Arbeitsgruppe für regionale Struktur- und Umweltforschung GmbH

The Regional Planning and Environmental Research Group

How well does IdentiFlight protect the red kite *(Milvus milvus)?*

Studies on the effectiveness of a Camera system to protect against collisions Wind turbines

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List of abbreviations

BfN: Federal Agency for Nature Conservation

ER: Acquisition rate

Hmax: Height of the outer spacer cylinder

Hmin: Height of the inner spacer cylinder

HLmax: Lower limit of the outer spacer cylinder

HLmin: Lower limit of the inner spacer cylinder

HUmax: Upper limit of the outer spacer cylinder

HUmin: Upper limit of the inner distance cylinder

IDF: IdentiFlight

KNE: Competence Center for Nature Conservation and the Energy Transition

KR: classification rate

LRF: Laser Range Finder

RA: spatial coverage

Rmax: radius of the outer spacer cylinder

Rmin: radius of the inner spacer cylinder

RRA: Timing shutdown rate

SCADA: Supervisory Control and Data Acquisition - German: Monitoring, control and data acquisition. A control system which is used to control technical processes in wind farms.

sh: horizontal airspeed

sv-: vertical rate of descent

sv +: vertical rate of climb

TTC: Time To Collision Method (see index of technical terms)

UMK: Conference of Environment Ministers

WEA: wind turbine / s

ZA: Time coverage

Glossary of terms

Outer distance cylinder: Defined three-dimensional area in which cut-off signals are generated according to the time-to-collision method (see technical terminology).

Azimuth: A horizontal angle oriented towards a point of the compass.

Blind area: Compared to human observers, IDF has no blind area "behind" it thanks to the 360 ° view.

Blind spot: Area that the IDF system cannot see when looking into the sun (15 °).

Blind zone: Area directly above the IDF system, which cannot be seen by the camera systems.

False negative rate: The rate at which a target species (e.g. red kite) is not determined as this (the wind turbine would not shut down although it should).

False positive rate: The rate at which a non-target species is wrongly determined as a target species (the wind turbine switches off although it shouldn't).

Hysteresis time: Time that must elapse after the shutdown command has been sent from IDF until the wind turbine is switched on again, after the target object is no longer in the inner distance cylinder or is no longer on a possible collision course with the rotor area. This applies to the prevention of frequent switching on and off of the wind turbine and ensures that the bird has already moved away from the danger area by the time the wind turbine is switched on.

Inner distance cylinder: Defined three-dimensional area in which a switch-off signal is generated immediately when a target species occurs.

Correct negative rate: The rate at which a non-target species is correctly identified as this (the wind turbine correctly does not switch off).

Correct positive rate: The rate at which a target species (e.g. red kite) is correctly identified as this (the wind turbine correctly switches off).

Laser Range Finder: Device for electro-optical distance measurement, with which z. B. the 3D position of birds can be determined.

NatForWINSENT: Ongoing research project of the BfN with the title “Development of a concept for accompanying nature conservation research within the framework of the WindForS wind energy test field Swabian Alb”. As part of this project, various technical systems for the needs-based shutdown of wind turbines are being tested by the Swiss Ornithological Institute.

Neural network: branch of artificial intelligence. Used here for the species classification of birds.

Time To Collision Method: Needs-based shutdown method in which a vector is calculated from the position, speed and flight direction of the target type as well as the shutdown time of the wind turbine, which describes a possible collision course with the rotor area of the wind turbine.
In addition, it is calculated when exactly the wind turbine has to be switched off in order to prevent a collision while the flight speed and direction remain the same.

Spin mode: In the context of this study, 2 revolutions per minute are assumed for spin mode.

True Files: Post-determined images of the target species for training the neural network.

1 Reason and Motivation

According to the expansion goals of the federal government, the share of renewable energies in electricity generation is to increase to 65 percent by 2030. The use of wind energy on land represents the most cost-effective expansion potential for this in the short and medium term.1 However, locations with little conflict under species protection law are increasingly difficult to find, especially with regard to the observance of the ban on killing certain species of raptor and large bird species that are in danger of collision. In such cases, temporary shutdowns of WTs (wind turbines) are required for approval under species protection law
(SCHUSTER & BRUNS 2018), which should be implemented according to general parameters or as required.

According to Section 44 (5) No. 1 BNatSchG, there is a violation of the ban on killing in Section 44 (1) No. 1 BNatSchG if there is a significant increase in the risk of killing and this cannot be avoided through the use of required, professionally recognized protective measures.

Technical systems for bird detection and connected, needs-based shutdowns (anti-collision systems) represent a currently discussed option to avoid a significantly increased risk of collision with species that are sensitive to wind energy. Currently, the red kite *(Milvus milvus),* due to its particular risk of collision and almost extensive distribution, but also the white-tailed eagle *(Haliaeetus albicilla),* are at the center of the development of image recognition algorithms for species-specific recognition and demand-controlled shutdown (AMMERMANN *et al.* 2020).

Compared to blanket shutdowns, shutdowns with the help of an anti-collision system better deal with forecast uncertainties with regard to the risk of death during wind turbine operation. These systems therefore offer more reliable protection for species at risk of collision - provided they are sufficiently effective - than the use of blanket shutdown times, mostly based on empirical values (KNE 2018). In addition, needs-based shutdowns - compared to blanket shutdown conditions -

to significantly reduce the time in which the wind turbine is at a standstill for reasons of species protection. The aim is therefore a needs-based shutdown that meets the species protection requirements for bird protection and at the same time minimizes losses in power generation.

The use of such anti-collision systems comes into consideration in particular if, in view of the scarcity of space, there are hardly any locations with low conflicts for the Expansion of renewable energies are available and by means of these systems on the one hand

[1] https://www.bundesregierung.de/breg-de/themen/energiewende/energie-generen/erneuerbare-energien-317608. Retrieved on February 15, 2021

species protection is preserved and, on the other hand, a significant reduction in switch-off times is enabled (UMK 2020).

There are currently various such technical systems on the market, but for them So far there is no sufficient proof of effectiveness. Accordingly, so far their use in case law is not yet seen as a reliable means of lowering the risk of killing below the significance threshold according to Section 44 (1) No. 1 of the Federal Nature Conservation Act (BNatSchG) (VGH Munich, judgment of March 20, 2016 on DTBird - AZ: 22 B 14.1875, 22 B 14.1876). In the meantime, however, it is recognized that systems with a certain technical performance can effectively reduce the risk of collision through an event-related shutdown (spin operation) (UMK 2020).

One such system is IdentiFlight (IDF), designed and manufactured in the USA (Figure 1, Figure 2). The protection of birds of prey and large birds from collisions with wind turbines is of particular importance not only in Germany but also in the USA. Against the background of heavy fines in the case of proven kills of protected species such as the golden eagle *(Aquila chrysaetos)* and the bald eagle *(Haliaeetus leucocephalus),* the IdentiFlight system (hereinafter: IDF) was developed by the company Boulder Imaging, Inc. of Colorado to detect eagles at a sufficient distance from wind turbines and to switch them off in good time in the event of a collision risk.2 IDF has already been tested in the USA with regard to its detection performance and its effectiveness in reducing the number of collision victims (MCCLURE *et al.* 2018; MCCLURE *et al.* 2021) . It was shown, among other things, that IDF effectively recognized birds from kestrel size with a detection rate of 96% compared to observers. In 94% of the cases, eagles were correctly classified. The collision rate was reduced by 82% compared to a control location. The results of these studies cannot yet be transferred to European species of birds of prey and large birds that are in danger of collision, such as the red kite, but they do show the basic performance of the system.

The company renewable energies europa e3 GmbH is planning to introduce IDF in Germany and is striving for this system to be recognized as an effective protective measure within the meaning of Section 44 (5) No. 1 BNatSchG, especially with regard to the red kite. According to SCHUSTER & BRUNS (2018), appropriate testing and, if necessary, further development is required for this, which proves the reliability and fundamental effectiveness. Controlled and scientifically supported pilot studies are to ensure the comparability and transferability of results in a uniform, based on scientific standards,

Follow method standard (SCHUSTER & BRUNS 2018).

This final report presents the results of the test investigations by IDF with regard to the target species red kite at six locations in eastern and southern Germany from 2018 to 2020, which were carried out under neutral control and quality assurance by TÜV NORD Systems GmbH & Co. KG .

[2] https://www.identiflight.com/, last accessed on August 12, 2019 16:14

The objectives and questions of the study carried out are based on the assessment criteria of the Competence Center for Nature Conservation and Energy Transition (KNE 2019) for the performance of the system in terms of detection range, detection rate and flight object classification.

Illustration 1: Installed IDF system with a mast height of 10 m.

2 How IdentiFlight works

2.1 Structure and functionality

An IDF system consists of a combination of two camera units - eight fixed wide-angle cameras and a movable stereo camera - and is mounted on a mast with a height of - currently - up to 10 m (Figure 1 and Figure 2).

Figure 2: The IdentiFlight system, consisting of 8 wide-angle cameras and a movable one Stereo camera.

To monitor the airspace, the two camera units interlock as follows: The lower unit, made up of eight wide-angle cameras arranged in a circle, monitors
permanent, in a horizontal 360 ° radius, the entire air space with a range of approx. 1,000 m. If necessary for technical or data protection reasons, certain areas can be masked. This means that these areas can theoretically be recorded by the cameras, but are technically "blackened" and are not recorded (see example Figure 16).

The wide-angle camera unit is used to detect movements in the airspace (objects that do not move for more than 30 s are ignored) and to filter out relevant objects in flight. It is possible to observe several objects at the same time.
Irrelevant flying objects (e.g. airplanes, vehicles, rotor blades, parachutists or small birds) are differentiated from relevant flying objects (e.g. specimens of the target species red kite or sea eagle) on the basis of certain object parameters that are set at a frequency of 5 Hz are recorded by the wide-angle cameras: brightness, approximate size, speed, position and movement pattern of the detected object.

If, based on these object parameters, it is concluded that a relevant flight object has been detected (e.g. specimen of a target species), a message is sent to the second camera unit - the stereo camera. The stereo camera then aligns itself to the corresponding object and records data on the flight object at a frequency of 10 Hz. This 10 Hz data becomes
Then the image with the highest confidence in the object classification is selected and stored as a 1 Hz data point, for which the position, size and flight route and speed of the object in three-dimensional space are then available in detail. The distance measurement and the angle when locating the bird can have an error of approx. 4% if the object is above the horizon line, and approx. 6%,

if it is below the horizon line (manufacturer information).

The high resolution of the stereo camera enables a more accurate color, shape and
Movement pattern recognition and thus a classification of the detected object with regard to the programmed object classes (target species versus non-target species). If the detected object is assigned to a target species, the stereo camera continues to capture the object, determines the flight route and documents it. However, if the object is assigned to a non-target species (e.g. birds with a different size or color than the target species), the stereo camera subsequently ignores this object. Just like the wide-angle camera unit, the stereo camera can also track several objects at the same time by panning back and forth between them - depending on the programmed prioritization.

The stereo camera can automatically calibrate itself with the help of two calibration boards, which are fixed at a distance of approx. 300 m and 500 m from the camera location (checking of the angle and distance measurement and, if necessary, correction). Automatically heated viewing windows of the cameras (e.g. in rain or snow) also ensure that IDF can be used all year round.
According to the manufacturer, the vertical field of view of the IDF wide-angle cameras extends from -1 ° ° to +64 ° and the IDF stereo camera from -18 ° to +77 ° or -18

up to + 83 ° for a version of the system used from 2020. Every IDF system thus has one "Blind zone" immediately above you, within which no objects can be detected (Figure 3). In addition, the manufacturer specifies a "blind spot" of 15 ° around when the sky is clear if an object is directly in front of the sun from the IDF's point of view. the However, according to the manufacturer, it should be possible to minimize restrictions of the field of view of IDF due to the technical parameters mentioned, the position of the sun or topographical conditions through a network of several IDF systems.

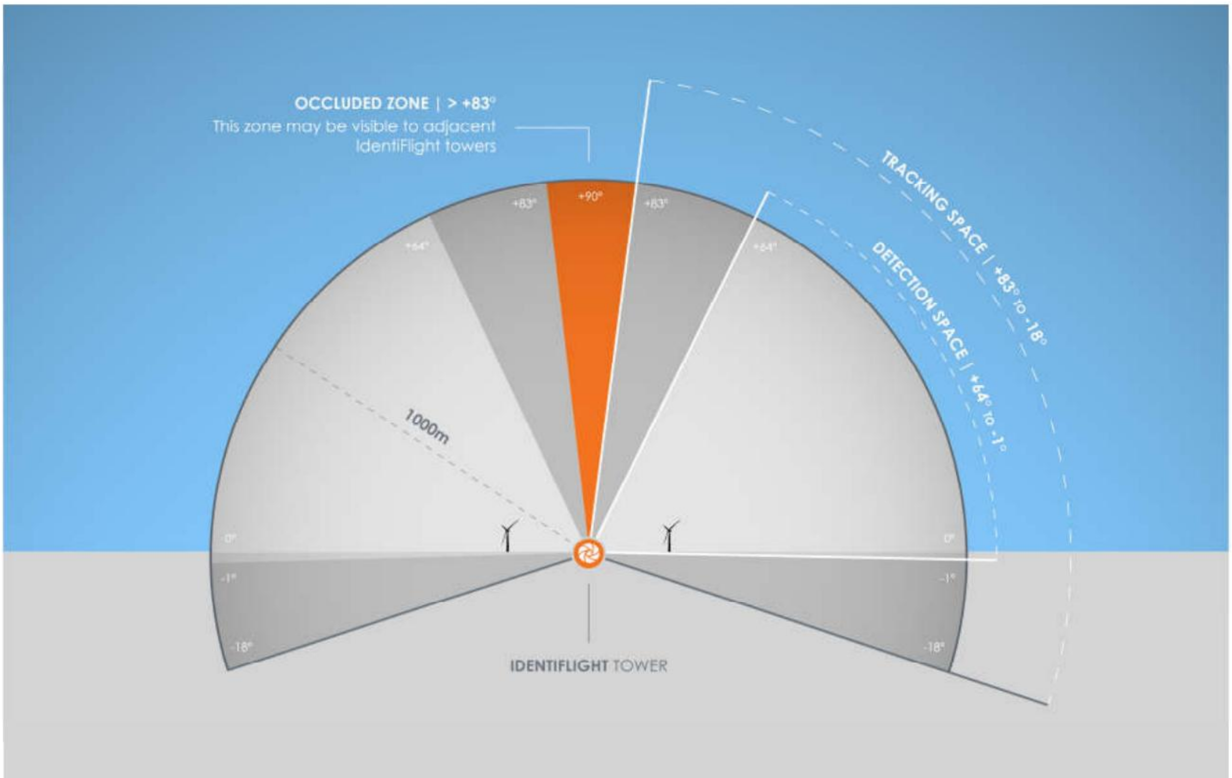

Figure 3: **Field of view of an IDF system showing the "blind zone" (occluded zone). Source: illustration by the manufacturer**

2.2 Classification software

2.2.1 Classification Algorithm

The classification of a detected flight object is based on a neural network. Information from the stereo camera in real time - the high-resolution photos and the distance information - are used by the neural network to determine the body length, wingspan, wing position and color of the flying object determine. The flight object is then classified from the combination of these features, combined with an associated confidence value. The confidence value indicates how certain the system is with the classification. In addition, the system has a "fail-safe" mechanism based on classic image processing methods.

Based on an image from the stereo camera, a confidence value is determined for every second data point and stored by IDF. To view the data, as in the present study, for example, IDF combines data points that are close enough to one another in time and space and have a similar flight direction in so-called “tracks” with a track ID. However, these tracks are not relevant for the decision of the classification algorithm.

The classification by the IDF system is characterized by a precautionary intentional overweighting of the false-positive error. This means that in case of doubt a non-target species is classified as a target species rather than the other way around. The classification is only changed when the confidence value for the non-target species exceeds that for the target species during the ongoing determination.

The focus of IDF in tracking objects is on the target species, which is also reflected in the duration of the tracking of a flight object by the stereo camera. The track length is often significantly shorter when IDF is tracking a non-target species than when a target species is being pursued (Figure 4). In addition, IDF has the ability to distinguish individual target species in a swarm from non-target species and to track them (information provided by the manufacturer).

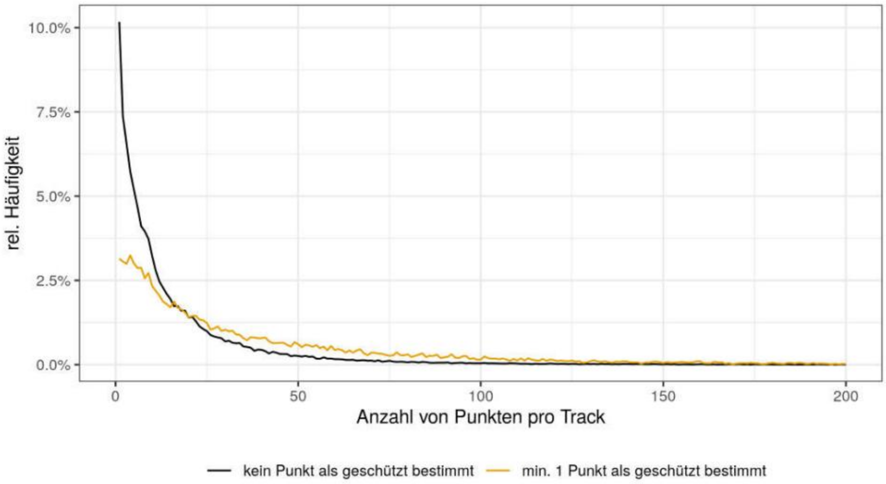

Figure 4: Number of points per IDF track for a target species (protected) or non-target species (not protected).

IDF saves the following information for each data point and saves it collectively in a file for the respective day: Track ID, time stamp, radial distance (with error information) and horizontal distance, x and y data with geographical longitude and latitude, object classification (Bird species) with confidence value, height above ground and above sea level, designation and distance of the wind turbine closest to the property as well as a photo of the property (Figure 5). To minimize the size of the data, the photo is cut to the size of the flight object before it is stored. Those flight movements for which a switch-off signal has been generated are also stored in a separate file with the same information.

2.2.2 Training the software on the red kite

The performance of the neural network on which the classification is based is determined by the data on which it was trained, with the following principle: the more training data, the better the performance of the neural network.

So that the IDF system can reliably recognize a target species, a sufficient number of images of this target species (so-called true files) must be fed in, as well as further images of other species that are similar to the target species in order to avoid mix-ups. However, the number of images actually required for training the neural network to a new target type depends heavily on the quality of the training images (e.g. distance of the recorded object, lighting conditions and the variety with regard to different viewing angles).

Since the IDF system had not yet been trained for the target species red kite at the beginning of the present study, training data for this target species first had to be collected in a first step. For this purpose, the photos created by IDF at the Helfta and Plate locations in the summer of 2018 were viewed by the manufacturer and each of the recorded species assigned. With the true files generated in this way, the neural network could be trained for the target species red kite for the first time and used from August 2018. Shortly afterwards it was started investigating IDF's ability to detect the red kite.

The first version of the neural network was trained with images that were taken over a period of about three months at different locations (see below). In April 2019, the manufacturer carried out a classification test with red kite images that were not recognized by the system. This test was intended to show whether the input of additional training data could further improve IDF's detection of the red kite target species. Since the test predicted a significant improvement, new training data were created from the photos of the examination periods 2018 and 2019, which were subsequently determined by ARSU GmbH, and entered into the system in October 2019. This improved the first version of the neural network for the classification of target species and a second version for the Investigations in 2020 (locations Bütow and Geislingen) will be applied. A special feature of the second version is that red kites and black kites *(Milvus migrans)* form the new category “Red-or-Black-Kite”. In view of the similarity of the two species, this should prevent confusion and thus reduce the false-negative rate will. The two types are no longer differentiated and are protected in the same way by the programmed shutdown.

In the present study, the following two versions of the neural network trained for the target species red kite were used:

- viNet 2.1 (Version 1) - August 2018: First neural network for the IDF systems used. This version of the neural network was trained with images of German species. The images used contain a wide range of images of the target species, which were taken at various German locations.
- viNet 2.2 v2 (Version 2) - October 2019: Current neural network for everyone here used IDF systems. The second version contains a large number of additional images with a focus on additional true files for the red kite (to improve the classification rate), and for the white-tailed eagle. The images used come from Investigations at various German locations over a period of approx. 12 months.

TrackID	DateTimeStamp	RadialDistance_	X	Y	Latitud	Longitu(	SpeciesTypeName	ConfidenceLev	HeightAGL_	HorizontalDistance_	ClosestTurbi	TurbineDistance_	Image
95df33f4-a4e0-4bf6-8f98-6f8ab713a7f1	4.17.2020 11:41:06,111	397,6852	561620	5390494	48,6645	9,836861	RED-OR-BLACK-KITE	1	93	385	FWEA-2	90,41352111	
95df33f4-a4e0-4bf6-8f98-6f8ab713a7f1	4.17.2020 11:41:08,113	383,3764	561605	5390505	48,6646	9,836659	RED-OR-BLACK-KITE	1	88	372	FWEA-1	78,72089748	
95df33f4-a4e0-4bf6-8f98-6f8ab713a7f1	4.17.2020 11:41:09,115	376,5801	561592	5390511	48,6646	9,836484	RED-OR-BLACK-KITE	1	89	365	FWEA-1	73,74848948	
95df33f4-a4e0-4bf6-8f98-6f8ab713a7f1	4.17.2020 11:41:10,116	371,4825	561586	5390516	48,6647	9,836403	RED-OR-BLACK-KITE	1	91	359	FWEA-1	71,04589854	
95df33f4-a4e0-4bf6-8f98-6f8ab713a7f1	4.17.2020 11:41:11,120	367,0082	561575	5390521	48,6647	9,836254	RED-OR-BLACK-KITE	1	92	354	FWEA-1	70,2360285	
95df33f4-a4e0-4bf6-8f98-6f8ab713a7f1	4.17.2020 11:41:12,121	360,7953	561570	5390528	48,6648	9,836188	RED-OR-BLACK-KITE	1	96	346	FWEA-1	68,87989329	

Figure 5: Extract from the original data stored by IDF (correctly identified red kite on April 17, 2020 in the Geislingen study area).

2.3 Shutting down the wind turbines

To protect the programmed target species (here with the focus on the red kite), IdentiFlight works with a vectorial shutdown algorithm (Time To Collision Method), which is based on two distance cylinders (outer and inner distance cylinder) around the wind turbine (Figure 6). The spacer cylinders extend from the floor to a defined height H.

Every second IDF records a data point for which, among other things, the position and flight direction of the detected red kite are calculated by IDF from the 10 Hz data.
As long as the red kite is outside the outer distance cylinder (with a radius of Rmax and a height of Hmax) , no switch-off signal is output. However, if the red kite falls below this distance (Rmax) , a switch-off signal is always generated when the bird is on a "collision course". This means that the vector of its flight route,
after a certain time *t* (time required by the wind turbine to bring the rotor to spin mode), with constant flight direction and speed, crosses the rotor area of the wind turbine.

When entering the inner distance cylinder (with a radius of Rmin and a height of Hmin), a switch-off signal is always output, regardless of the flight direction and -
speed of the red kite. After that, the red kite is there for a certain period of time (Hysteresis time) again outside of the inner distance cylinder and if no more switch-off conditions are met (no collision course), the switch-off command is canceled and the relevant wind turbine goes back into operation after this hysteresis time.

The hysteresis was set up to prevent e.g. For example, by circling a red kite on the edge of the inner spacer cylinder, constant switch-off and switch-on signals can be generated in order to protect the wind turbine from unnecessary multiple switch-offs. After IDF has sent a switch-off signal to the monitored wind turbine, it is only put back into operation if no further switch-off command has been generated within the freely programmable hysteresis period.

The radius and height of the distance cylinder can be programmed variably and essentially depend on the wind turbine dimensions (hub height and rotor radius), the time required for the wind turbine to reach spin mode from the switch-off signal and the mean airspeed of the target species. In Table 2 (see Chapter 4.1.1) the parameters defined for the examinations carried out are listed.

The following formula was used to calculate Rmin at the beginning of the investigation:

= + ÿ

Here, Rmin is the radius of the inner spacer cylinder, r the rotor radius of the wind turbine, s the airspeed of the target species and t the time required for the wind turbine to switch from sending the switch-off signal to spinning mode. This switch-off time was estimated at 30 seconds at the beginning of the investigations, which was carried out in the further course of the investigations own measurements could be confirmed. The flight speed was assumed to be 6.9 m / s before the start of the investigations. On the basis of this data, a risk area of 200 m (rounded off from 207 m) was defined around the rotor area of the wind turbine. For example, this results in the following value for the Rmin of the inner spacer cylinder at the Bütow site:

$$250.5 = 50.5 + 200$$

The height of the inner spacer cylinder was set at 200 m on the recommendation of the manufacturer.

The values for the distance cylinder sizes of the respective locations are shown in Table 2 in Chapter 4.1.2 and are explained in more detail there.

