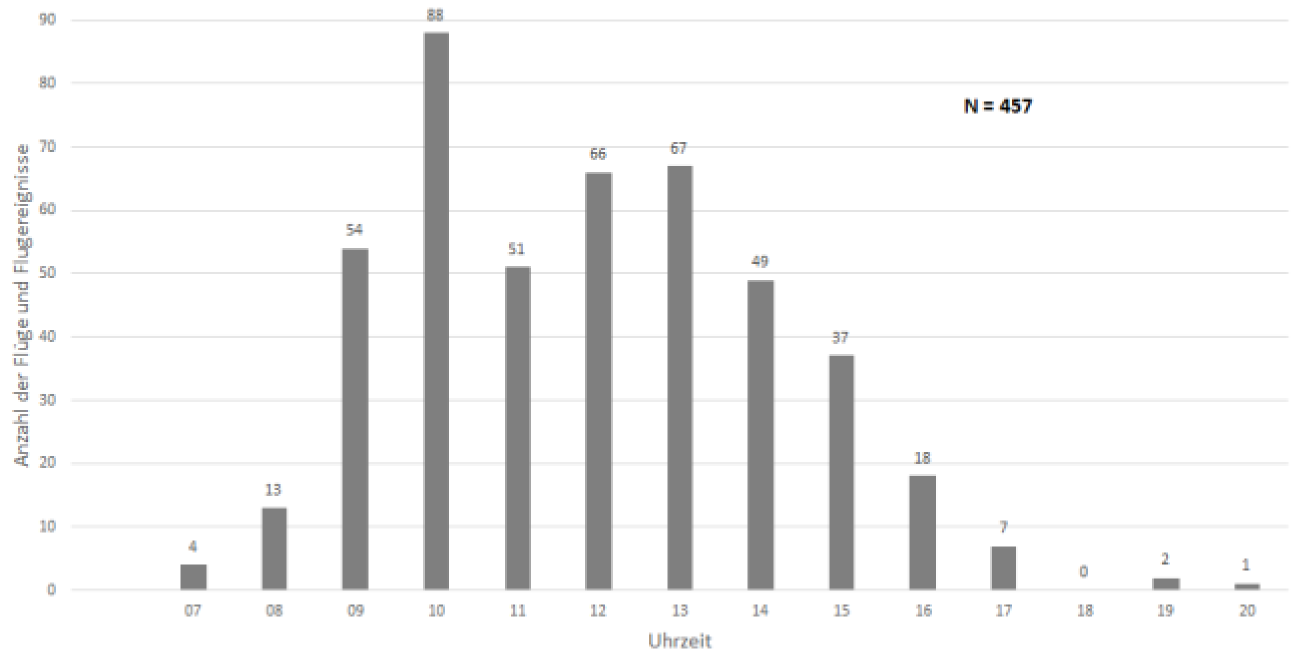

Figure 104: Black stork activity by time of day

Anzahl der Flüge …	Number of flights and flight events
Uhrzeit	Time