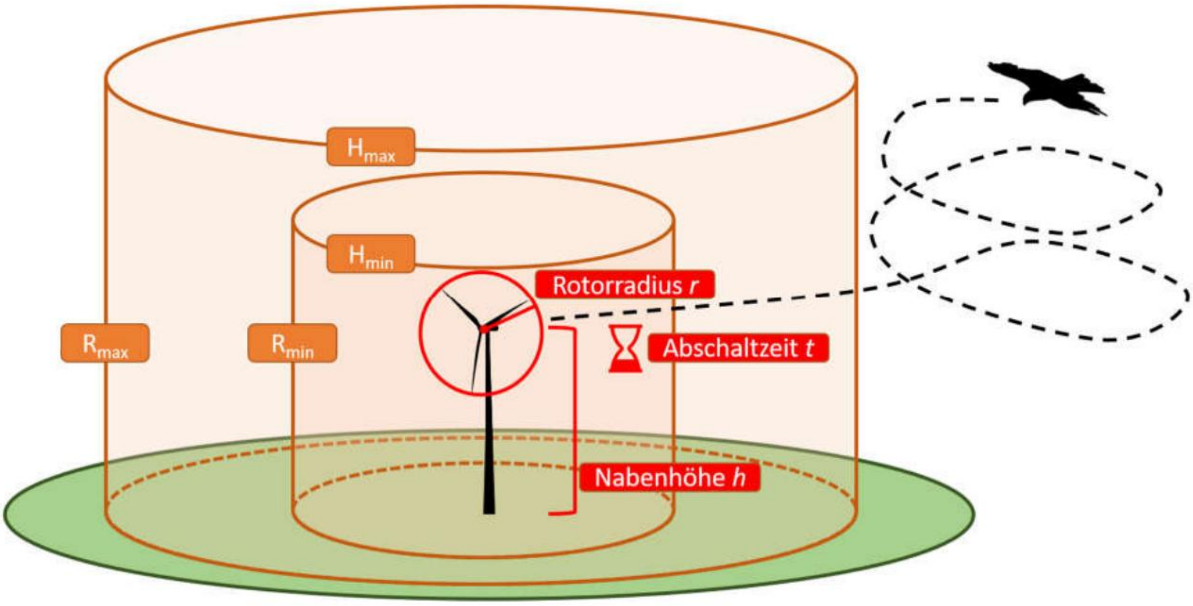

Figure 6: Basics of the demand-controlled shutdown algorithm of IdentiFlight in the context of this study

3 questions and research concept

3.1 Basics of system testing

According to the recommendations of the Competence Center for Nature Conservation and Energy Transition (KNE 2019), a number of questions must be answered as part of a system test at the respective location in order to achieve a differentiated representation of the system performance depending on different location characteristics and prevailing conditions:

1. What spatial and temporal coverage is basically achieved by the tested system and what are the limiting system and location-specific factors?
2. At what distance to the wind turbine are the relevant objects in flight reliably recorded and what factors can influence this?
3. How many of the actually occurring objects in flight are recorded?
4. To what extent are the objects in flight recorded by the system correctly in differentiated between system-specific classes (e.g. large or medium-sized birds or specific target species)?
5. What effectiveness and efficiency are achieved by the system reaction, ie by the Generation of shutdown signals, achieved?

This results in the test criteria specified by the KNE (2019), on the basis of which in the present study the effectiveness of IDF for the protection of red kites
Collisions on wind turbines has been checked:

- Spatial and temporal coverage,
- detection range,
- acquisition rate,
- classification rate,
- Effectiveness and efficiency of the shutdown.

In the meantime, the KNE has in some cases developed proposals for quantitative assessment criteria for these criteria.3 These are discussed in Sect. 6.2 used to classify the results obtained in the present study.

[3] https://www.naturschutz-energiewende.de/wp content / uploads / 20201014_KNE_Vortrag_Bruns_Streiffeler_KNE.pdf, accessed on April 24, 2021

3.2 Testing criteria

The study carried out covers a period of three years (2018 to 2020) at two different wind farm locations annually (a total of six
various wind farms). During this time, the test criteria specified by the KNE (2019)
were examined as follows.

For spatial and temporal coverage by the IDF, the data from all six
Locations are analyzed with regard to downtimes and visual shading in order to determine statements about the temporal system availability as well as any restrictions on the monitoring of the observation area around the respective wind turbine.

The distance up to which red kites were detected by the system was determined at each location (detection range).

To check the acquisition rate, the collection of reference data by a so-called.
Second system required (KNE 2019). In turn, the performance of the second system must be sufficiently known in relation to the test questions. In an initial test in 2018, the general detection performance of the IDF was tested using GPS data from a drone and the accuracy of the location by the IDF was determined. Subsequently, the detection rate of red kites in the field of view of the IDF was recorded at all six locations with flight path data collected specially by a laser range finder (LRF, laser rangefinder)
matched. In 2020, this comparison was expanded to include additional data from a red kite transmitted with GPS.

The rate of correct classification (target species versus non-target species) was determined for all six locations by comparing the manually determined photos with the respective classification by IDF. The two versions of the neural network that were used (see Chapter 2.2.2) were considered separately.

The effectiveness of the IDF system in terms of correct operational control of the wind turbine for
Protection of red kites from the risk of collision has been made through virtual as well as through real
Shutdowns determined. The following three scenarios were used for this: 1. The IDF system simulates a virtual shutdown of a virtual wind turbine. 2. The IDF system simulates a virtual shutdown of a real wind turbine. 3. The IDF system initiates a real shutdown of a real wind turbine.

In addition to the test criteria developed by KNE (2019), parameters of flight behavior - flight speed (horizontal and vertical) and flight altitude - of the red kite were also examined in the present study. These are essential in order to be optimized for a specific species
To be able to derive shutdown algorithms from wind turbines. The data generated by the IDF with a high temporal and spatial resolution were used to determine the parameters for flight behavior.

For the efficiency of the IDF system it is also crucial which external influencing factors could limit the acquisition rate. As possible weather-related

Precipitation and the position of the sun were identified and any influencing factors were identified Limitations evaluated.

3.3 Project constellation

The studies were coordinated and financed by e3 GmbH (Figure 7).
The technical project monitoring and management was the responsibility of ARSU GmbH, the data evaluation was taken over by OekoFor GbR. The LRF data were taken from the
Landscape architecture office Oevermann, Ökotop GbR and at the Geislingen site from the Swiss Ornithological Institute. The report was created jointly by ARSU GmbH and OekoFor GbR.

External project monitoring was set up by TÜV Nord Systems GmbH & Co. KG to maintain the neutrality and quality assurance of the investigation. She presented one
Carrying out the investigation in accordance with the given rules safely and taking into account the relevant framework conditions (institutions and people involved, test set-up, implementation, special features, etc.).

A central task was to monitor neutral data collection. For this purpose, TÜV Nord provided a server to which all data collected by the observers (LRF data and log sheets) were transmitted by 12 noon on the working day following the day of the investigation. The data was then provided with a hash value by TÜV Nord in order to identify any subsequent manipulations. Only after a transmission as well
Documentation of the collected data of all actors could circulate the data and
be evaluated. Both the data collection and its evaluation were randomly checked.

The data recorded by the IDF (flight paths and photos of the recorded birds) were saved on site and accessed remotely. From there, the data was also made available on the TÜV-Nord server.

The LRF data were uploaded directly to the TÜV Nord server as a csv file by the Oevermann and Ökotop offices. This included a log sheet and a weather table.
To illustrate the weather conditions, photos were taken for each appointment, which were made available on the TÜV-Nord server together with all other results.

Figure 7: **Project constellation to check the effectiveness of IdentiFlight**

4 methodology

4.1 Study areas

4.1.1 Overview

The investigations were carried out in the years 2018 to 2020 at six locations in the federal states of Mecklenburg-Western Pomerania, Saxony-Anhalt and Baden-Württemberg (Figure 7 and Figure 8), which were specifically selected with regard to the high flight activities of the red kite. All locations, with the exception of Geislingen, are located in similar natural areas and show comparable landscape conditions. These are open land locations with agricultural use, as are typical for many potential areas on which wind energy can be used. Due to the small proportion of forest and the largely flat relief, the selected study sites are suitable for testing IDF (little shading). Only the Geislingen site differs in this respect and has a stronger relief in areas with height differences of up to 150 m in the field of view of IDF. In addition, Geislingen is the location with by far the largest proportion of forest in the field of vision of IDF (Figure 14).

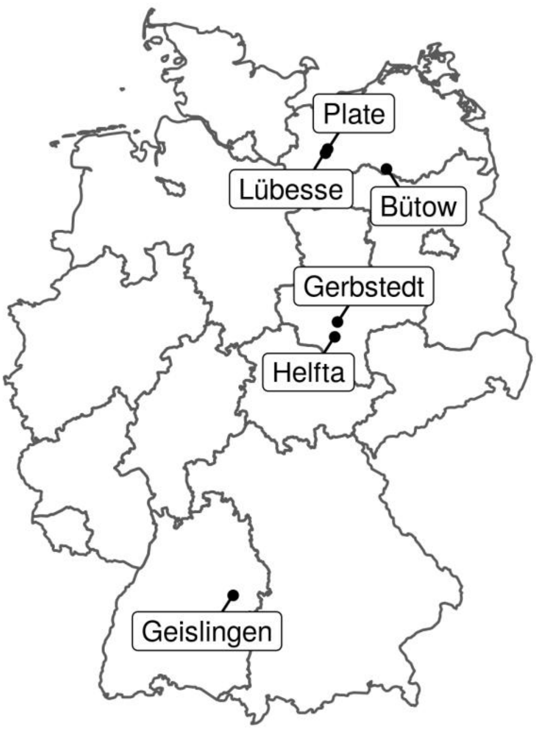

Figure 8: Location of the study areas in 2018 (Helfta and Plate), 2019 (Gerbstedt and Lübesse) and 2020 (Bütow and Geislingen)

4.1.2 Shutdown programming

The red kite was specified as the target species for which a shutdown had to be triggered for all locations (Table 1). In version 1 of the neural network, this was referred to as the “Red Kite”, in version 2 as the “Red-Black-Kite”, which then also included the similar Black Kite. For the years 2019 and 2020, white-tailed eagles and other eagles were added as target species, which, however, are not the subject of this study and are evaluated separately. In 2020, version 2 of the neural network added the target species "Protected", which included all large birds that were previously subsumed under "Eagle" but were not eagles (e.g. storks, cranes).

Table 1: **Programmed target types for which the wind turbine was switched off.**

Location	year	Neural network	Target type (shutdown)			
Helfta	2018	Version 1	Red kite			
Plate	2018	Version 1	Red kite			
Gerbstedt	2019	Version 1	Red kite	White Tailed Eagle	eagle	
Luebesse	2019	Version 1	Red kite	White Tailed Eagle	eagle	
Butow	2020	Version 2	Red-or-Black Kite	White Tailed Eagle	eagle	Protected
Geislingen	2020	Version 2	Red-or-Black Kite	White Tailed Eagle	eagle	Protected

Since there were no wind turbines at the Helfta, Plate and Geislingen sites at the time of the investigation, virtual wind turbines were simulated for these locations and the shutdowns were carried out virtually. There were already existing wind turbines at the Gerbstedt, Lübesse and Bütow locations, which were switched off in real or virtual form for part of the investigations. Depending on the availability at the location, one to three wind turbines were covered by IDF and switched off as required (Table 2).

As described in Chapter 2.3, an inner and an outer spacer cylinder are placed around each wind turbine (Figure 10 to Figure 14). Since these are adapted to the project-specific wind turbines (shutdown time and rotor radius) in order to switch off the wind turbine in good time as required, they are of different sizes in the various study areas. The radii and heights for the inner and outer spacer cylinders of all study locations are shown in Table 2. Two periods of time are listed for the Bütow location in Table 2, as the cylinders were adjusted to updated values for the flight speed of the Red Kite and the time required for the wind turbine to switch to spin operation after approx. One month (see Chapter 2.3 Shutdown).

Two minutes was selected as the hysteresis time at the Helfta and Plate locations (Table 2). In order to further minimize multiple shutdowns, the hysteresis time was extended to three minutes for the Gerbstedt, Lübesse, Bütow and Geislingen sites (Table 2).

The duration from the transmission of the switch-off signal to the transition of the wind turbine to idle mode (Time-To-Collision, TTC)) was estimated at 30 seconds at the beginning of the investigation (see Chapter 2.3) and checked by shutdown tests at the Lübesse, Gerbstedt and Bütow sites. The 30 seconds were confirmed or not reached. No subsequent adjustment was made because the tests confirmed the value as conservative.

Table 2: **Characterization of the locations with regard to wind turbines, their specifications and the resulting values for the distance cylinders on which the shutdown algorithm is based. The cylinders start at the bottom and have a height of Hmin and Hmax . (V: virtual wind turbine, R: real wind turbine, TTC: time-to-collision)**

Location	Acquisition time space	number WEA (F / R)	circuit Virtual/ real	WEA type	hub height (m)	Rotor diameter (m)	height Rotor lower edge (m)	Rmin (m)	Hmin (m)	Rmax (m)	Hmax (m)	Hysteresis (s)	TTC (s)
Helfta	Aug 15, 2018 - October 18, 2018	3 (V)	virtual	Enercon E-115	135	115	77.5	257.5	200	750	400	120	30th
Plate	Aug 15, 2018 - October 18, 2018	1 (V)	virtual	Enercon E-115	135	115	77.5	257.5	200	750	400	120	30th
Gerbstedt	07/12/2019 - 08/10/2019	3 (R)	real	GE 1.5s	64.7	70.5	29.5	235.0	200	750	400	180	30th
Luebesse	07/01/2019 - 19.09.2019	1 (R)	real	Nordex S70	65	70	30th	235.0	200	750	400	180	30th
Butow 1	04/30/2020 - 05/28/2020	2 (R)	1 virtual 1 real	Enercon E-101	149	101	98.5	251.0	200	750	400	180	30th
Butow 2	May 29, 2020 - 07/28/2020	2 (R)	1 virtual 1 real	Enercon E-101	149	101	98.5	291.5	200	600	400	180	29
Geislingen	04/16/2020 - June 16, 2020	2 (V)	virtual	SG705.54	73	54	46	227.0	200	750	400	180	30th

4.1.3 Spatial coverage and site layout

The spatial coverage of a location describes how well IDF does the relevant, three-dimensional space with restrictions such as shading (e.g. from trees or other wind turbines) or differences in relief and shows how these influences affect the effectiveness of the system on site. Since these differ between the examined locations, the respective restrictions or
Special features of the different locations are included.

The landscape in the study area **Helfta** consists mainly of agricultural areas and hardly contains any elements that could limit the spatial coverage of the IDF system (Figure 9). In addition, there are no wind turbines in Helfta, which is why they cannot result in shading from view (Figure 15). For technical reasons, there are no stored images from the wide-angle cameras for the Helfta location, in contrast to the other locations.

In Helfta, IDF was just 260 m away from the three virtual wind turbines (Figure 9). The sight radius of 750 m thus completely covered the inner distance cylinders of the three virtual systems. However, the outer edge of the outer spacer cylinder could not be completely covered in every direction. The shutdowns of the inner spacer cylinder were not restricted by this, a shutdown using the TTC method in the outer cylinder could, however, only occur from within sight of IDF.

In the investigation area in Helfta there was a known red kite nest about 2,000 m northeast of the IDF system. It was also known from preliminary investigations that this area is heavily frequented by foraging red kites.

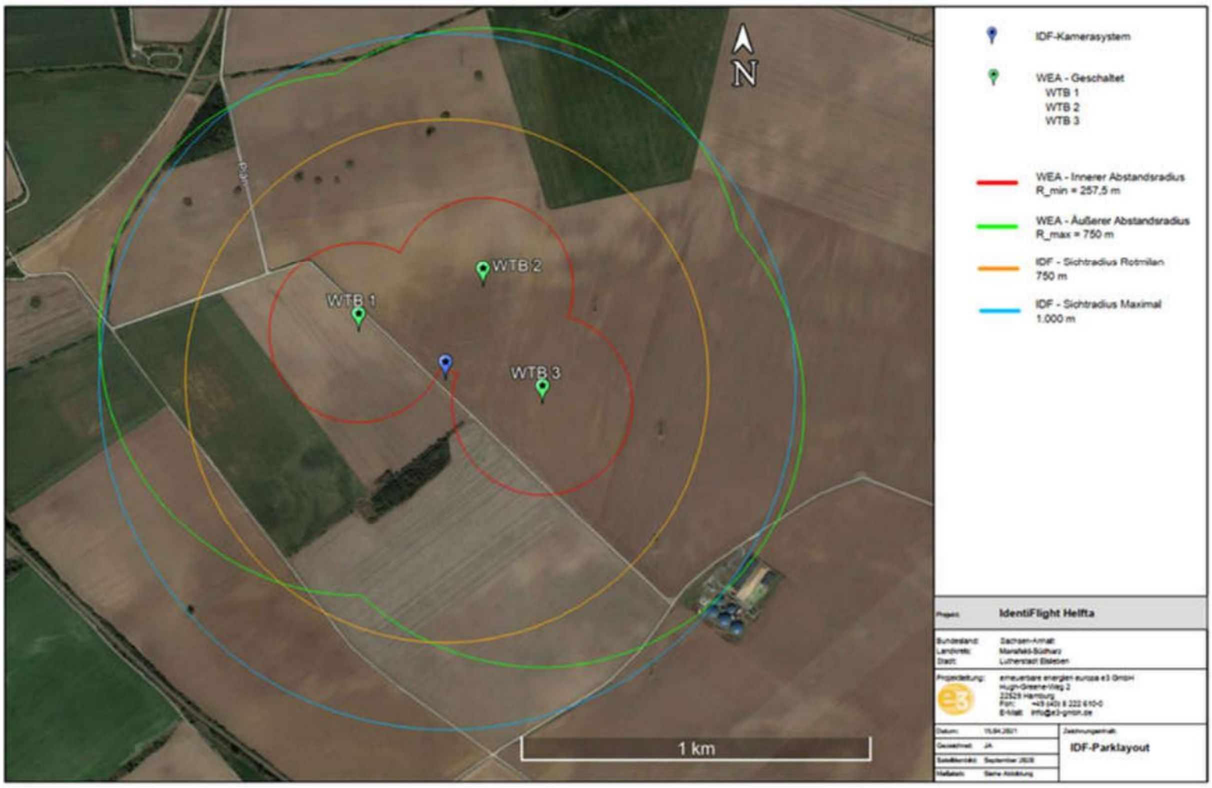

Figure 9: Study area Helfta with IDF location and location of the virtual wind turbine

The landscape in the **Plate** study area consists mainly of agricultural areas and shows hardly any elements towards the north that could limit the spatial coverage of the IDF system (Figure 10). To the south there is a row of trees at the location approx. 300 m away, which had to be masked in order to avoid interference with the camera by moving trees. This means that the detection of low flights to the south is only possible to a limited extent (Figure 16 and Figure 17). Wind turbines were not available.

In Plate, IDF was approx. 250 m away from the virtual wind turbine and thus on the edge of the inner spacer cylinder (Figure 10). The sight radius of 750 m thus completely covered the inner distance cylinder of the virtual systems. The outer distance cylinder could be completely monitored by IDF to the south, but to the north IDF could not completely cover the outer cylinder with a visibility of 750 m.

In the investigation area in Plate there was a known red kite nest about 1,300 m northwest of the IDF system.

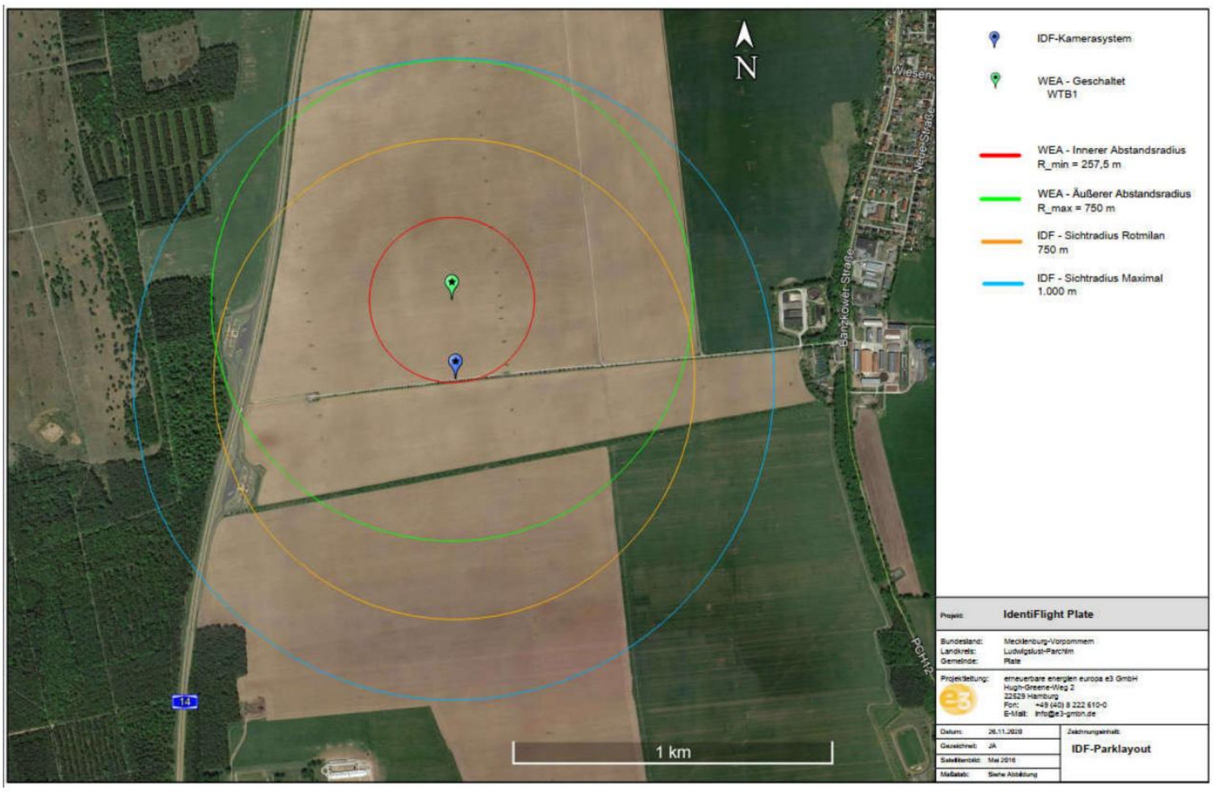

Figure 10: Plate study area with IDF location and location of the virtual wind turbine

The landscape in the **Gerbstedt** study area consists mainly of agricultural areas and includes several hedges or woody structures that could limit the spatial coverage of the IDF system (Figure 11). Above all in the southeast of the IDF system there is a row of trees at the site, which restricts the near-ground view in the direction of the wind turbine 9 (Figure 18 and Figure 19). The study area is part of the existing Gerbstedt park with 9 GE 1.5s systems, which provide isolated, small-scale visual shading, especially towards the south. Three of the nine systems were monitored on site by the IDF system and actually shut down (Table 2).

In Gerbstedt, IDF was located approx. 240 m from two of the three wind turbines (7 and 9) and approx. 400 m from wind turbine 6 (Figure 11). The sight radius of 750 m thus completely covered the inner distance cylinder of all three systems. The outer spacer cylinder could to the west and east cannot be completely covered and in particular the outer distance cylinder of the wind turbine 6 could not be completely covered by IDF in the south.

In the investigation area in Gerbstedt there were three known red kite nests approx. 3,000 m south of the IDF system.

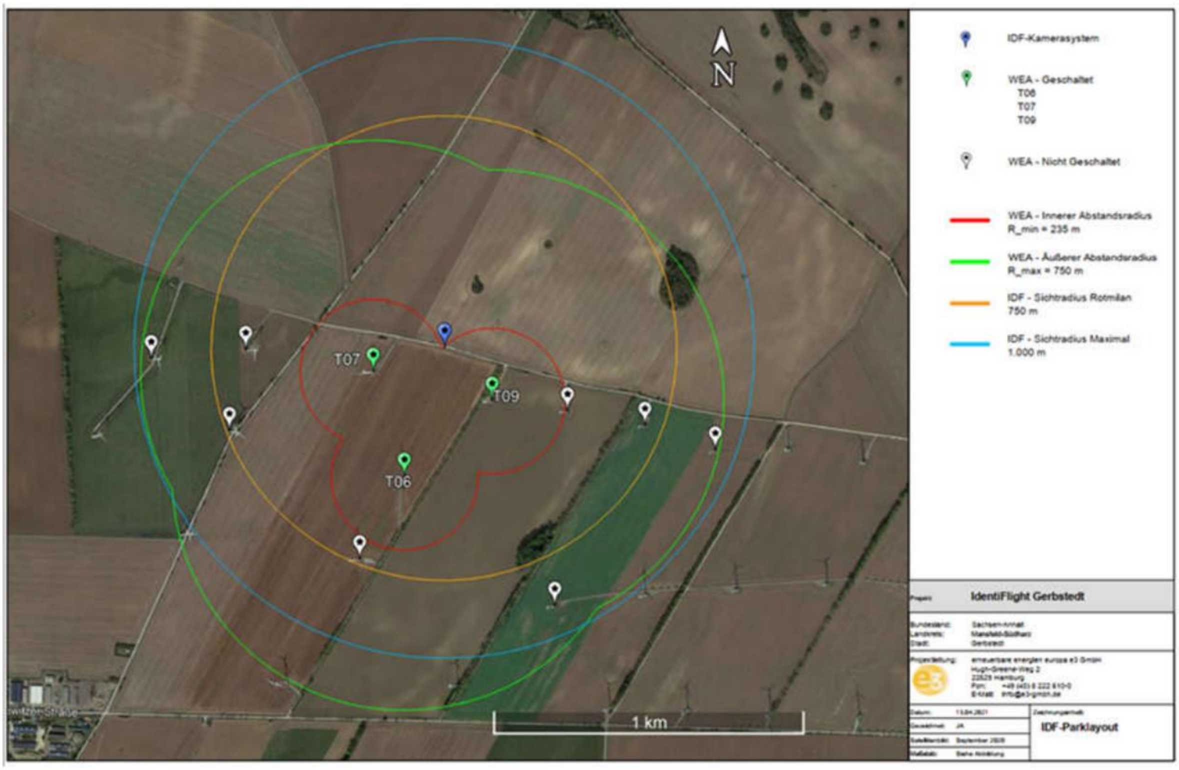

Figure 11: Gerbstedt study area with IDF location and location of the existing wind turbine

The landscape in the **Lübesse** study area consists mainly of agricultural areas and, apart from a small area of forest on the eastern edge of the IDF's visual range, shows hardly any elements that could limit the spatial coverage of the IDF system (Figure 12). The study area is part of the existing Lübesse park with 14 Nordex S70 turbines, which provide occasional shading (Figure 20
and Figure 21). One of these systems was monitored on site by the IDF system and actually shut down (Table 2).

In Lübesse, IDF was located approx. 150 m from the monitored wind turbine. The sight radius of 750 m thus completely covered the inner spacer cylinder. The outer spacer cylinder could also be recorded almost completely by IDF (Figure 12).

In the investigation area in Lübesse there was a known red kite nest in the wood approx. 700 m east of the IDF system.

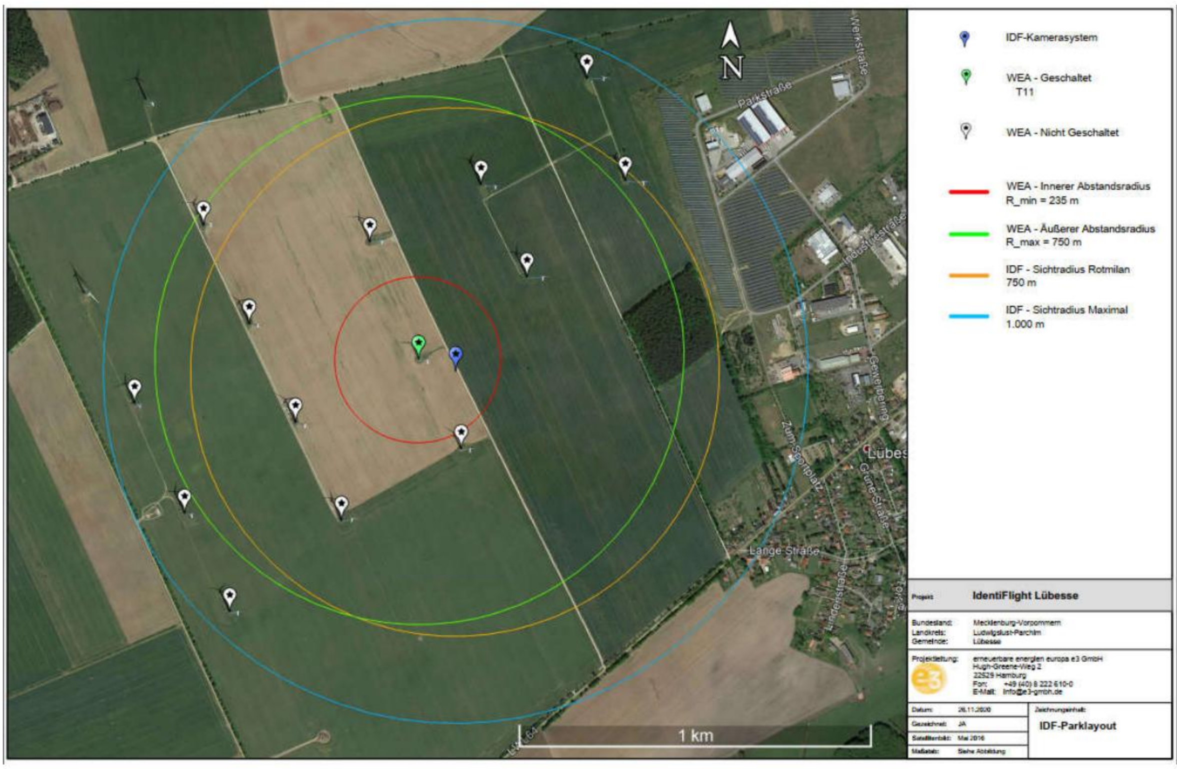

Figure 12: Lübesse study area with IDF location and location of the existing wind turbine

The landscape in the **Bütow** study area consists mainly of agricultural areas and includes several small forest areas (Figure 13). In particular, the forest areas to the east and south-west of the IDF system resulted in smaller ones
Limitations of the field of view in the area slightly above the horizon line (Figure 22 and Figure 23). The investigation area is part of the existing Bütow park with 41 DEWind D4 systems (32 units) and Enercon E-101 (9 units). Some of these systems provided slight visual shading (Figure 23), whereby the location was chosen by IDF so that the forest areas with potential red kite nests could be seen very clearly. The wind turbine 13, which is located east of the IDF system, was actually switched off, while the wind turbine 11
to the west of the IDF system was virtually replicated and switched off (Table 2).

In Bütow, IDF was located in the middle of the two wind turbines 11 and 13 at a distance of approx. 150 - 200 m each (Figure 13). In Bütow, after about a month of the investigation, the calculation of the size of the distance cylinder was adapted to current values of the airspeed and the shutdown time of the systems on site, since from this point on a sufficient database was created by IDF to use the newly determined values (see chapter 2.3). As a result of this adaptation, the radius of the inner spacer cylinder has increased slightly and the radius of the outer spacer cylinder has decreased slightly (Table 2, Figure 13). The sight radius of 750 m completely covered the inner distance cylinders of both wind turbines for both variants. The outer spacer cylinder could be used at the first variant cannot be completely covered after the cylinder has been adjusted however, almost the entire area of the outer cylinder is covered.

In the investigation area in Bütow there was a known red kite nest in the wood approx. 450 m east of the IDF system. The eyrie at this location was therefore in the border area of the inner spacer cylinder.

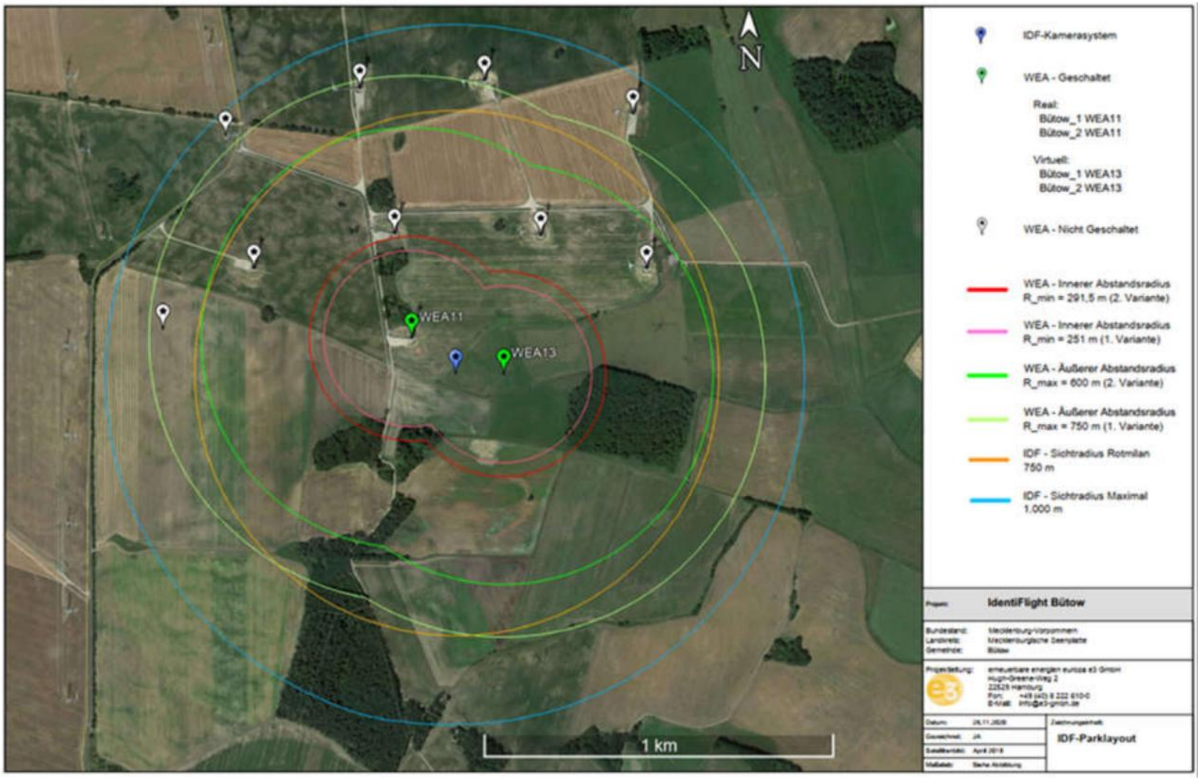

Figure 13: Bütow investigation area with IDF location and location of the existing wind turbine (above)

The landscape in the **Geislingen** study area consists largely of agricultural land. In addition, there are several structures in the investigation area that restricted the field of vision of IDF at least close to the ground. These include B. larger forest areas in the north and west of the IDF system (Figure 14) and a pigsty as well as several roads that had to be masked for data protection reasons and thus reduced the field of vision of IDF (Figure 24 and Figure 25).
In addition, the terrain slopes sharply to the west, which further restricted the field of vision of IDF. The investigation area is part of the WindForS wind energy test field Swabian Alb 4. At the time of the investigation, there were only two on site

[4] https://www.natur-und-erneuerbare.de/projektdatenbank/projekte/natforwinsent-naturschutz-im-windtestfeld/, accessed on May 27, 2021

Wind measurement masts and not yet a wind turbine. In the area south of the IDF, the wind measurement masts ensure low visibility, similar to what would be caused by wind turbines (Figure 24 and Figure 25).

In Geislingen, IDF was located comparatively far north of the two planned wind turbines at a distance of approx. 300 m and 450 m respectively (Figure 14). These positions to the wind turbines were not ideal due to the great distance, but had to be selected in Geislingen due to the limited power supply, which had to be taken into account in the evaluations. The sight radius of 750 m completely covered the inner distance cylinders of both wind turbines, but only partially covered the outer distance cylinders. In particular, the southern edge of the outer spacer cylinder of the southern wind turbine could only be covered to a very limited extent by IDF.

In the investigation area in Geislingen there was a known red kite nest of the red kite with transmitters in the forest area approx. 250 m north of the IDF system.

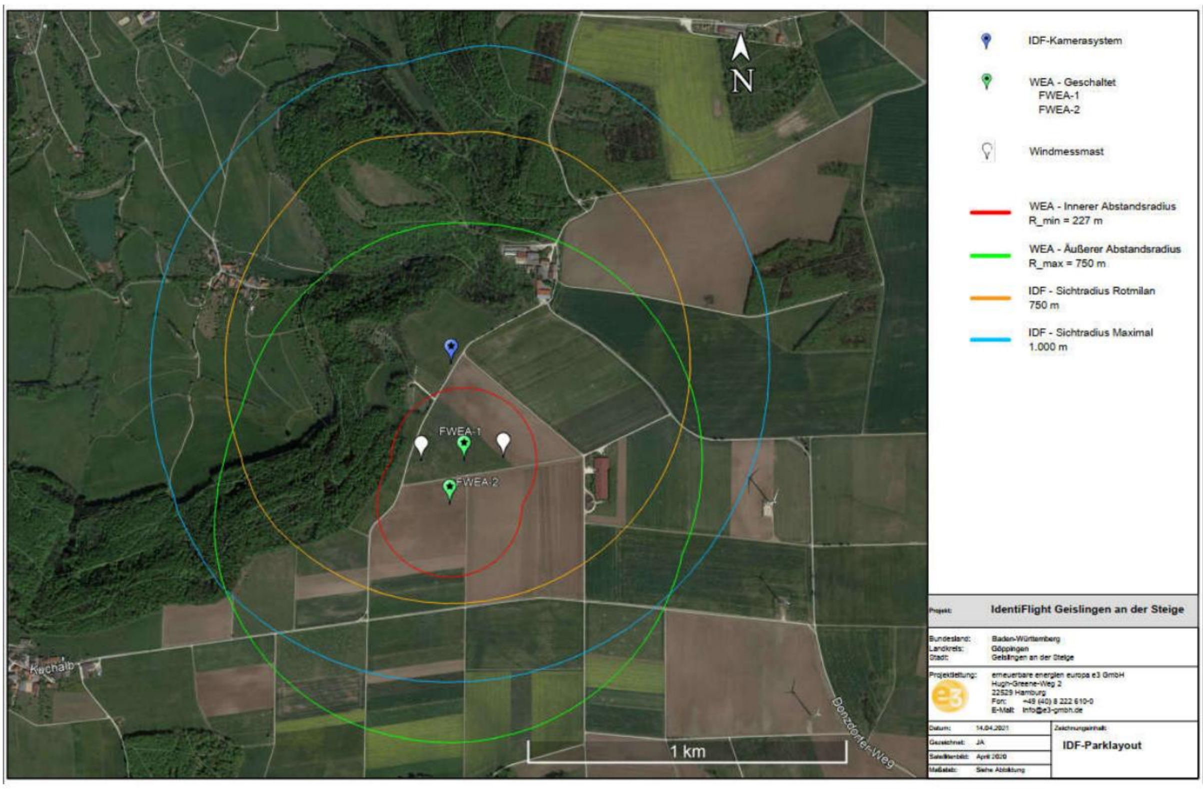

Figure 14: Geislingen study area with IDF location and location of the virtual wind turbine

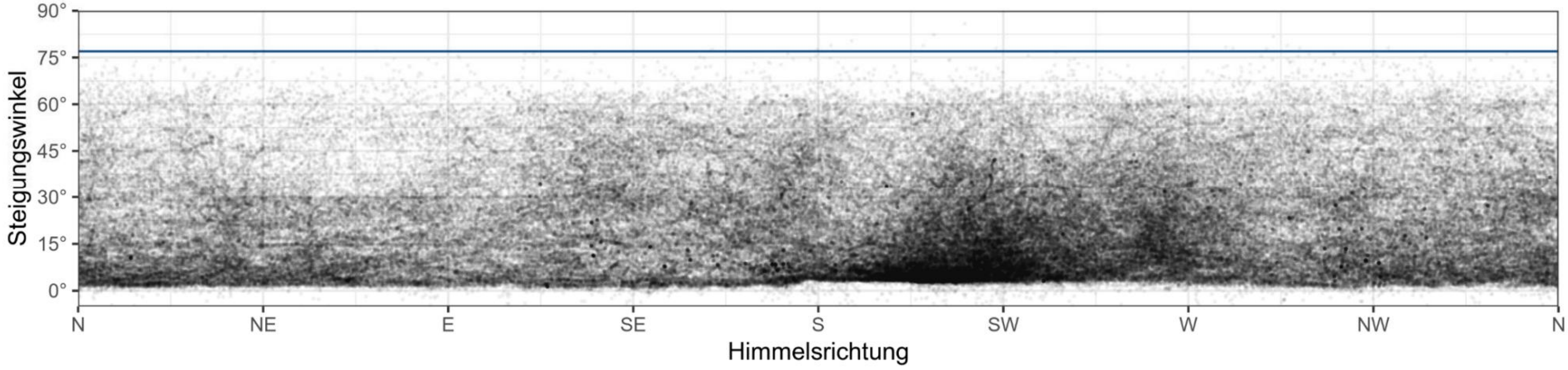

Figure 15: Data cloud of the total data from IDF at the Helfta site. This data shows IDF's actual field of view as well as obscuring ones Structures behind which no data points were generated.

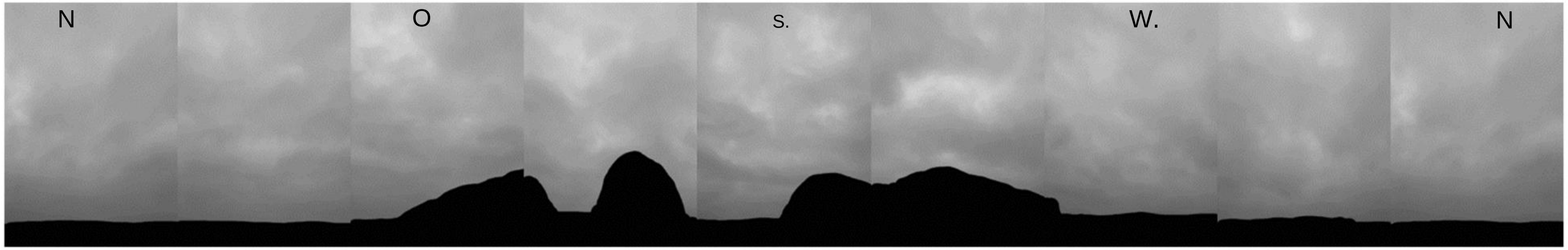

Figure 16: Field of view of the wide-angle cameras with masking at the Plate location.

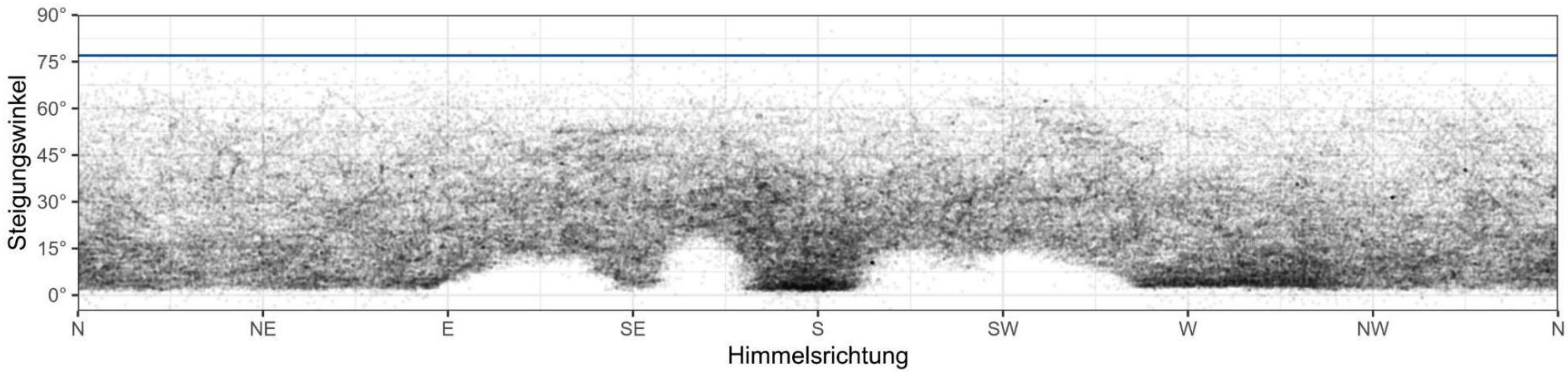

Figure 17: Data cloud of the total data from IDF at the Plate site. This data shows the actual field of view of IDF as well as structures that are obscuring the view and behind which no data points were generated.

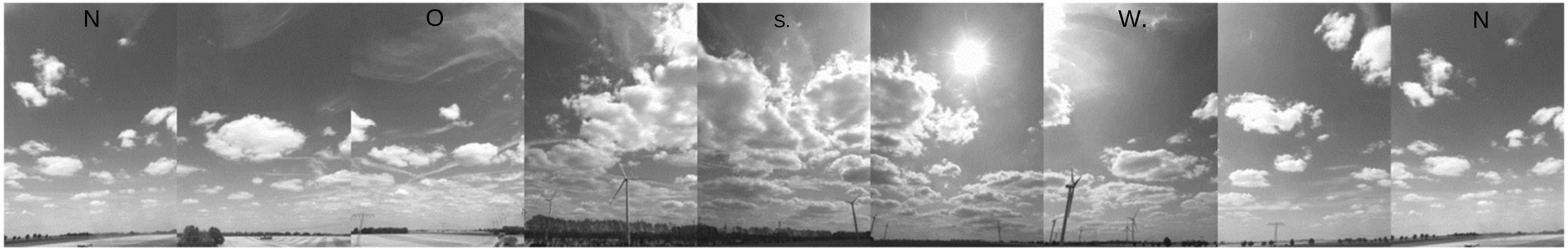

Figure 18: Field of view of the wide-angle cameras at the Gerbstedt site.

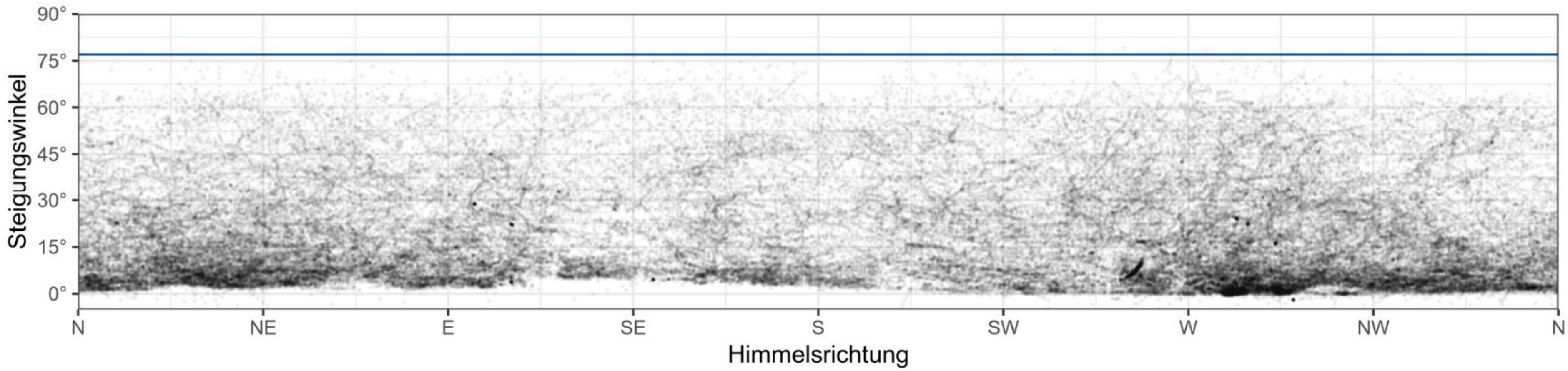

Figure 19: Data cloud of the total data from IDF at the Gerbstedt site. These data show the actual field of view of IDF as well as structures that are obscuring the view and behind which no data points were generated.

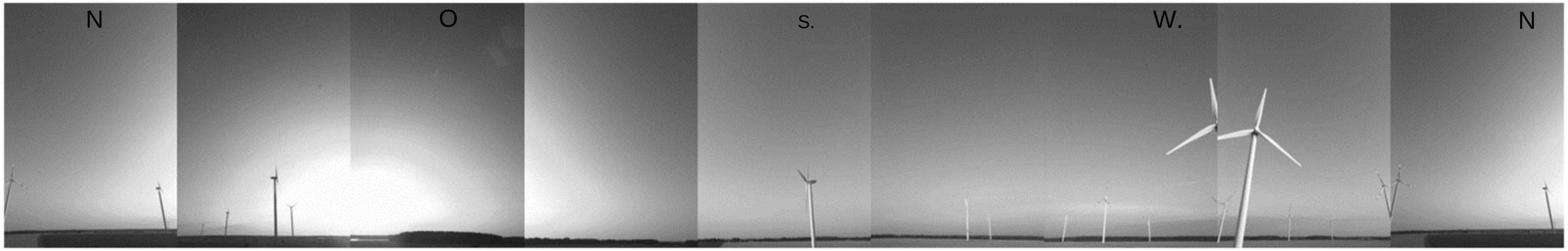

Figure 20: Field of view of the wide-angle cameras at the Lübesse site.

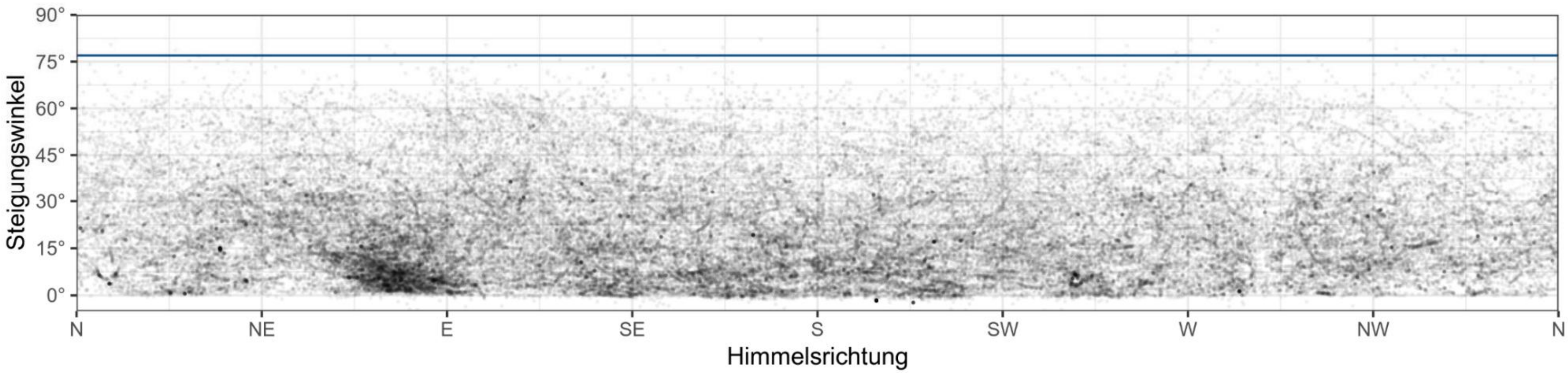

Figure 21: Data cloud of the total data from IDF at the Lübesse site. These data show the actual field of view of IDF as well as structures that are obscuring the view and behind which no data points were generated.

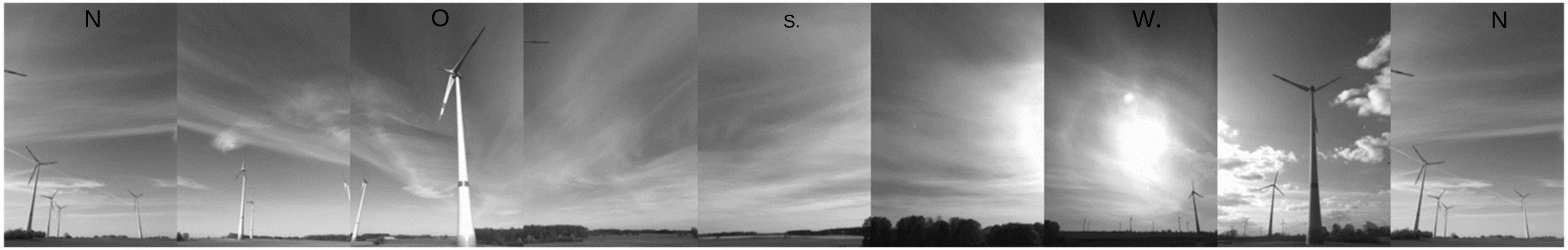

Figure 22: Field of view of the wide-angle cameras at the Bütow site.

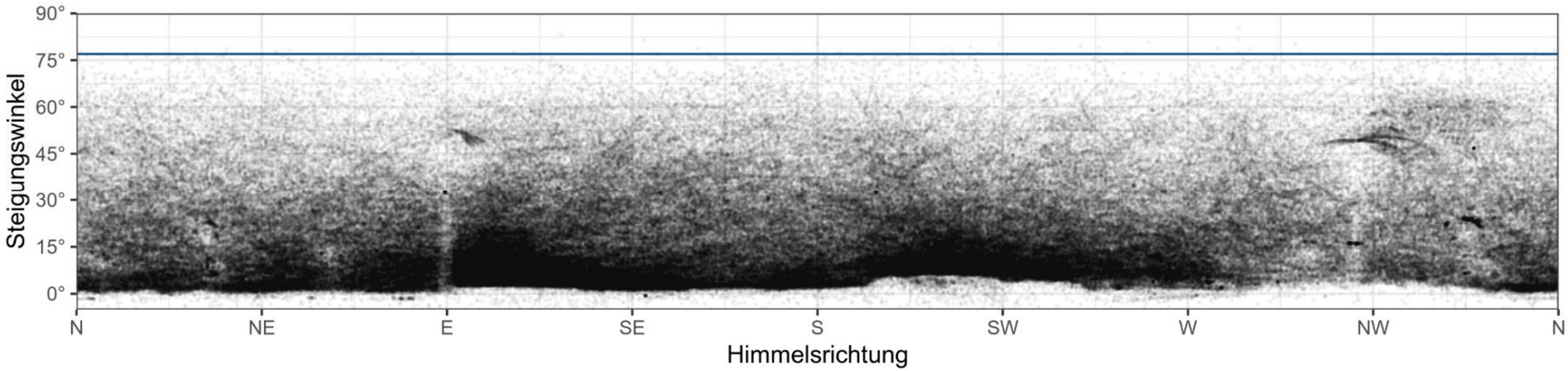

Figure 23: Data cloud of the total data from IDF at the Bütow location. This data shows IDF's actual field of view as well as obscuring ones Structures behind which no data points were generated.

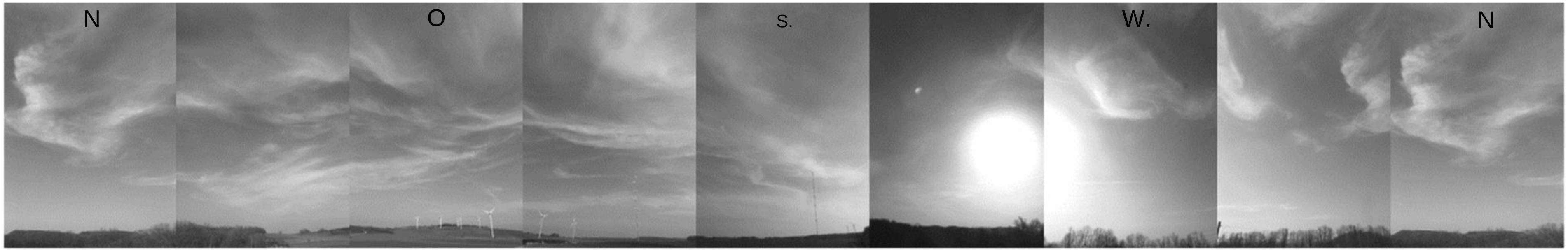

Figure 24: Field of view of the wide-angle cameras at the Geislingen site.

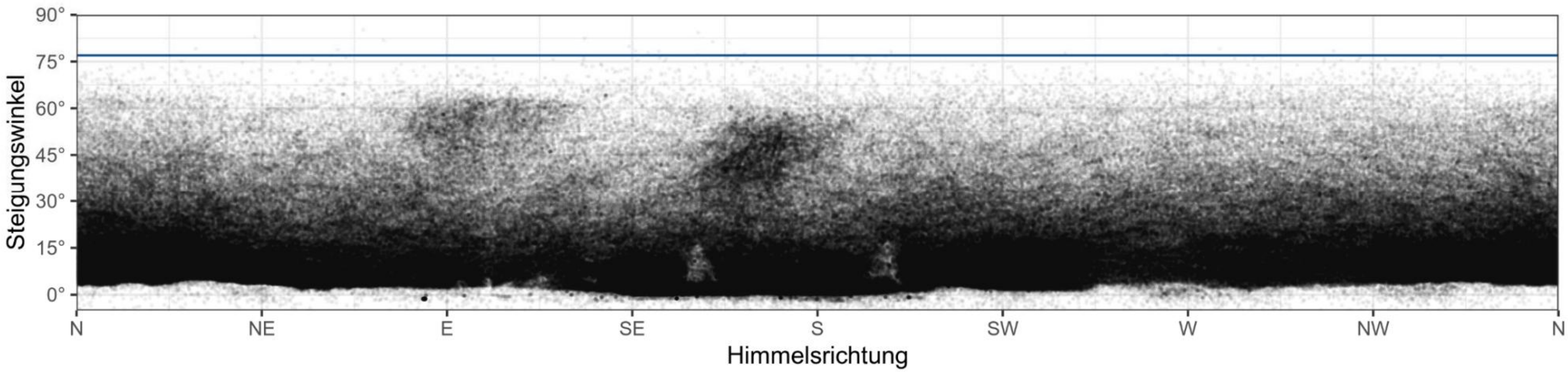

Figure 25: Data cloud of the total data from IDF at the Geislingen location. These data show the actual field of view of IDF as well as structures that are obscuring the view and behind which no data points were generated.

4.1.4 Time coverage

4.1.4.1 Overview

The duration of the respective investigation phases varied between 60 and 90 days, only in Gerbstedt had to be canceled after 30 days due to vandalism.
This results in a total of 393 study days for all study areas. After deducting technical failures, complete data is available for a total of 364 days, spread from mid-April to mid-October (Table 3).
This results in a time availability of the IDF systems of 93%, if one - conservative - also counts the days with power supply problems as unavailable.

The system failures can have different causes. A large part (12 out of 29 days with total or partial failures) can be traced back to problems with the power supply. It must be taken into account that these occurred in part due to the shutdown of the entire wind farm or are related to the fact that a generator was used in the first investigation phases and that it was caused by technical malfunctions
has failed. These problems are no longer to be expected in the normal operation of IDFs in wind farms. Without these failures, the number of system-related lost days would have been reduced from 29 to 17. This results in a technical availability of IDF of at least 95%.

However, there were also failures due to defective components and planned software updates.

Table 3: **Temporal overview table of the surveys.**

Location	Beginning	end	number Days	Fully recorded days	Failures partially	Failures whole days
Helfta	08/15/2018	October 18, 2018	65	58	4th	3
Plate	08/15/2018	October 18, 2018	65	63	1	1
Gerbstedt	07/12/2019	08/10/2019	30th	27	0	3
Luebesse	07/01/2019	19.09.2019	81	67	0	14th
Butow	04/30/2020	07/28/2020	90	87	3	0
Geislingen	April 16, 2020	June 16, 2020	62	62	0	0
total			**393**	**364**	8th	**21**

4.1.4.2 Site specifics

Since there were no wind turbines at the **Helfta site** at the time of the investigation, IDF was supplied with electricity via a generator. The three completely failed days and the four partially failed days (approx. 20 hours, Table 3) were caused by problems with the generator. If IDF is used in a wind farm, IDF can be connected to the power supply of the wind farm and problems that lead to failures of this type can be avoided.

At the time of the investigation, there were also no wind turbines at the **Plate** investigation site, and IDF was supplied with electricity via a generator. During the entire study period, there were failures of a full day and a partial failure, both of which were caused by problems with the power supply from the generator (Table 3). When deployed in an existing park, this type of failure is not expected.

At the **Gerbstedt** investigation site , at the time of the investigation, there were already wind turbines in the existing park, through which IDF could be supplied with electricity. At the Gerbstedt site, IDF was not in operation for three days (Table 3) because the electricity was cut off in the entire wind farm due to maintenance work. Since the systems were not in operation at this time and the failures were a process planned in advance, these failures must be considered separately as there was no risk of collision.

Existing systems were also already in place in **Lübesse ,** which enabled IDF to obtain power from the wind turbine. In Lübesse there were failures of 14 days (Table 3). Most of the failures are due to a defect in the rotating mechanism of the stereo camera
which was noticed no later than one day after the failure. After replacing the relevant component, the system had to be recalibrated, which resulted in a prolonged failure of 12 days.

In the existing **Bütow park ,** the power supply was also set up via the wind turbine. The three partial failures in Bütow (Table 3) were caused by software problems or defective components. These errors can occur during operation and are caused by

automatic error diagnoses are usually recognized quickly so that failures can be reacted to in a timely manner.

At the time of the IDF investigation, there were no existing systems in **Geislingen .** A generator could be dispensed with, however, as a direct power connection via a 400 V line could be set up at the site. There were no system failures in Geislingen.

4.2 Reference data

In order to test the performance of a system like IdentiFlight, the collection of reference data by a so-called second system is necessary (KNE 2019). In the present study, reference data from a total of three "secondary systems" were used:

1. With the help of a drone, the accuracy of the position determination by IDF examined.
2. The detection rate of birds by IDF was examined by using a laser range finder (LRF, laser rangefinder). The LRF enables the recording of flight paths that are accurate in terms of height and position.
3. On the basis of data from a GPS-transmitted red kite at the Geislingen site, the detection rate of birds could also be checked by IDF. This procedure corresponds to that of the Swiss Ornithological Institute when testing a similar system, DTBird (HANAGASIOGLU *et al.* 2015), as well as in the current research project NatForWINSENT5 (ASCHWANDEN & LIECHTI 2020).

4.2.1 drone

In order to be able to test the accuracy of the position determination of objects by the IDF system at different angles, test flights were carried out with a drone (Figure 26). The drone flights took place at the Plate site in 2018, with flights at different heights (50 m and 100 m), from different directions and in at different distances (maximum 150 m from the IDF system).

The flight pattern of the drone was determined in advance and recorded by an integrated GPS transmitter. The center of this pattern corresponded to the mast center of the IDF system, from which eight sectors of a circle (150 m radius) were flown in sequence in a clockwise direction (Figure 44). At the same time, the respective flight route should be recorded and documented by IdentiFlight so that the two data sets could be compared afterwards. The drone and IDF both had access to the same time server (de.pool.ntp.org), which ensured a synchronous time stamp. The flight speed of the drone was programmed to 24 km / h (6.7 m / s).

A DJI drone (PHANTOM 4 PRO, model GL300F, diagonal 350 mm) was used for the drone flights. The manufacturer of the drone specifies an accuracy of: ± 0.5 m vertically for hovering and an accuracy of ± 1.5 m horizontally. 6

[5] https://www.naturschutz-energiewende.de/wp-content/uploads/Aschwanden_Musiol_KNE-Konferenz.pdf, accessed on May 6, 2020

[6] https://www.dji.com/de/phantom-4-pro/info, accessed on April 7th, 2020

Figure 26: Acquisition test with a GPS-located drone. The small picture shows a picture of the drone by the IDF from a distance of approx. 150 m.

4.2.2 Laser Range Finder

In order to be able to examine the detection performance of birds by IDF, reference data were collected using a laser range finder (LRF, laser rangefinder). The LRF is operated by an observer and, at the push of a button, measures the slope distance, the azimuth and the vertical angle of a target object aimed at with the laser beam (Figure 27). The device uses these parameters to calculate the height of the target object above ground relative to the observer's position. The position of the observer can either be determined by the smartphone via GPS or indicated by the observer as a fixed position on a map in the computer. Multiple generation of data points of a flying bird (system-related maximum approx. 12 per minute) creates a corresponding sequence of three-dimensional flight points. This data as well as a referenced time stamp will be stored either via Bluetooth transmission on an Android smartphone or directly in a connected computer. A flight path (track) with a correspondingly precise location can then be reconstructed from these measurement points.

An LRF from Safran Vectronix AG (model Vector 21 Aero, 7x magnification) was used for the present study. The manufacturer gives the accuracy of the distance measurement with +/- 5 m and that of the angle measurement with +/- 0.2 ° to 0.6 ° at.

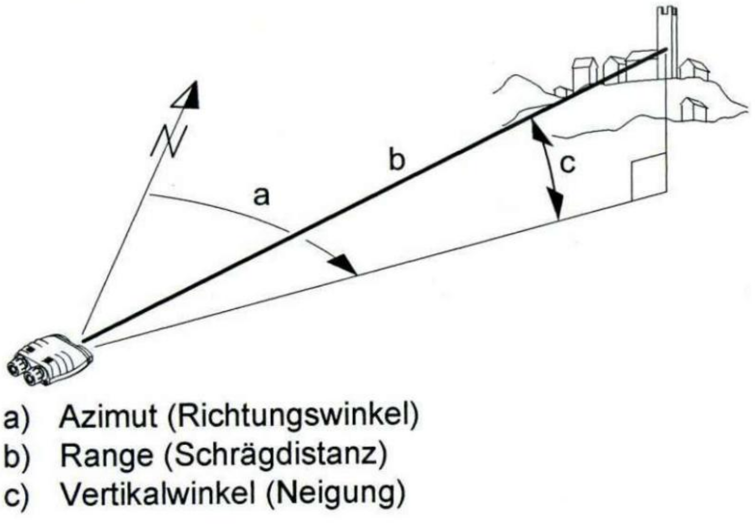

Figure 27: Data determination of the Laser Range Finder Vector 21 Aero (excerpt from the Instructions for use)

Reference data from red kite flight routes were collected with the LRF at all six study sites (Figure 28). At the Helfta, Plate, Lübesse and Bütow sites, LRF data were recorded on 25 days for 6 hours each (6 x 45 min observation and 15 min break), spread over the respective study period. At the Gerbstedt site,

due to a vandalism-related failure of IDF, LRF data is only collected on six days. At the Geislingen site, LRF data were collected on nine days as part of NatForWINSENT II.

The survey phases were varied according to the time of day, but were mainly in the time of the highest flight activity of the red kite between 9 a.m. and 6 p.m. (HEUCK *et al.* 2019). For each LRF track, the species affiliation as well as other peculiarities, such as birds present at the same time or the behavior of the target bird, were recorded. The recording was always carried out with two people, one of whom operated the LRF and the other observed the airspace and logged the data.

At the Helfta and Gerbstedt locations, LRF data acquisition was carried out by the Ökotop GbR office, and by the landscape architecture office Oevermann at the Plate, Lübesse and Bütow locations carried out. At the Geislingen location, the reference flight paths were recorded using LRF by the Swiss Ornithological Institute as part of the NatForWINSENT II7 project .

With the help of the LRF recordings, parallel to the data recording by IDF, an independent sample of red kite trajectories could be generated within the field of vision of IDF will.

Locating using LRF has three potential sources of error that had to be taken into account when analyzing the data: The time stamps of IDF and LRF were not congruent, the position information provided by the observer did not correspond to reality and the LRF tracks contained an angular offset due to an incorrect azimuth measurement.

The time lag between the LRF data and those from IDF could occur due to the use of the LRF in connection with a smartphone. The internal clock of a smartphone, which is set as a time stamp, does not correspond to an official reference time, which is why the error could only be corrected after installing a corresponding app. In the case of data that had already been collected with an incorrect time stamp, the correct time stamp could no longer be reconstructed afterwards. These data were used in the further

Evaluation was not taken into account any further and had to be excluded.

If the observer's position information did not correspond to reality, which could occur due to incorrect position detection by a smartphone, was one Reconstruction of the actual observer position from the further data of the Acquisition days possible. In order to generally rule out this error, the observer position was used as the median of the observer positions in the present analysis Calculated daily, whereby deviating position information was excluded and not taken directly from the recordings.

If the LRF tracks showed an angle error due to an incorrect azimuth measurement, the data could only be reconstructed to a limited extent. If the angular offset was too large, the actual course of the flight path could no longer be traced and the data were excluded from further evaluation.

Due to the strong and largely incomprehensible errors in the LRF data at the Lübesse location, this location was excluded from the further evaluation of the recording rate, as the LRF data from this location does not have the quality that is required as reference data. However, this only applies to the criterion of the acquisition rate; The IDF data from Lübesse can be used without restriction for the additional evaluations.

™ https://www.natur-und-erneuerbare.de/projektdatenbank/projekte/natforwinsent-ii/, accessed on November 27, 2020

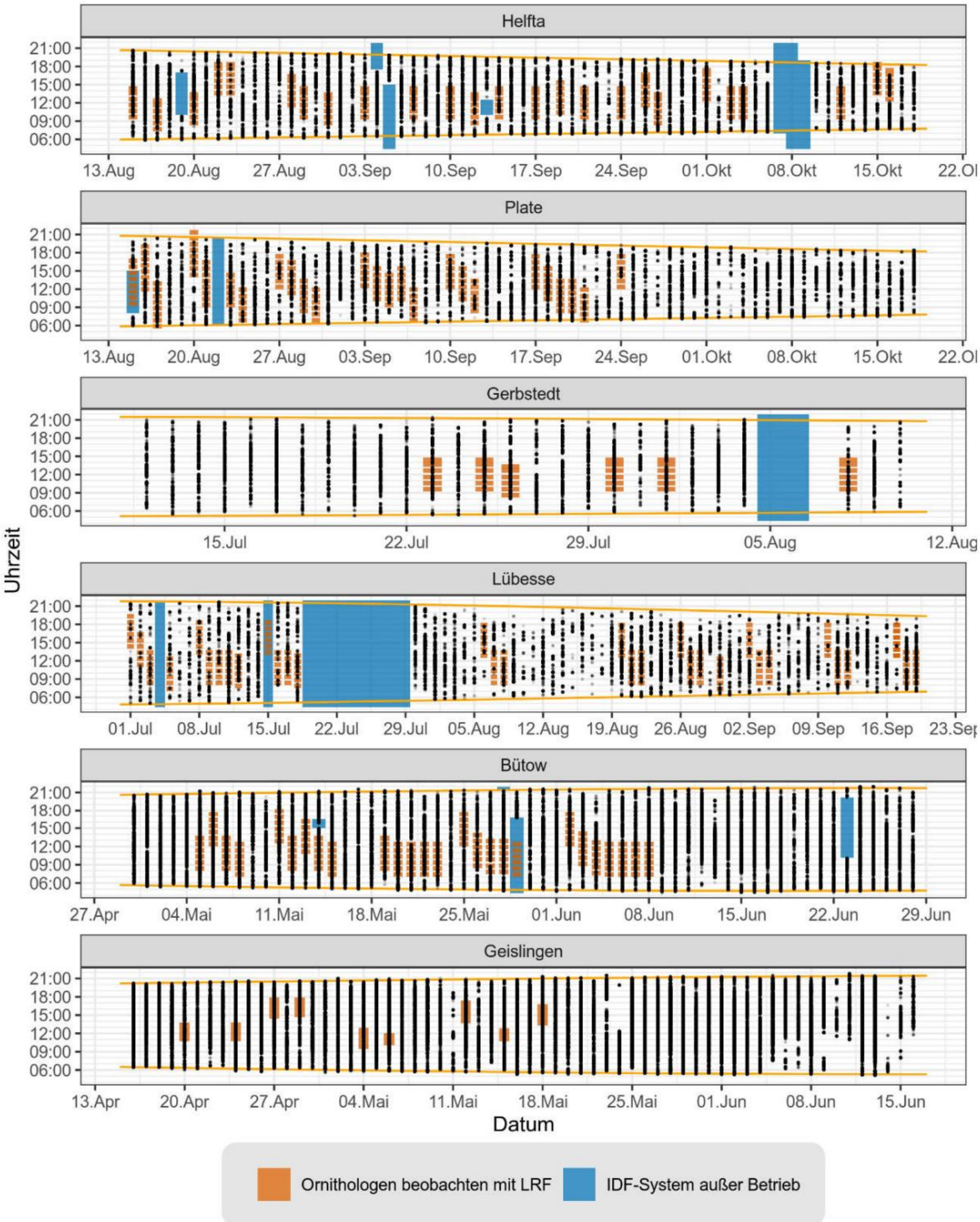

Figure 28: Distribution of IDF and LRF data over the time of day from sunrise to sunset (yellow lines) and over the acquisition period. Each bird position recorded by the IDF system is shown as a black dot. The orange boxes represent the phases of the LRF data collection. IDF downtimes are marked in blue.

4.2.3 GPS telemetry

In addition to the recordings by means of LRF, GPS data from a male red kite with a transmitter was also available at the Geislingen site, which could be used by IDF to check the detection accuracy.

The male red kite "Donzi" was already equipped with a GPS transmitter (model OrniTrack ÿ E25B 3G) in 2019 as part of the NatForWINSENT project8 (Figure 29).
During the IDF investigation at the Geislingen site in 2020, the nesting site of this red kite was approx. 250 m north of the installed IDF system.

The GPS transmitter of the telemetered red kite was set in such a way that it saves the bird's position data at least every 2 minutes when the battery charge status is over 75%; if the battery charge status falls below 75%, data points were collected less frequently. In addition to these general settings, the so-called geofence function enables certain
Specify spatial areas in which data points are to be collected more frequently (depending on from the battery charge status here a maximum of every 2 s). In the case of the male red kite with a transmitter "Donzi", these geofence areas also covered the IDF investigation radius, so that the position data of this red kite - depending on the battery charge status - was largely available in a very precise resolution for this area.

For each data point of the GPS transmitter, the speed (km / h), the direction (°), the altitude (m above sea level) determined with GPS triangulation and the barometrically determined altitude (m above sea level) of the broadcasted red kite recorded. Based on this data, another
independent reference data set of flight movements can be generated, which could be compared with the flight movements recorded by IDF.

The Swiss Ornithological Institute is warmly thanked for providing the data and for the constructive cooperation.

[8] https://www.natur-und-erneuerbare.de/projektdatenbank/projekte/natforwinsent-ii/, accessed on November 19, 2020

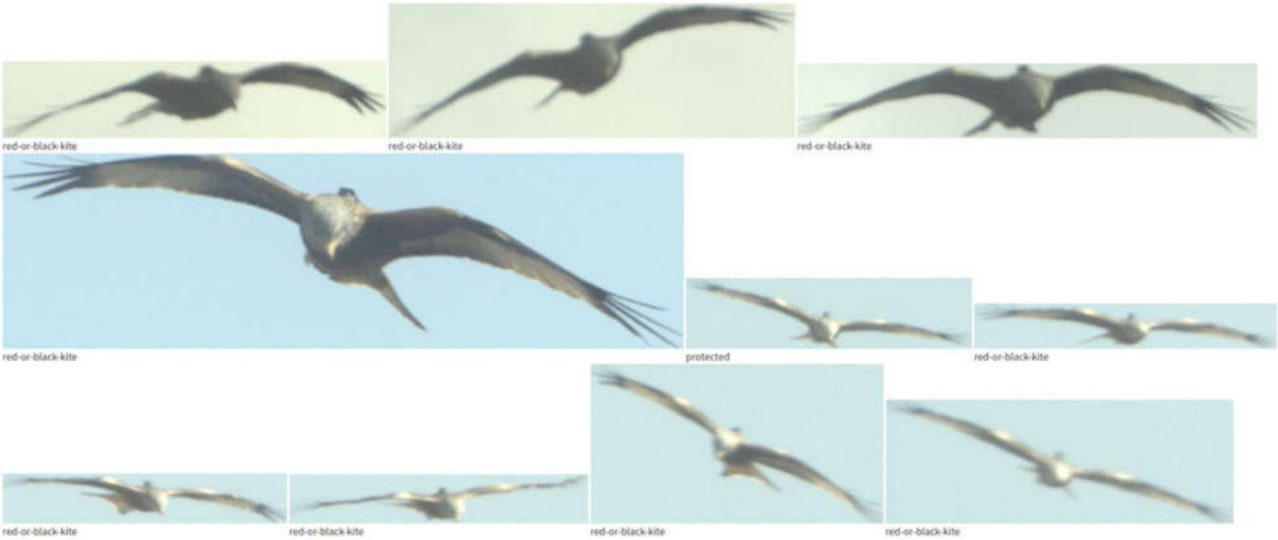

Figure 29: The red kite "Donzi" with a transmitter on it at the Geislingen site in 2020 , its GPS transmitter on the back can be clearly seen in the IDF images.

4.3 Evaluation and statistical analysis

4.3.1 Evaluation software

An efficient processing of the large amounts of data was made possible by the development of its own software solution based on the software "R" by OekoFor GbR, which intersects the data of the reference systems with those of IDF and visualizes them as a whole.
There are three tabs with different functions within the software interface: "IDF data overview", "Detection rate" and "Curtailment".

The register "IDF data overview" was used to view the overall data from IDF and made it possible filter this data according to various parameters (e.g. according to location, species identification or date) and view individual tracks in detail. The images of the selected tracks as well as a cartographic view of the tracks and a representation of the flight altitude over time were displayed. The species information was coded differently in color (Figure 30).

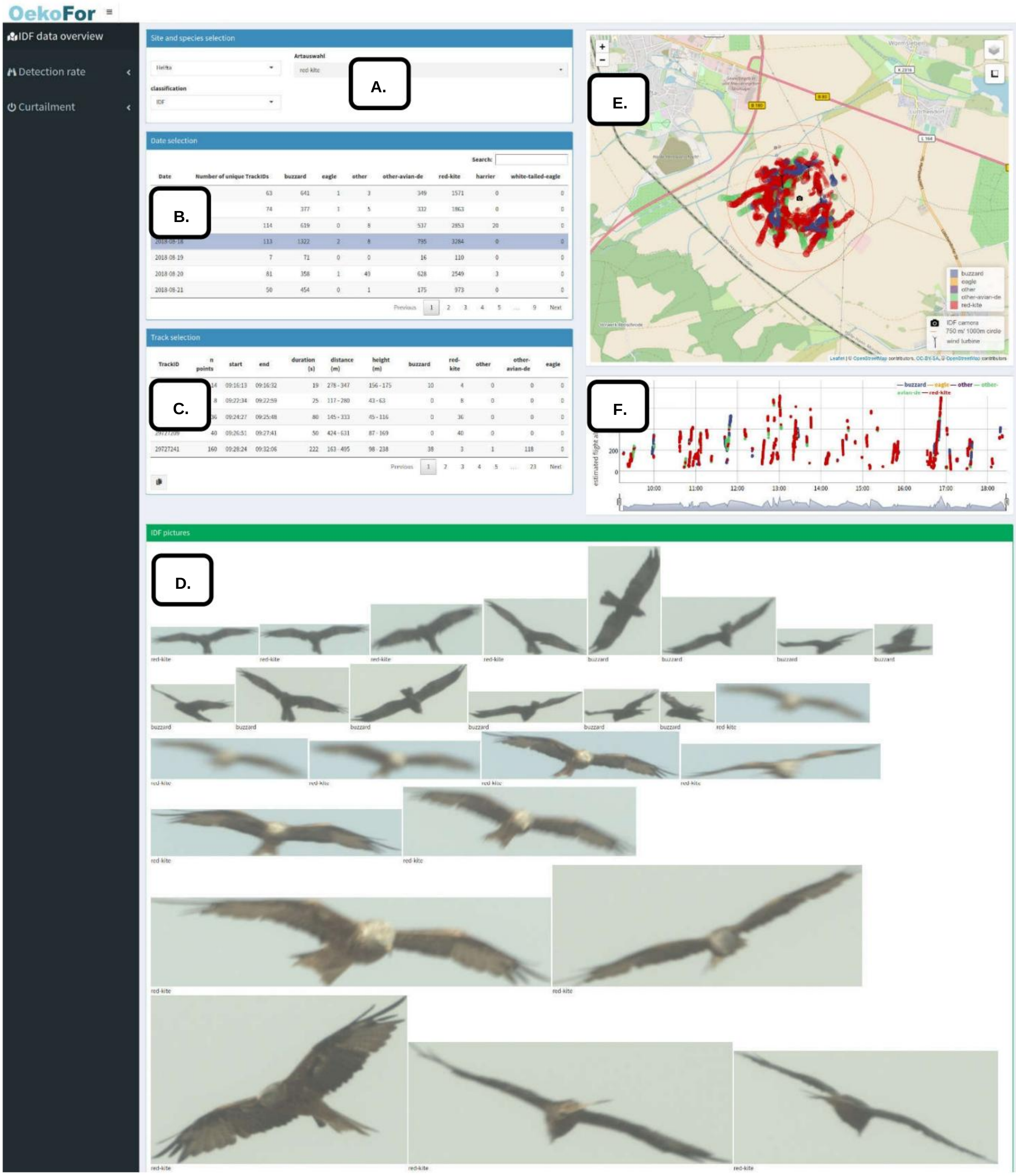

Figure 30: Interface for viewing the IDF data. This view offered the possibility of the IDF data Filter by location by type (A) and day (B) and select individual tracks (C). The images of the selected tracks (D) as well as a cartographic top view of the tracks (E) and a representation of the flight altitude over time (F) were shown, the species information being color-coded.

In the “Detection rate” tab, the IDF data were blended with those of the reference systems (LRF data and GPS data). This view enabled each reference track to be viewed on a case-by-case basis with the associated IDF track (Figure 31). For each bird recorded by a reference system (a reference track) it was possible to evaluate whether IDF also recorded this bird (“positive”) or not (“negative”), or whether the bird was or was not visible to IDF Another protected bird was detected by IDF at the same time
("Neutral"). The assigned categories (“positive”, “negative” or “neutral”) were then taken into account accordingly in the evaluation and are described in detail in the following chapter (chapter 4.3.2).

The "Curtailment" register made it possible to check IDF tracks in which a red kite was verifiably recorded (redefined red kite tracks, see Chapter 5.1) and should have been switched off because the bird was in the inner distance cylinder.

The "Curtailment" view (Figure 32) offered a detailed overview of the individual red kite tracks that were subsequently determined and the parameters recorded by IDF (time of detection of the bird by IDF (outside or inside the inner spacer cylinder) and the classification of the bird by IDF (correctly recognized as Red Kite or not)) as well as the subsequent action by IDF (initiation of shutdown or no initiation of shutdown).

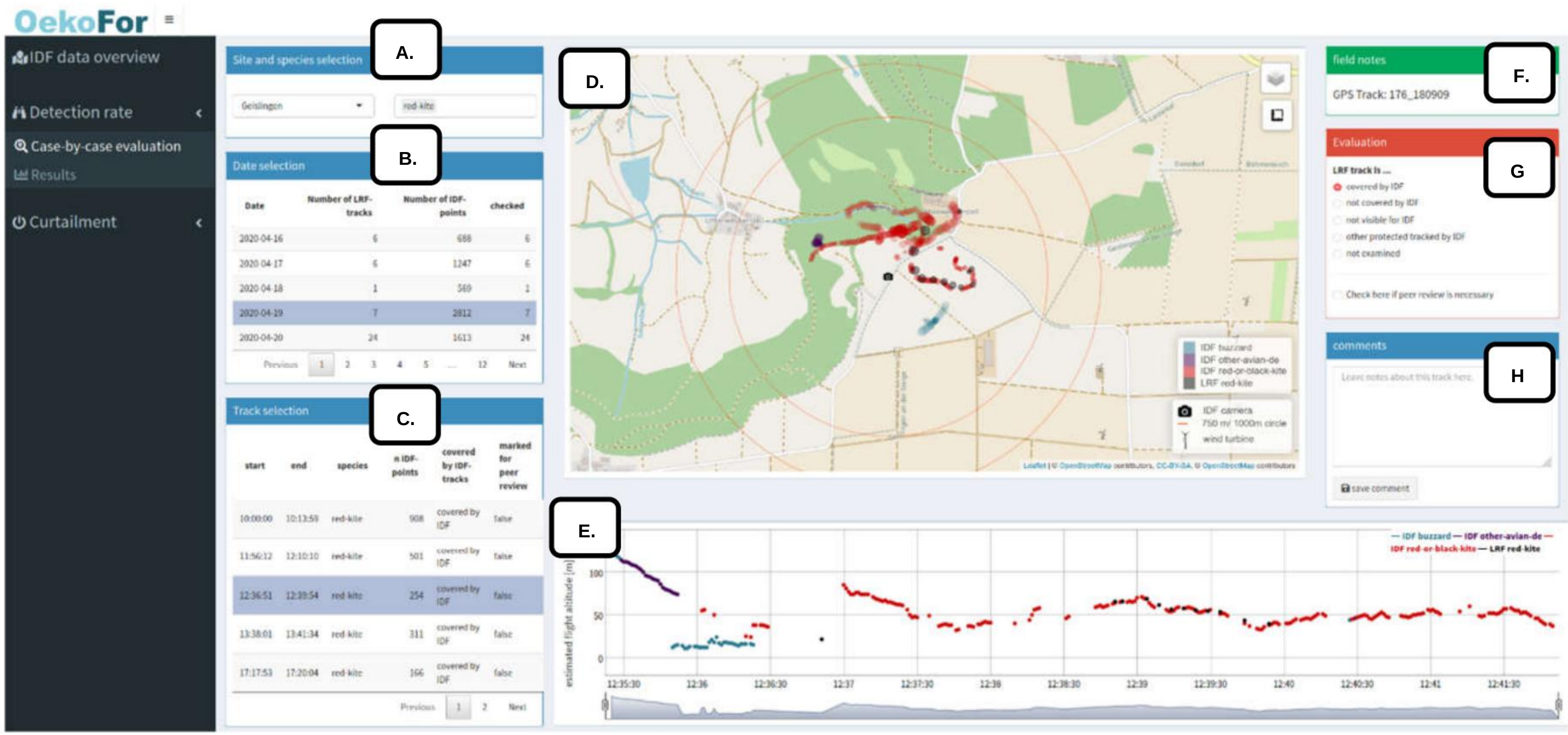

Figure 31: Surface for assessing the detection performance of IDF in relation to LRF and GPS trajectories. This view offered the opportunity Filter overall data by location, type (A) and day (B) and select individual reference tracks (C). The images of the selected data, a cartographic view of the tracks (D) and the altitude over time (E) were displayed, with the type information and the reference track being color-coded. The ornithologists' notes from the log sheets for the recorded tracks were also given (F). Each reference track was assessed by IDF with regard to its discovery (G) and a comment could be added (H).

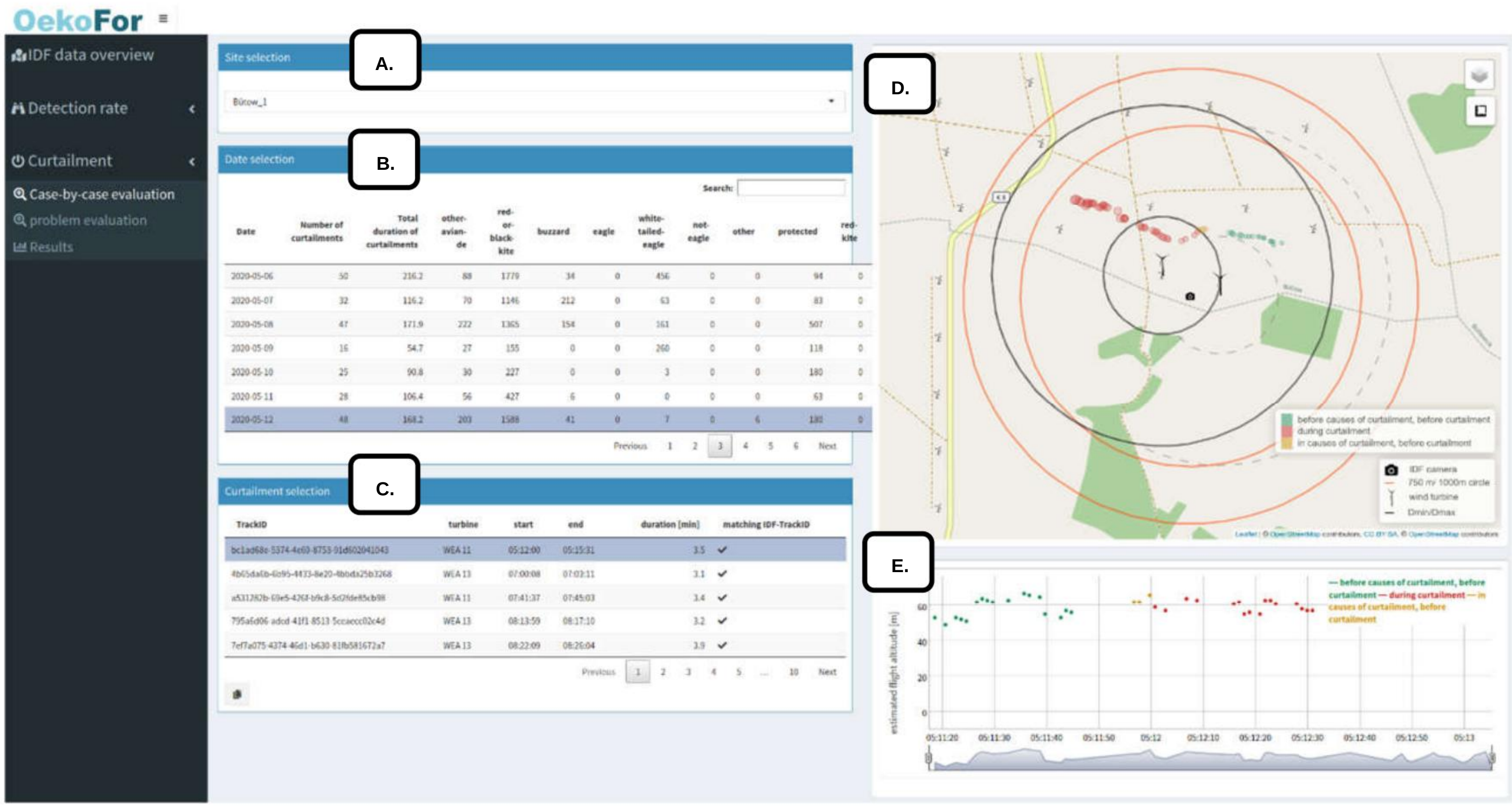

Figure 32: User interface for checking the shutdown processes. This view offered the possibility of red kite flights that crossed the inner spacer cylinder filter by location (A) and day (B) and select individual tracks (C). The images of the selected tracks as well as a cartographic view of the tracks (D) and a representation of the flight altitude over time (E) were shown. The information whether and from when a The individual data that was switched off was color-coded.

4.3.2 Acquisition Rate

4.3.2.1 Reference data from LRF and GPS

A total of 872 LRF tracks and 668 GPS tracks were assessed with regard to their detection by IDF. These were tracks that were recorded during the IDF operating hours (without power failures), were located at a horizontal distance from the IDF within a 750 m radius and were in an area that was visible to the IDF.

To determine the detection performance, the collected LRF and GPS tracks were viewed individually and divided into one of the categories listed in (Table 4).

Table 4: **Evaluation categories of the reference data of LRF and GPS tracks.**

Valid tracks	Recorded	Vogel was also tracked by IDF
	Not recorded	Vogel was not tracked by IDF - for no apparent reason
Invalid tracks	Invalid	Bird was not detected by IDF - Bird was not visible to IDF
	Invalid	Bird was not recorded by IDF - another bird was recorded by IDF at the same time

The “Recorded” category was deemed to have been met if an LRF or GPS track was accompanied by a spatially similar trajectory (position and altitude) was recorded by IDF (Figure 33).
This assessment was more reliable for the GPS tracks than for the LRF data, since the possibility of potential measurement errors was greater with the LRF recordings (see Chapter 4.2.2).

An LRF or GPS track was rated as “Not recorded” if it was not possible to determine a temporally and spatially suitable IDF track for the track (Figure 34). The difficulty with the “Not recorded” rating was to separate this category from those cases in which the bird was not visible to IDF or in which IDF was simultaneously chasing another bird that was classified as protected. Since the IDF system, according to the manufacturer, takes up to 30 seconds to switch between two different birds, this time was set as the limit value for the assessment of a technically possible detection of a bird by IDF.

If one of the two categories “recorded” or “not recorded” was met, the relevant LRF or GPS tracks were rated as “valid” and were included in the evaluation
(see chapter 5.4.1).

On the other hand, LRF or GPS tracks that fulfilled one of the following conditions were rated as "invalid" and excluded from the evaluation (see Section 5.4.1):

The bird measured by the LRF or GPS was not visible to the IDF because the measured bird was Bird was clearly in a shaded area (in front of or behind an object or below the horizon line) or in a masked area of IDF (Figure 35). This assessment was generally carried out very conservatively and only assessed as not visible to the IDF in clear cases.

LRF or GPS tracks were also rated as “invalid” if IDF was chasing another target species bird at the same time and, for this reason, did not record the bird measured with the LRF or GPS (Figure 36).

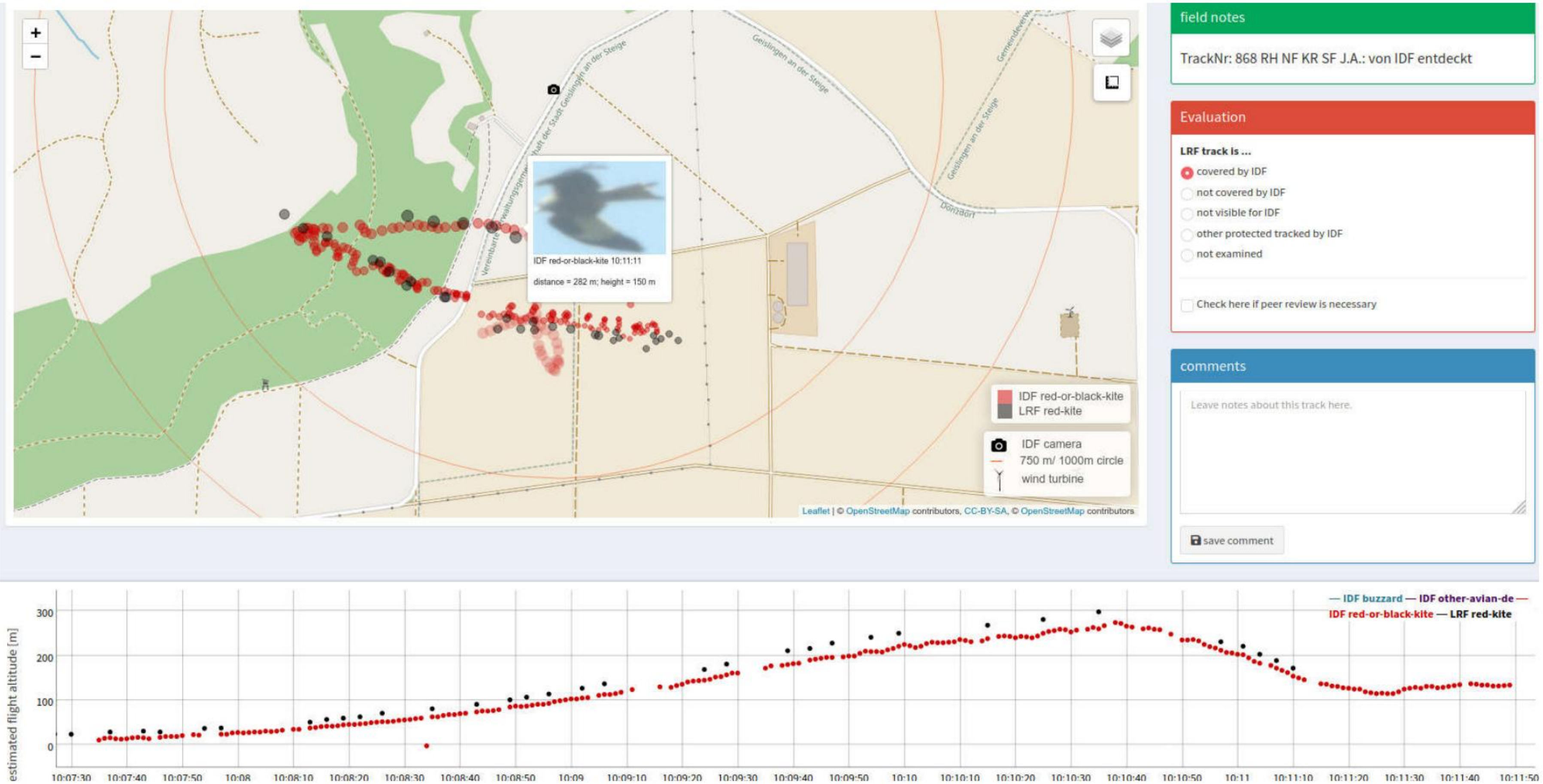

Figure 33: Example for the detection evaluation - category "Recorded". The red kite recorded by the LRF was also recorded by the IDF. Geislingen site, 05/06/2020.

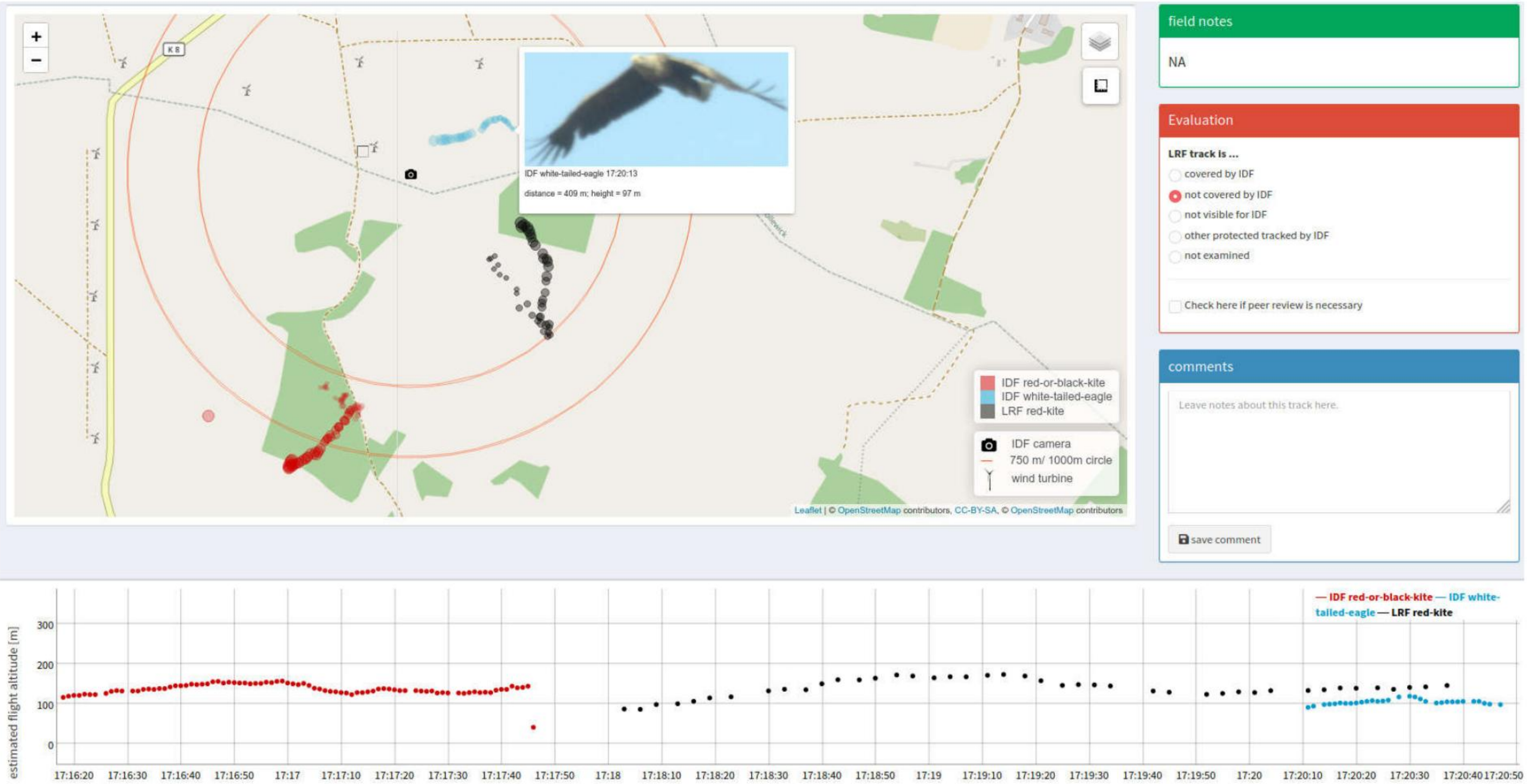

Figure 34: Example for the detection evaluation - "Not recorded" category. The red kite captured by an LRF was not captured by IDF, although no other bird was captured by IDF for more than 30 seconds before IDF captured a white-tailed eagle. Location Bütow, May 6th, 2020.

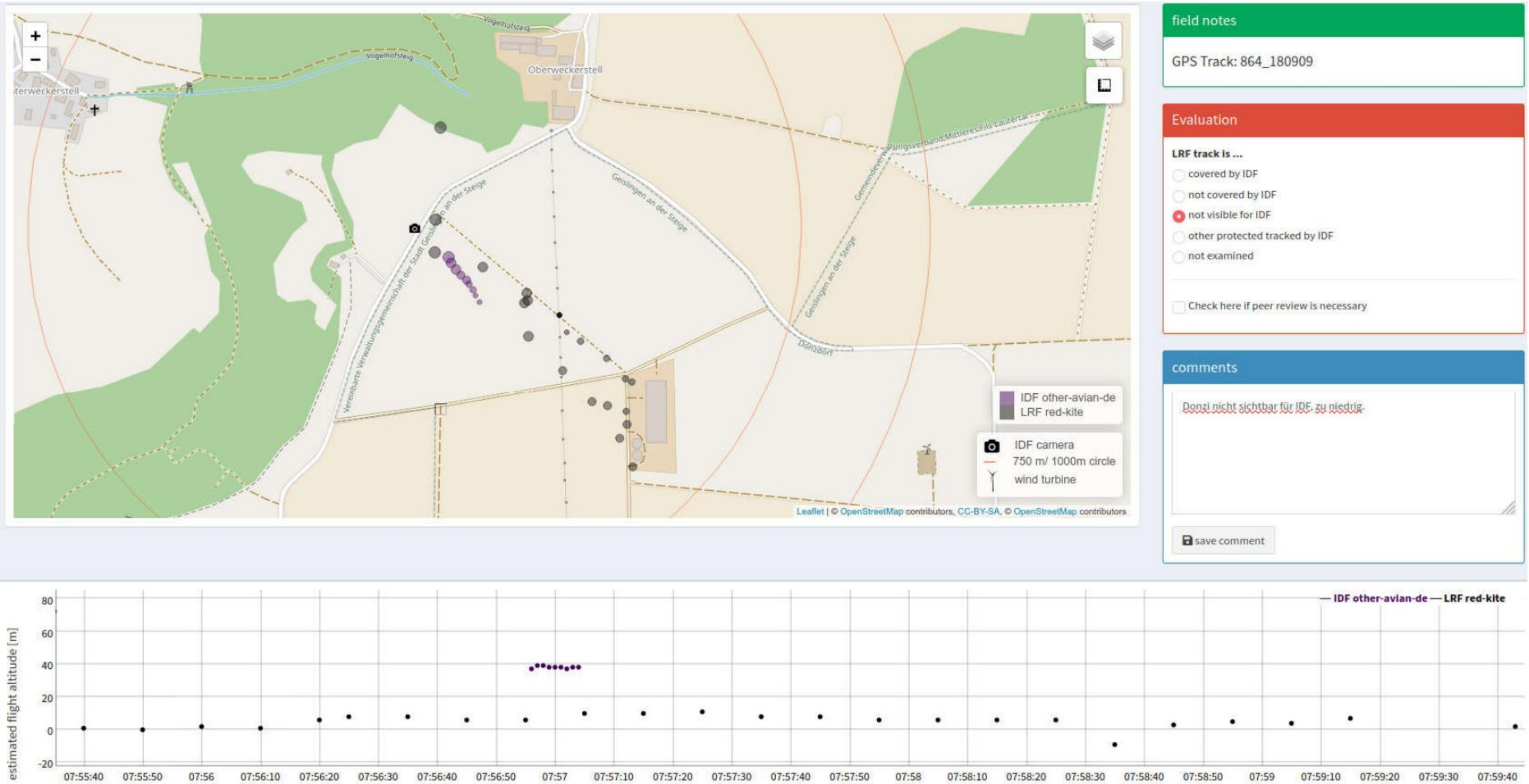

Figure 35: Example for the detection evaluation - "Invalid" category. The red kite "Donzi", which is localized by his GPS transmitter (in the illustration differently called "LRF red-kite") starts from a power pole and flies very low and invisible to IDF below the horizon to his nest to the north by IDF. Geislingen site, May 6th, 2020.

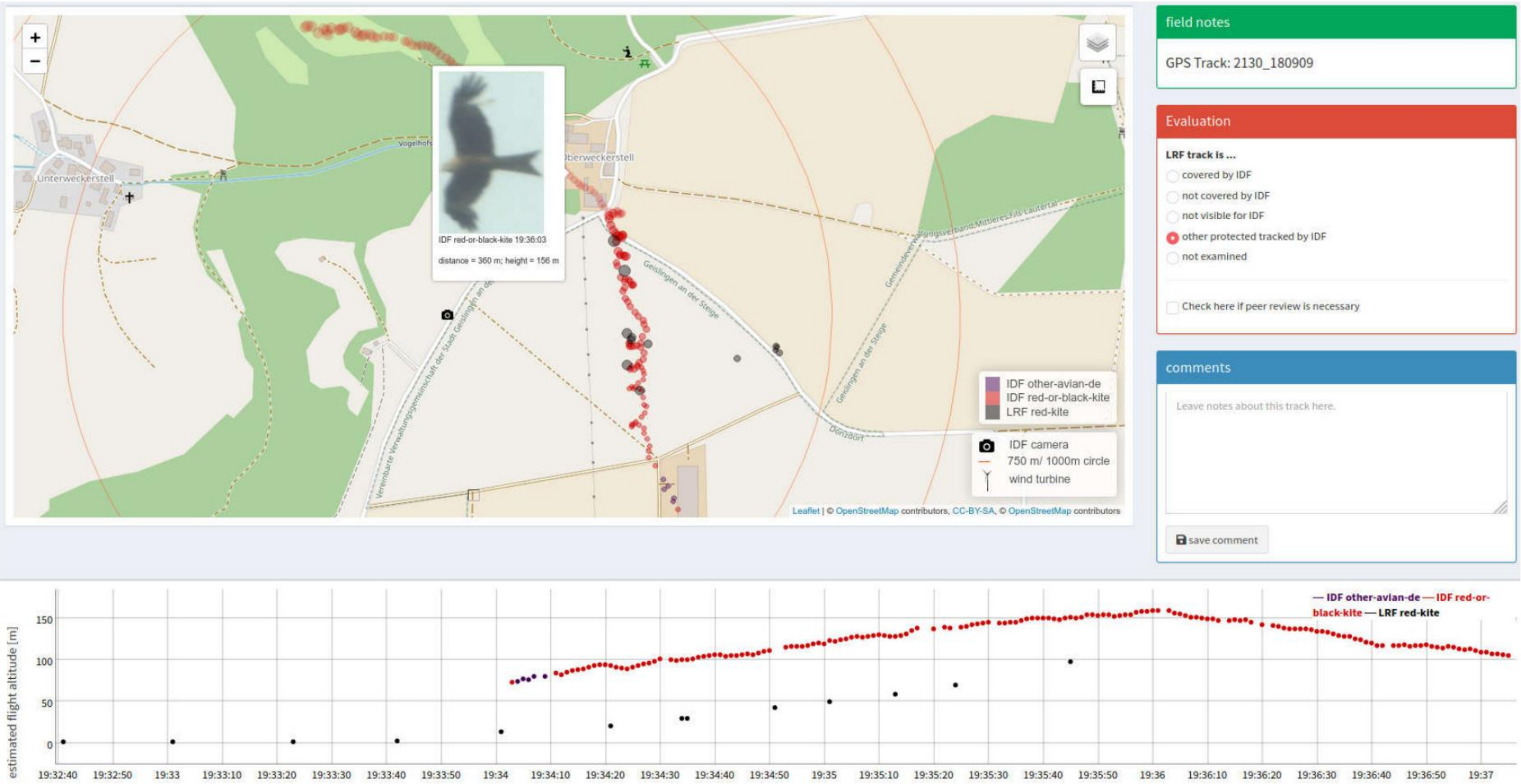

Figure 36: Example for the detection evaluation - category “invalid”. A red kite captured by IDF is being chased by "Donzi". Here is only through the Flight altitude shows that the red kites recorded are two individuals. In addition to the IDF recording points, the illustration shows the GPS data of the red kite (differently referred to as "LRF red-kite"). Geislingen site, June 7th, 2020.

4.3.2.2 The influencing factor precipitation

The detection rate of IDF can be reduced by weather influences such as precipitation, as these influences can affect the visibility or visibility of flying objects - analogous to the perception by the human eye.

For this reason, precipitation data were collected at the Helfta and Plate locations in 2018 by a small, locally installed weather station. Precipitation data is also available for 2020 at the Geislingen site, which was collected in the course of the NatForWINSENT II project and made available for the present study.

For the evaluation of the influence of precipitation on the collection rate of IDF, the available precipitation data were temporally blended with the corresponding IDF collection data for the respective locations.

4.3.2.3 Influence of the position of the sun

According to the manufacturer, the direct view from IDF into the sun leads to a "blind spot" of 15 ° around the sun due to the high level of brightness. A bird cannot be detected by the IDF system in this area.

It was assumed that when the sky is overcast, no effect with regard to possible overexposure can be detected and thus the position of the bird relative to the sun should not have any influence on the detection performance of IDF. On the other hand, the effect should be particularly noticeable when the sky is clear.

In order to check this information, the influence of the position of the sun on the detection performance of IDF at the Bütow location was examined in 2020. For this purpose, the respective weather situation was photographed every minute with a camera (GoPro Hero 7 Black) (Figure 37). From this data, periods of overcast skies (60 hours) and periods of clear skies (112 hours) were identified for a period of 19 days.

In order to determine the influence of the position of the sun on the detection performance, for both Cloudy situations the minimum difference angle of the first point of a flight path to the position of the sun is calculated and for differences between the minimum

Investigated difference angle with overcast or clear sky. It should be noted that, for geometric reasons, a uniform frequency distribution cannot be assumed. In addition, the frequency distribution is influenced by the distribution of birds in space and the course of the position of the sun. For example, very large difference angles close to 180 ° are rare and can only occur at sunrise or sunset if the bird is on the horizon in the opposite direction to the sun at that time.

Later in the day, however, such large difference angles can no longer occur, the difference angle would be mathematically in the opposite direction below the horizon.

Figure 37: Images from the weather camera in Bütow on June 14, 2020, on the left at 8:23 a.m. when the sky is overcast, on the right at 6:20 p.m. when the sky is clear.

4.3.3 Classification

The basis for the assessment of the classification performance are the photos stored by IDF, which are available for the data point recorded every second. For this purpose, a total of 863,100 individual items from 39,782 tracks were evaluated (Table 5).

From the investigations in 2018 and 2019 at the Helfta, Plate, Lübesse and Gerbstedt sites, all recorded tracks were determined by ornithologists from ARSU GmbH and OekoFor GbR (Table 6, Chapter 5.1). At the locations in 2020 (Bütow and Geislingen), such high flight activity was recorded that not all photos could be viewed and only a number of tracks comparable to previous years was determined. In Geislingen there were a total of 10 days between April 20th. and 18.05.2020, for Bütow 18 days between 13.05. and 08.06.2020. A sufficiently large sample could be ensured for all data collection years (Table 5).

The software tool viInspector from the IDF manufacturer was used for all subsequent determinations.

This software tool made it possible to collectively evaluate the data points summarized by IDF as a track (see chapter 2.2.1). Since data points are summarized as a track, which are temporally and spatially close to each other and are very similar in terms of flight direction, it could also happen that IDF trajectories of different birds

summarized in a track when the individuals flew very close together.
These mixed tracks were divided according to the detected birds in the evaluation of the classification.

Table 5: **Data basis for the classification performance of IDF**

	Tracks	Single items
Helfta	10,072	248.287
Plate	8,120	149,707
Luebesse	5,554	86.014
Gerbstedt	4,711	105.118
Butow	4,673	145,100
Geislingen	6,652	128,874
total	**39,782**	**863.100**

To assess the classification performance, two distance radii around IDF were examined, one up to 250 m, which corresponds approximately to the radius of the inner distance cylinder around the wind turbine. On the other hand, up to 750 m, which corresponds to the detection range for IDF according to the manufacturer or the radius of the outer spacer cylinder.

4.3.4 Effectiveness and efficiency of the shutdown

To test the effectiveness and efficiency of the shutdowns generated by IDF
only tracks of post-determined red kites are used, in which a shutdown was triggered by passing the inner distance cylinder.

Shutdowns due to the detection of a red kite in the outer distance cylinder were not considered further, since the generation of the shutdown is based on a prediction of the algorithm ("collision course", based on the flight behavior and the flight speed of the bird, see Chapter 2.3), which is not in detail could be checked. For this reason, only those shutdowns that occurred on the

criterion actually occurred - target species is in the inner spacer cylinder - are based, in particular also because these are mandatory shutdowns, not optional ones as in the outer cylinder.

On the basis of the determined position of the bird (distance to the wind turbine and flight altitude) at the time of the shutdown, it was possible to calculate in how many cases the shutdown was still outside of the inner spacer cylinder, when entering the inner spacer cylinder or only within the inner spacer cylinder.

In the case of "shutdown when entering the inner distance cylinder", it should be noted that IDF can only generate a shutdown when the target species (here the red kite) has been detected in the inner distance cylinder, which means that the target species is present for at least one data point must have already been in the inner spacer cylinder. For this reason, horizontal and vertical buffer areas were assumed for the case of "shutdown when entering the inner spacer cylinder", within which a shutdown had to take place in order to be assessed as correct. The buffer areas applied from the border of the inner spacer cylinder to the wind turbine. The horizontal buffer was 25 m and the vertical one

Buffer fixed at 10 m. At an average airspeed of 8.5 m / s (see chapter 4.3.5), 25 m of horizontal buffers correspond to a time buffer of around 3 s. During this time, the IDF system can detect and classify a flight object and, if necessary, switch it off initiate.

4.3.5 Flight behavior of the red kite

The positions of the red kites determined by the IDF allow the trajectories of the recorded birds to be traced in detail in terms of space and time (Figure 38 to Figure 40, see also Chapter 5.2). In this way, the altitude and the airspeed
can be calculated both horizontally and vertically. The flight speed can be used to determine the length of time that the bird needs at a certain distance from the wind turbine to get into the rotor radius from the side or from below or above. Based on these results, the necessary parameters for the spacer cylinder (see Chapter 2.3) can then be derived.

The IDF system does not detect red kites randomly, but prioritizes target birds in the danger area (proximity to the wind turbine, flight at rotor height). In addition, birds that fly very low below the horizon or in front of the background are poorly recorded by the IDF system compared to those in front of a light background. This means that the flight altitude distribution based on the IDF data cannot be directly compared with that determined on the basis of telemetered birds, since the altitude ranges prioritized by the IDF system are overrepresented.

The altitude calculated by IDF refers to the altitude relative to the height of the stereo camera (4 m to 10 m, depending on the location). This is based on the fact that, on the one hand, no exact digital terrain models were available for the sites under investigation, and on the other hand, the site heights of the IDF system and the examined virtual or real wind turbines differed by only a few meters, if at all. This difference lies within the fluctuations in the detection accuracy of the IDF system and was therefore not considered relevant. In the further evaluations, the altitude above the camera is therefore equated with the altitude above the ground. However, this must be taken into account when determining the flight altitudes at locations at which the heights between the IDF system and the wind turbine differ significantly.

For the calculation of the altitude and flight speed of the red kite, only those tracks from the six investigation areas were used which could be reliably determined as red kite tracks based on the photos.

An IDF track is made up of the totality of all data points that IDF assigns to a single flight object (see chapter 2.2.1). For the calculation of the flight speed of the red kite, only data points from the tracks with a maximum interval of 1.5 s and a minimum of 0.5 s were used. This was to ensure that only sufficiently precise and coherent trajectories were used for the speed calculation in Figure 38. The movement of the bird between the individual data points could thus be assumed to be straight, even if the flight path of the bird as a whole (all data points of the track are connected) describes, for example, a circular shape (Figure 38).

Furthermore, only tracks were used for the calculations in which speeds of <40 m / s (144 km / h) were output for the individual data points. At speeds> = 40 m / s, it was assumed that these were jumps between different individuals that were incorrectly assigned to a single track by IDF, or other incorrect measurements. In addition, an attempt was made to use only the most accurate possible measurements of the data points by IDF, which is why points at a horizontal distance of more than 600 m to the IDF locations and those with an altitude of more than 400 m were excluded as the basis for calculation.

Since the calculated altitude and speed can fluctuate greatly between the individual points for technical reasons, a "moving average" was calculated, which averages the altitude and speed of each point with the two points before and the two points after. This method approximates the actual flight altitude and speed of the bird by averaging out the measurement errors of IDF. The flight altitude was calculated as the height of the bird above the position of the IDF stereo camera at a height of approx. 10 m.

In this way a total of 76,175 averaged altitudes and speeds were calculated. This corresponds to more than 20 hours of continuous recording every second, distributed over the various red kite individuals in the six study areas.

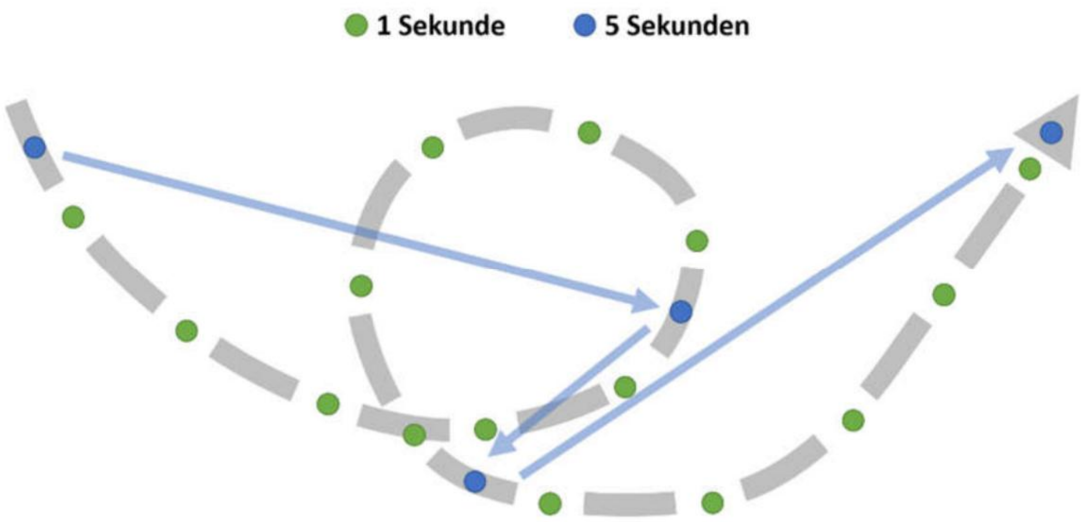

Figure 38: Schematic sketch of a flight path (gray dashed line), which was recorded every second (green points) or every 5 seconds (blue points). The blue arrows show the direct route between the blue measuring points, but this does not represent the actual distance traveled by the bird, which is why only data points with a maximum distance of 1.5 s were used to calculate the flight speed.

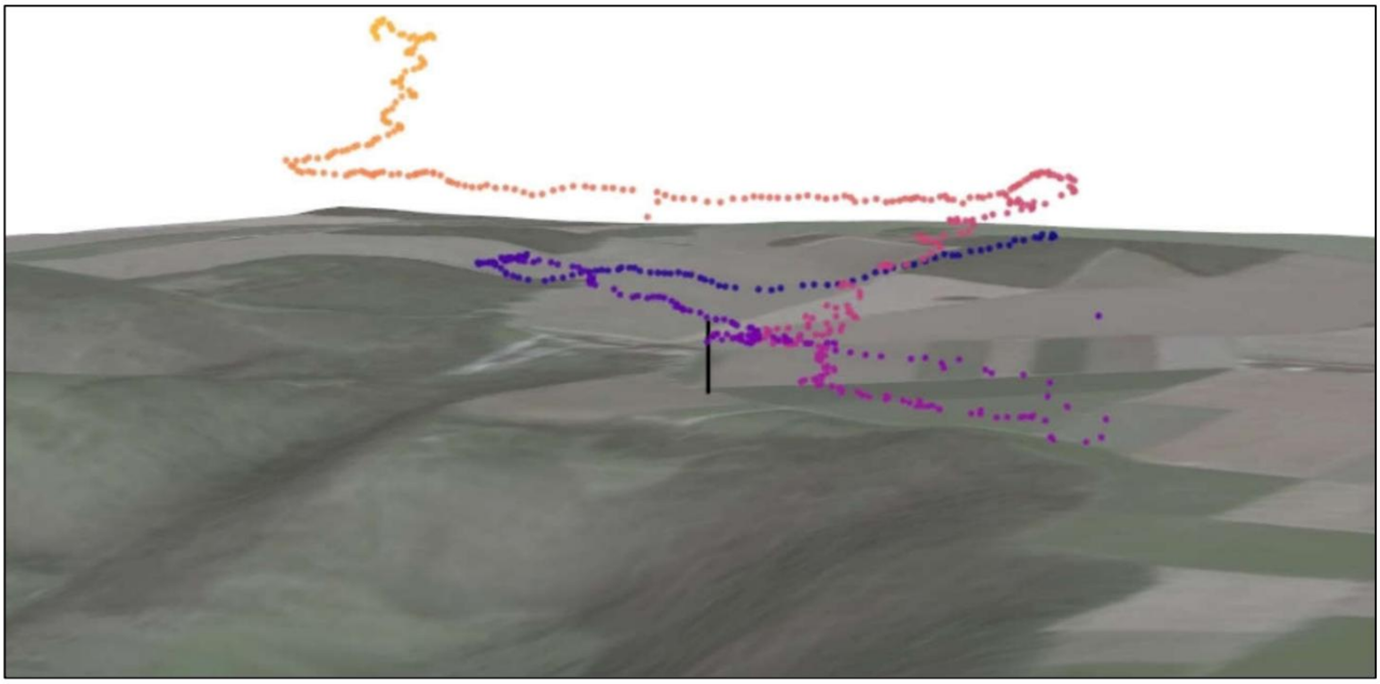

Figure 39: 3D illustration of a red kite trajectory. The trajectory is made up of 627 individual detections. The black line in the center marks the position of the IDF system (not to scale). Geislingen site, June 3rd, 2020.

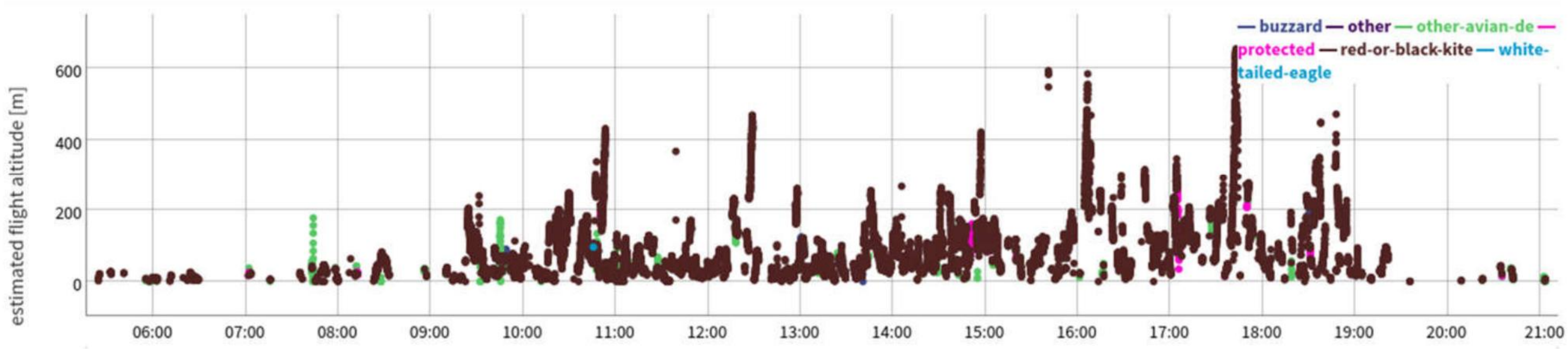

Figure 40: Typical height distribution of tracks of red kites determined by IDF. The vertical distribution of the tracks, which was used to determine the flight altitudes, can be clearly seen. Data basis: all red kite points of a sample day at the Geislingen location, June 1st, 2020.

5 results

5.1 Achieved data basis

In this study, a total of 77,254 flight paths (tracks) of detected objects in flight were recorded by IDF at the six investigation locations. In total, all tracks result in over 1.8 million data points. A re-determination of all tracks was not possible due to the wealth of data at the Bütow and Geislingen sites (see Chapter 4.3.3). The red kite was reliably determined in 8,522 tracks, with which 275,394 data points could be collected for this species (Table 6).

Table 6: **Number of evaluated tracks and individual points for the classification performance of IDF.**

	Total data		Post-determined red kites	
	Tracks	**Single items**	**Tracks**	**Single items**
Helfta	10,072	248.287	1.963	69,429
Plate	8,120	149,707	1,379	35,077
Luebesse	5,554	86.014	989	21,880
Gerbstedt	4,711	105.118	1,079	34,403
Butow	22,417	442.966	1,813	43,243
Geislingen	26,380	806.798	1,299	71,362
total	77,254	1,838,890	8,522	275.394

The data collected by IDF is available as point information in three-dimensional space.
If one looks at the horizontal distribution of the positions of all recorded birds around an installed IDF system, it becomes apparent that the local distribution of bird activity between the locations shows significant differences (Figure 41). For example, in Plate there was an area with particularly high bird activity north and further south of IDF. This information provides information about particularly heavily frequented areas in the vicinity of IDF and also allows conclusions to be drawn about the general horizontal detection range of IDF.

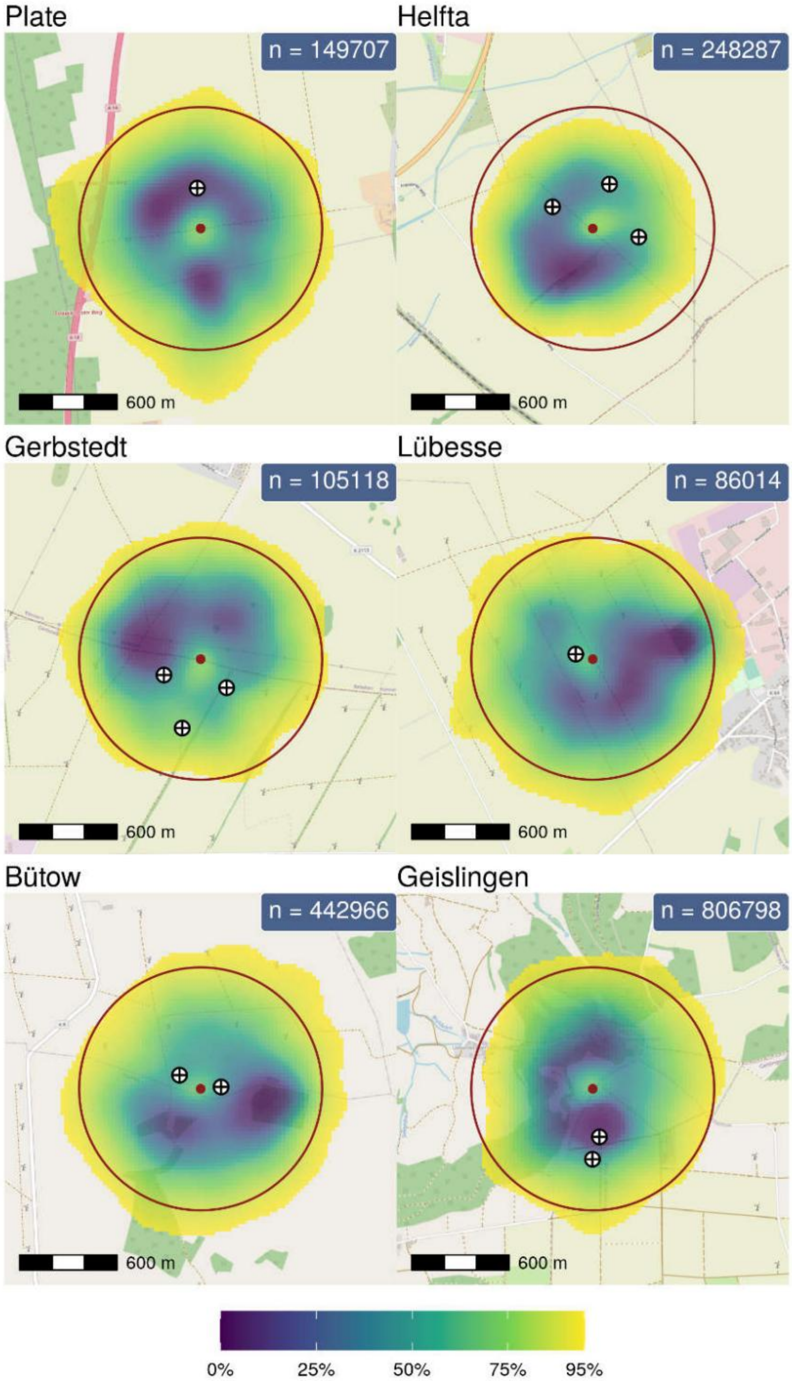

Figure 41: Kernel density estimate of the locations of all trajectories recorded by IDF (all Bird species). The darker the color, the higher the activity recorded by IDF. The color gradient is to be read cumulatively, so that, for example, 50% of the measured activity occurred in the areas that have the colors from 0% to 50%. The installed IDF system is marked as a red point and the 750 m radius around IDF as a red circle. The virtual or actual wind turbines are marked with black and white symbols.

Looking at the distribution of the recorded red kites from the position of IDF in horizontal and vertical direction, detailed views of the flight activity of the red kite in all directions around IDF can be generated, but without knowing the respective distance to IDF.
In addition, it should be noted that the two-dimensional projection of a "dome" around IDF causes the display to become increasingly distorted with increasing angle of inclination, which means that the point clouds appear less dense with the same activity (Figure 42 and Figure 43).

At the Helfta site there is a strong concentration of the recorded red kite activity in the south-eastern area detectable flat above the horizon. In this area there is a small wood, in which carrion was at times, which was a great attraction. In Lübesse, there is a concentration of flight activity over the breeding forest there in the east (distance approx. 700 m, see Figure 12). A similarly noticeable increase in flight activity can also be seen at the Bütow site, with the forest area with the breeding ground for a pair of red kites only approx. 400-500 m away. In Geislingen there is generally increased activity in the north (left and right edge of the picture), located at this point

the breeding site is only 250 m away. There is also a noticeable concentration in the south. There, hunting activities increased around a pigsty (see also Figure 51).

The absolute differences in the red kite flight activity with an overall significantly higher point density in Helfta, Bütow and Geislingen compared to lower densities in Plate, Gerbstedt and Lübesse can also be seen.

Overall, all locations showed a sufficiently high level of red kite activity to be able to carry out the studies on the effectiveness of IDF with regard to the red kite.

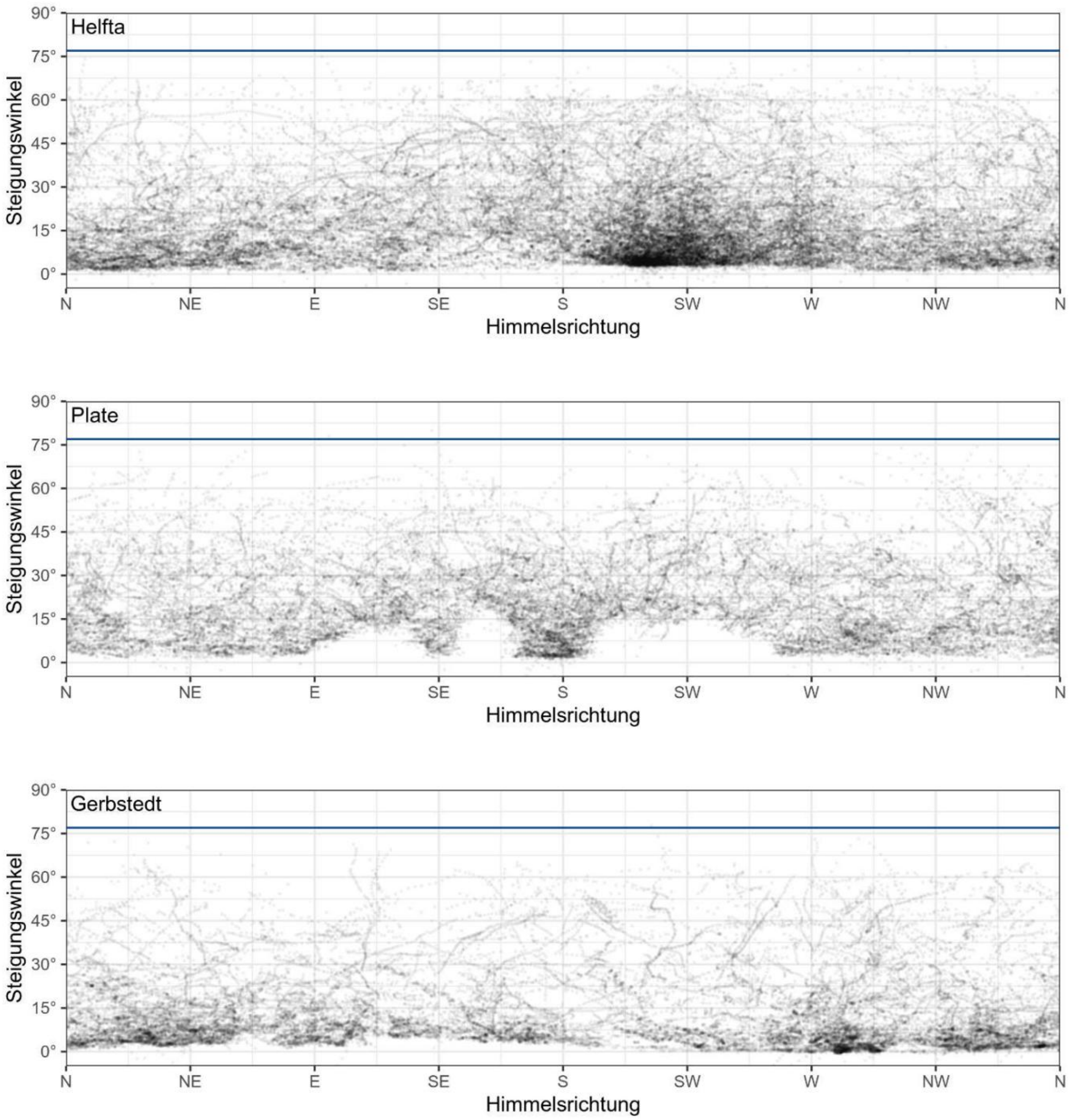

Figure 42: Red kite activity at the Helfta, Plate and Gerbstedt sites. The graphics show all positions of the kites recorded by IDF (Red-Black-Kite) over the direction of the compass and the angle of incline. The maximum pitch angle of the IDF stereo camera of 77° is marked with a blue line.

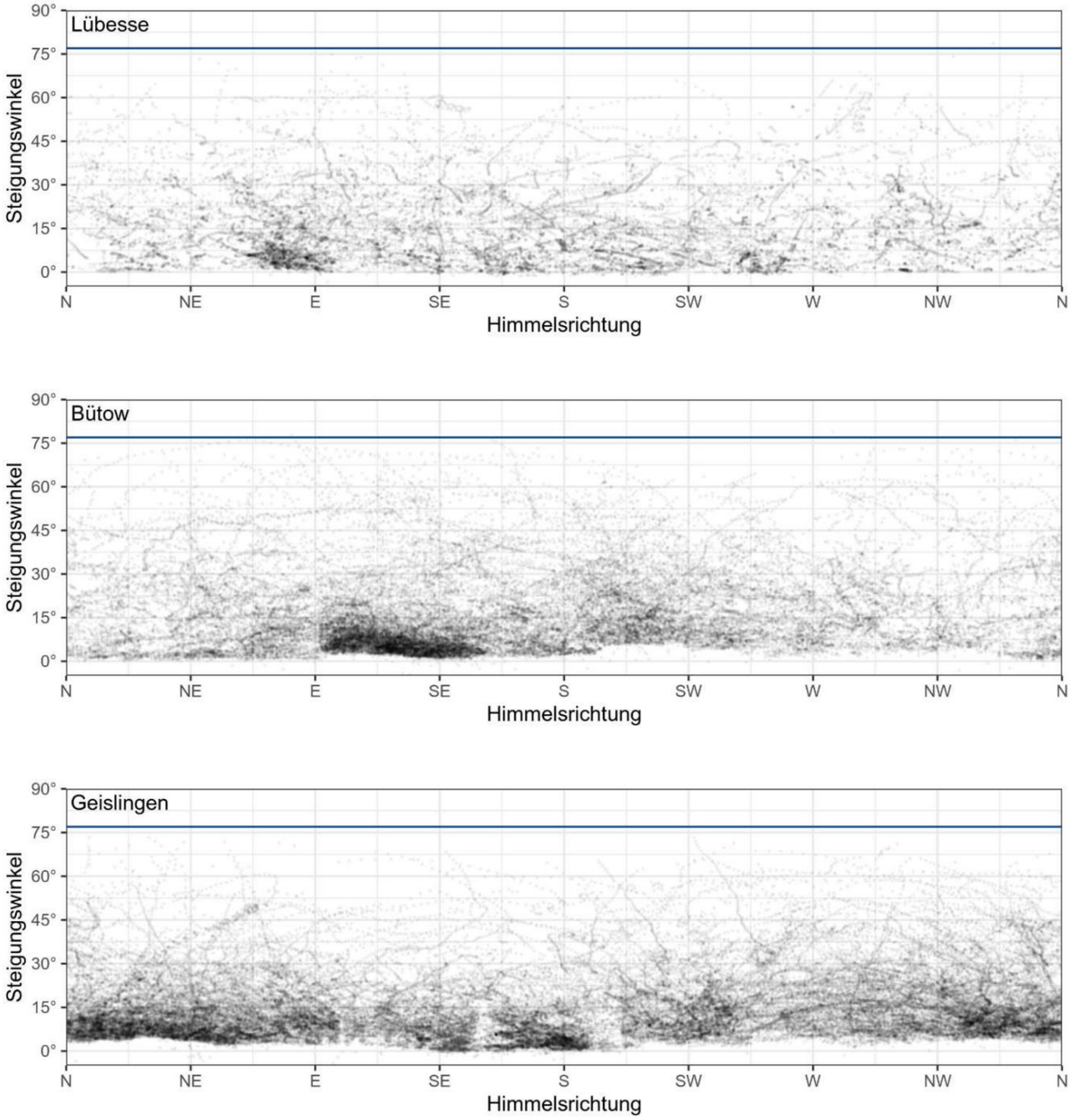

Figure 43: Red kite activity at the Lübesse, Bütow and Geislingen sites. The graphics show all positions of the kites recorded by IDF (Red-Black-Kite) over the direction of the compass and the angle of incline. The maximum pitch angle of the IDF stereo camera of 77° is marked with a blue line.

5.2 Location accuracy

5.2.1 GPS data from a drone

Overall, the trajectories of the drone recorded by IDF show a very high level of correspondence with the GPS points of the drone flights. There are no differences in accuracy with regard to the two tested flight heights (50 m and 100 m) (Figure 44 and Figure 45).

Horizontally, the median of the deviation of the IDF measurement points from the GPS drone positions is around 8 m. This result corresponds to the expected error in the GPS positioning of the drone in combination with the measurement accuracy of IDF of +/- 5% (Figure 45).

Vertically, the median of the deviation of the IDF measurement points from the GPS drone positions is even significantly lower and is between 1.7 m and 3.2 m (Figure 45). Given this high level of agreement, it is noteworthy that IDF was not trained on the drone as a target species.

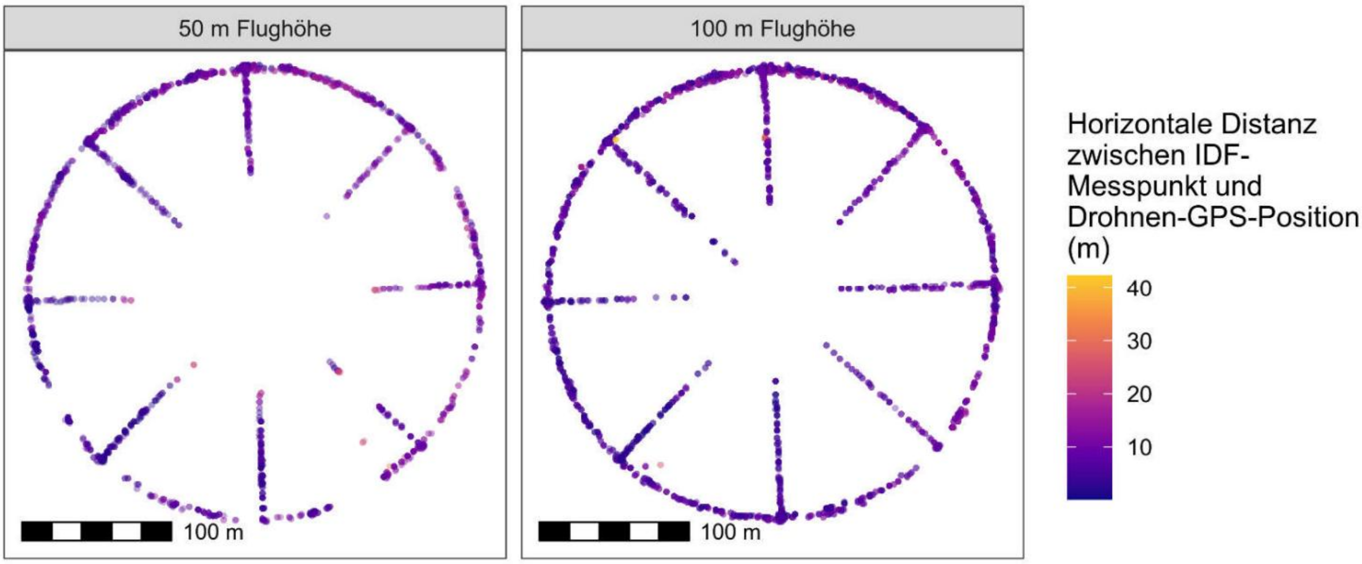

Figure 44: Locations of the drone by the IDF at different flight altitudes (50 m and 100 m). Of the The color gradient shows the difference between the horizontal position determination by IDF and the GPS position of the drone. The radius of the flight paths is 150 m.

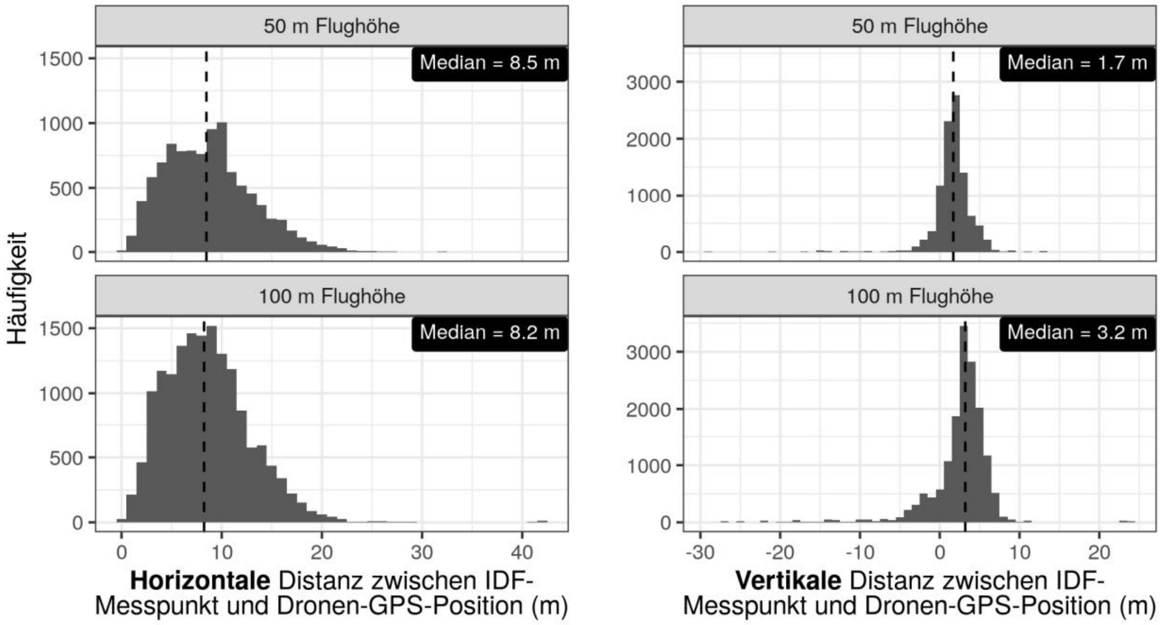

Figure 45: Deviation between the GPS position of the drone from the horizontal (left) and the vertical (right) positioning by IDF for two different altitudes (50 m and 100 m).

5.2.2 Laser range finder data and GPS data of the red kite with a transmitter

The comparison of flights of the red kite, which were recorded by reference systems and Data from the LRF surveys as well as the GPS transmitter from the red kite "Donzi" were primarily used to determine the acquisition rate and not the location accuracy.

If one looks at the correspondence between the IDF locations and the data of the LRF, it becomes apparent that the IDF data has a high degree of positional accuracy with regard to the locations of the LRF (Figure 46). In such cases, the high level of correspondence between the IDF and the LRF allowed a clear assessment of whether the bird recorded by the LRF was also recorded by the IDF.

However, interference with the electronic compass used to determine the azimuth can easily lead to angular misalignments in the LRF when it is located by the LRF (Figure 47 and Figure 48). The assessment of whether it is the same bird depends on the respective data situation. The examples in Figure 47 and Figure 48 show simultaneous flight paths for the IDF and the LRF with sufficient individual locations to be able to conclude that it must be the same bird. Was this not the case because e.g. B. there were only a few points without temporal overlap, and there was also an angular offset
(which would not be recognizable in such a case), it could not be judged whether it was the same bird and it had to be assumed that the IDF was the one from the LRF

has not detected the detected bird. Such cases occurred particularly frequently at the Lübesse location, which is why the LRF data at this location could not be used as reference data for the acquisition rate.

If you look at the accuracy of the location in comparison to the GPS transmitter, it turns out that the IDF data show a high degree of agreement with the GPS data (Figure 49 and Figure 50). The determination of the flight altitude is partly consistent (Figure 49), but partly the flight altitude between IDF data and GPS data deviates more clearly (Figure 50). This is probably due to the fact that the determination of the altitude with GPS transmitters can be relatively imprecise. The high degree of correspondence between the IDF data and the data from the GPS transmitter made an assessment of whether the bird recorded by IDF was "Donzi" very reliable.

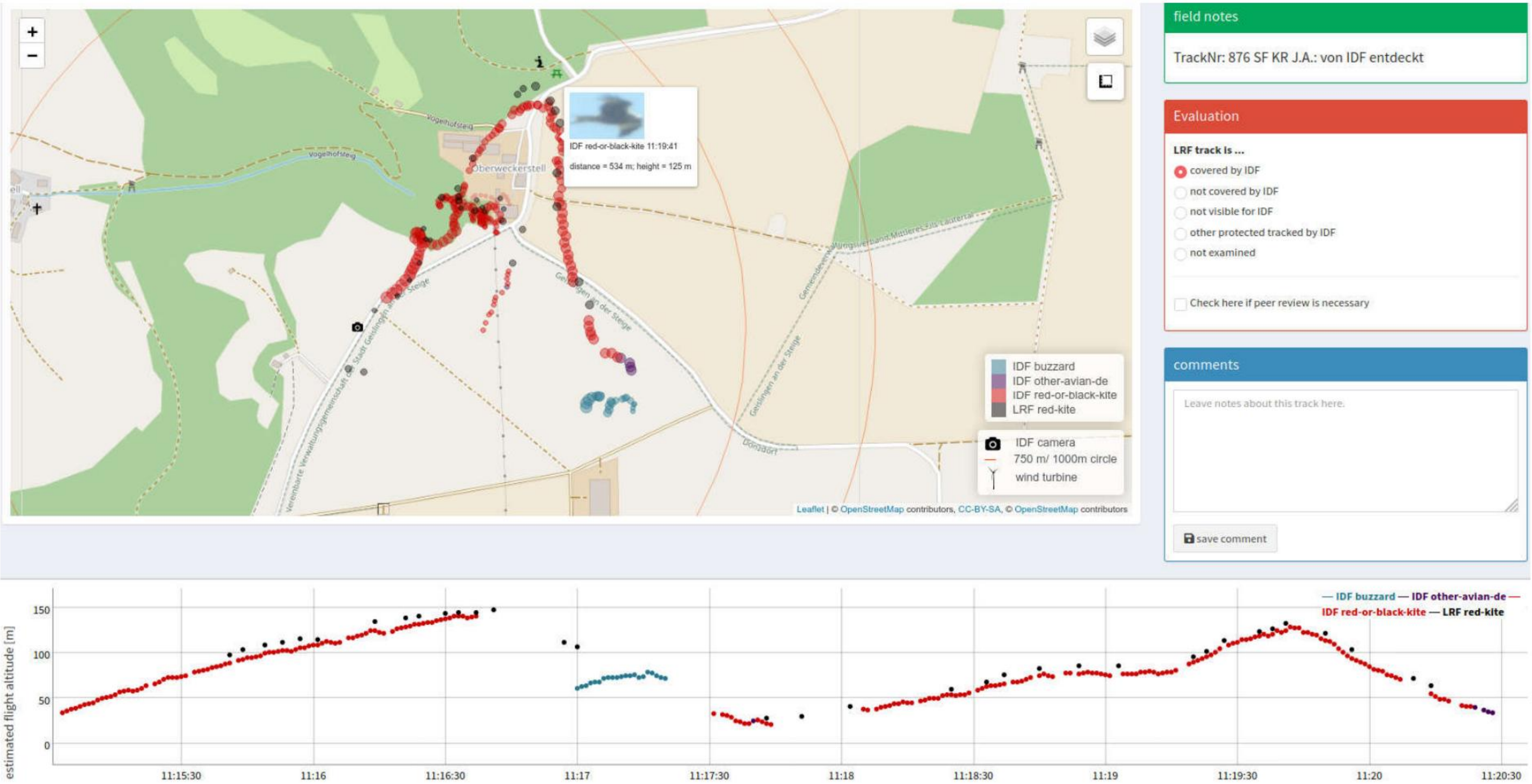

Figure 46: Example of the accuracy of the recording using LRF: the recorded flight path was also recorded by IDF. The data points are very vertical well above one another, horizontally there is a slight offset based on an azimuth offset of the LRF. Geislingen site, May 6th, 2020.

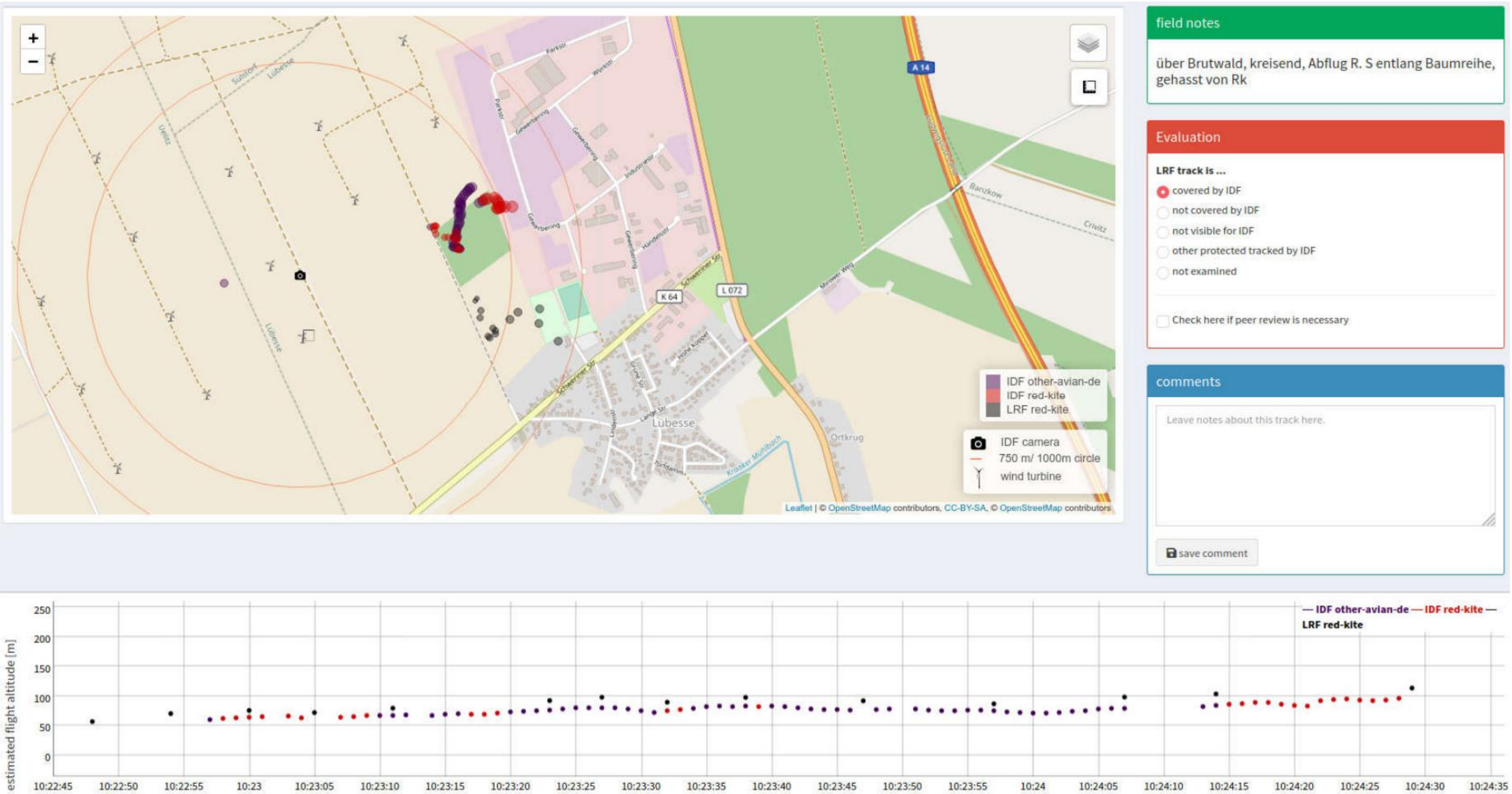

Figure 47: LRF and IDF tracks with a significant angular offset at the Lübesse location. In this example, the offset is visible through the similar trajectories and the comment on LRF detection. Lübesse location, September 18, 2029.

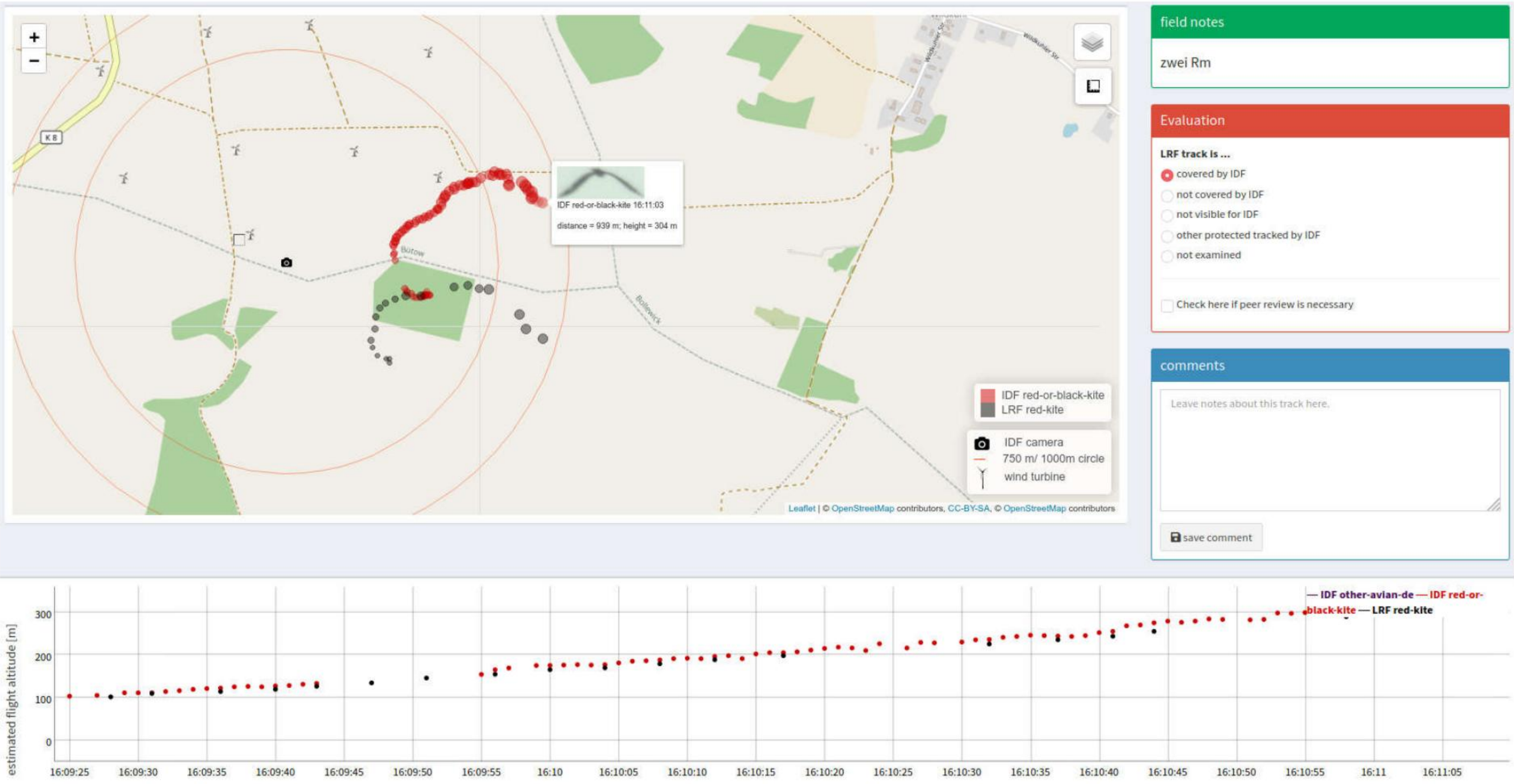

Figure 48: LRF and IDF track with angular offset at the Bütow location. In this example, too, the offset is due to the similar trajectories and the Corresponding height distribution can be seen well. Location Bütow, May 13th, 2020.

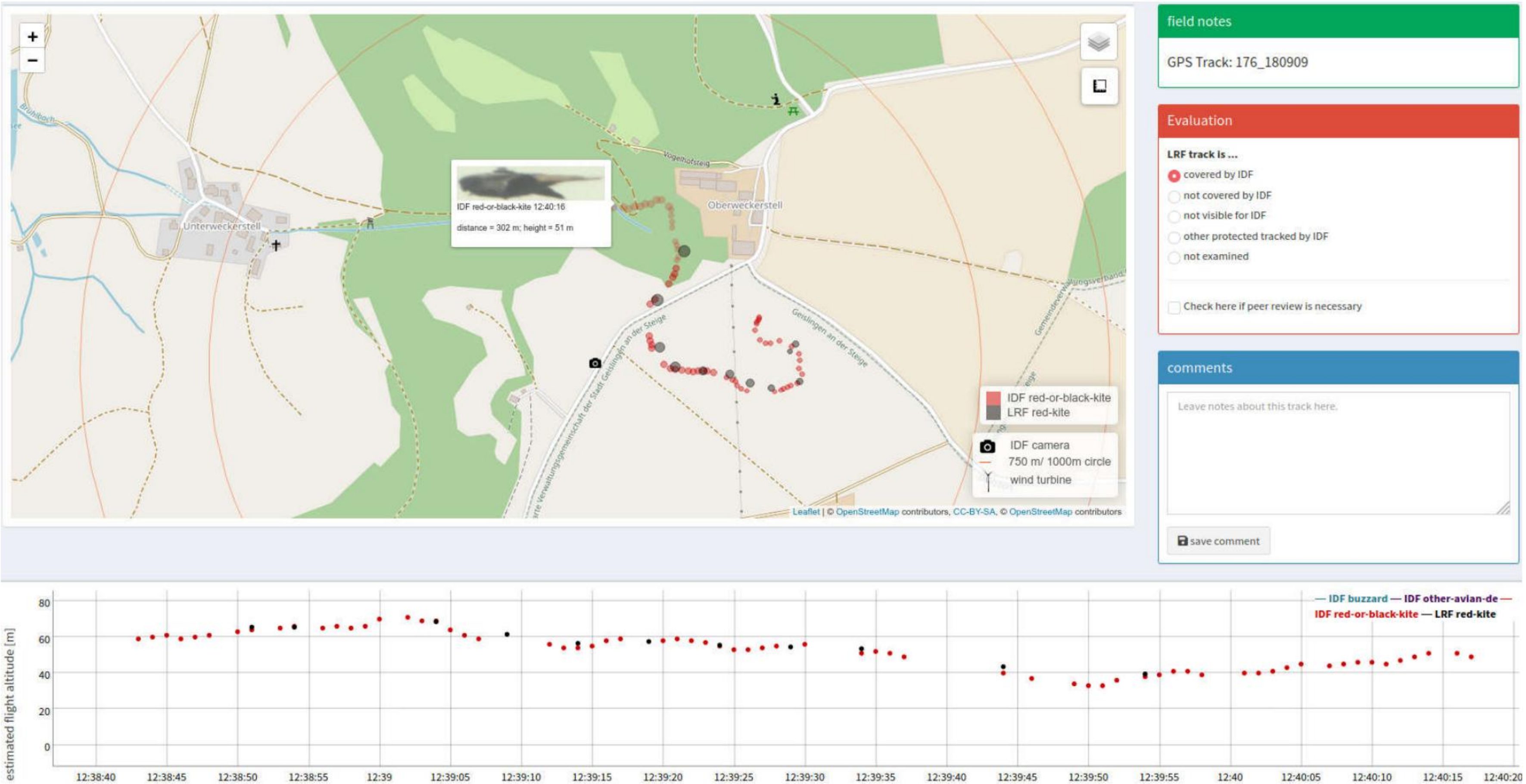

Figure 49: GPS and IDF track of a red kite with high spatial accuracy. Geislingen site, April 19, 2020.

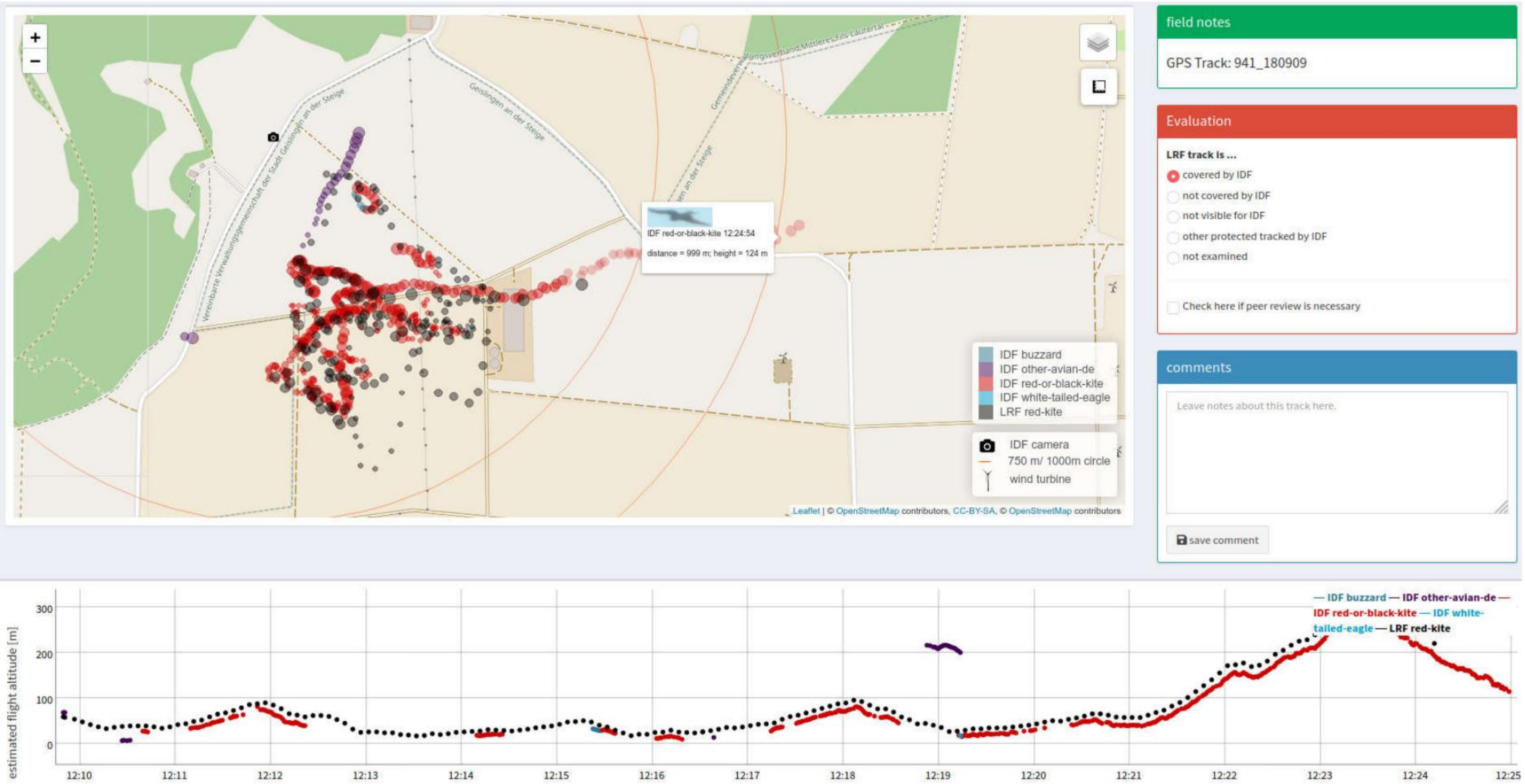

Figure 50: GPS and IDF track of a red kite with high spatial localization accuracy, but different height determination. The GPS locates the Vogel higher than the IDF. Geislingen site, May 7th, 2020.

5.3 Detection range

The detection range of IDF for the reliable detection of red kites was calculated from a total of 275,394 individual positions of subsequently determined red kites. The detection range of 750 m specified for the red kite corresponds well with the 95% kernel distribution based on the available data and, viewed overall, even goes beyond that (Table 7 and Figure 51). Here, however, the distribution of the red kites in the landscape surrounding the IDF system plays a major role. In Lübesse the breeding forest was located approx. 700 m away, in Bütow approx. 300 m distance east of the IDF, which means that it is in each of these Areas with particularly high flight activity and consequently more measurements at this distance (Figure 51). In comparison, the data from Lübesse in particular clearly show that the distribution of the location points shown below a distance of 750 m primarily depends on the spatial distribution of bird activity and not on the performance of the camera in relation to the detection range.

Table 7 summarizes the detected detection ranges for the 95% and 99% percentiles as well as the maximum detected distances for the horizontal distance, the vertical height above IDF and the radial distance. This shows that 95% of the red kite activities were detected within the horizontal distance of 803 m. This

The result exceeds the 750 m detection range specified by the manufacturer for the red kite.

Table 7: **Proven distances of subsequently determined red kites.**

	95% percentile	**99% percentile**	**Maximum proven distance**
Horizontal distance	803 m	1,006 m	1,199 m
Vertical height	407 m	599 m	1,103 m
Radial distance	861 m	1,070 m	1,199 m

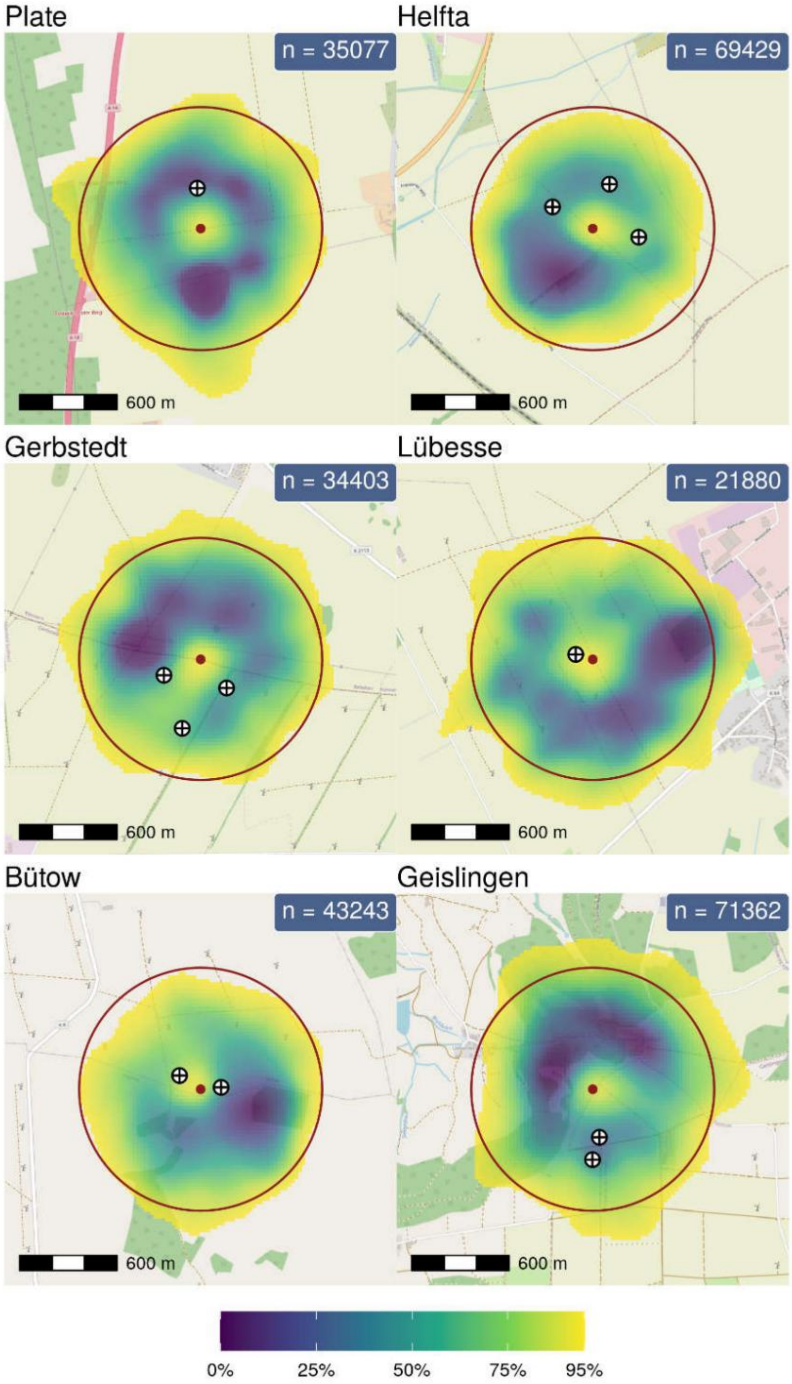

Figure 51: Kernel density estimate of the locations of all red kites recorded by the IDF. The darker the color, the higher the activity recorded by IDF. The color gradient is to be read cumulatively, so that, for example, 50% of the measured activity occurred in the areas that have the colors from 0% to 50%. The IDF system is marked as a red point and the 750 m radius around IDF as a red circle. The virtual or actual wind turbines are marked with black and white symbols.

5.4 Acquisition Rate

5.4.1 Detection performance in relation to reference samples

The detection rate of IDF was determined at all six locations on the basis of the trajectories measured with the LRF and also on the basis of the GPS data of the red kite in Geislingen. This data set of LRF and GPS trajectories served as a reference sample for determining the detection performance of IDF, whereby only trajectories classified as "valid" were used and "invalid" trajectories (not visible to IDF or IDF tracks another protected bird at the same time) were excluded (Table 4 and Chapter 4.3.2).

In this way, a reference data set consisting of 476 valid GPS flight paths and 626 valid LRF flight paths could be formed, which corresponds to a total of 1,102 valid reference flight paths (Table 8).

At the Geislingen site, the GPS-transmitted red kite “Donzi” was rated as not visible to IDF (140 of 668 tracks) (Table 8). This is due to the fact that this red kite often flew very low and below the horizon in the area of the geofence
and was therefore not or only with difficulty visible to IDF (Figure 55). It is also noticeable that at the Bütow and Geislingen locations, which had particularly high flight activity, the IDF relatively often recorded birds other than those located by the LRF or the GPS transmitter (Table 8).

Table 8: **Derivation of the reference sample of the LRF or GPS tracks**

year	Location	Method number of tracks		Not visible Another bird		Valid tracks
2018	Helfta	LRF	107	0	4th	**103**
2018	Plate	LRF	65	9	4th	**52**
2019	Gerbstedt	LRF	63	8th	0	**55**
2020	Butow	LRF	419	20th	92	**307**
2020	Geislingen	LRF	115	3	3	**109**
2020	Geislingen	GPS	668	140	52	**476**
	total	**LRF & GPS**	**1,437**	**180**	**155**	**1.102**

Examples of reference trajectories with the trajectories recorded by IDF are shown in Figure 52 through Figure 57. In most cases, the red kites of the reference trajectories were also recorded by IDF. Figure 53 shows a special case in which the IDF detects the red kite “Donzi” while chasing another red kite. Here, IDF pans from southwest to east within 20 seconds, detects the red kite "Donzi" for one point and pans back to the previously captured red kite. The reference trajectory of "Donzi" shows that he was moving away from the collision area south of the IDF and was probably therefore no longer recorded by the IDF.

A similar prioritization exists in cases in which IDF detects a bird other than the reference flight path (Figure 56 and Figure 57), whereby it cannot be understood in detail why IDF decides to pursue which bird.

Of the total of 1,102 valid reference trajectories, 1,011 (92%) were detected by IDF (Table 9). At five of the six locations, the collection rates largely matched between 85 and 96%.

In the chapters 4.2.2 and 5.2.2 reference is already made to the sources of error in the LRF records in general and in particular at the Lübesse site. For this reason, the Lübesse site was excluded from this analysis. .

Table 9: **Acquisition rates achieved by IDF at the investigation sites in relation to the reference samples from flight paths that were collected using the Laser Range Finder (LRF) and telemetry data (GPS).**

Year	Location	Method	Valid Tracks	Detected	Not Detected	Acquisition rate
2018	Helfta	LRF	103	99	4th	**96%**
2018	Plate	LRF	52	48	4th	**92%**
2019	Gerbstedt	LRF	55	52	3	**95%**
2020	Bütow	LRF	307	261	46	**85%**
2020	Geislingen	LRF	109	100	9	**92%**
2020	Geislingen	GPS	476	451	25th	**95%**
	Total LRF & GPS		**1.102**	**1.011**	**91**	**92%**

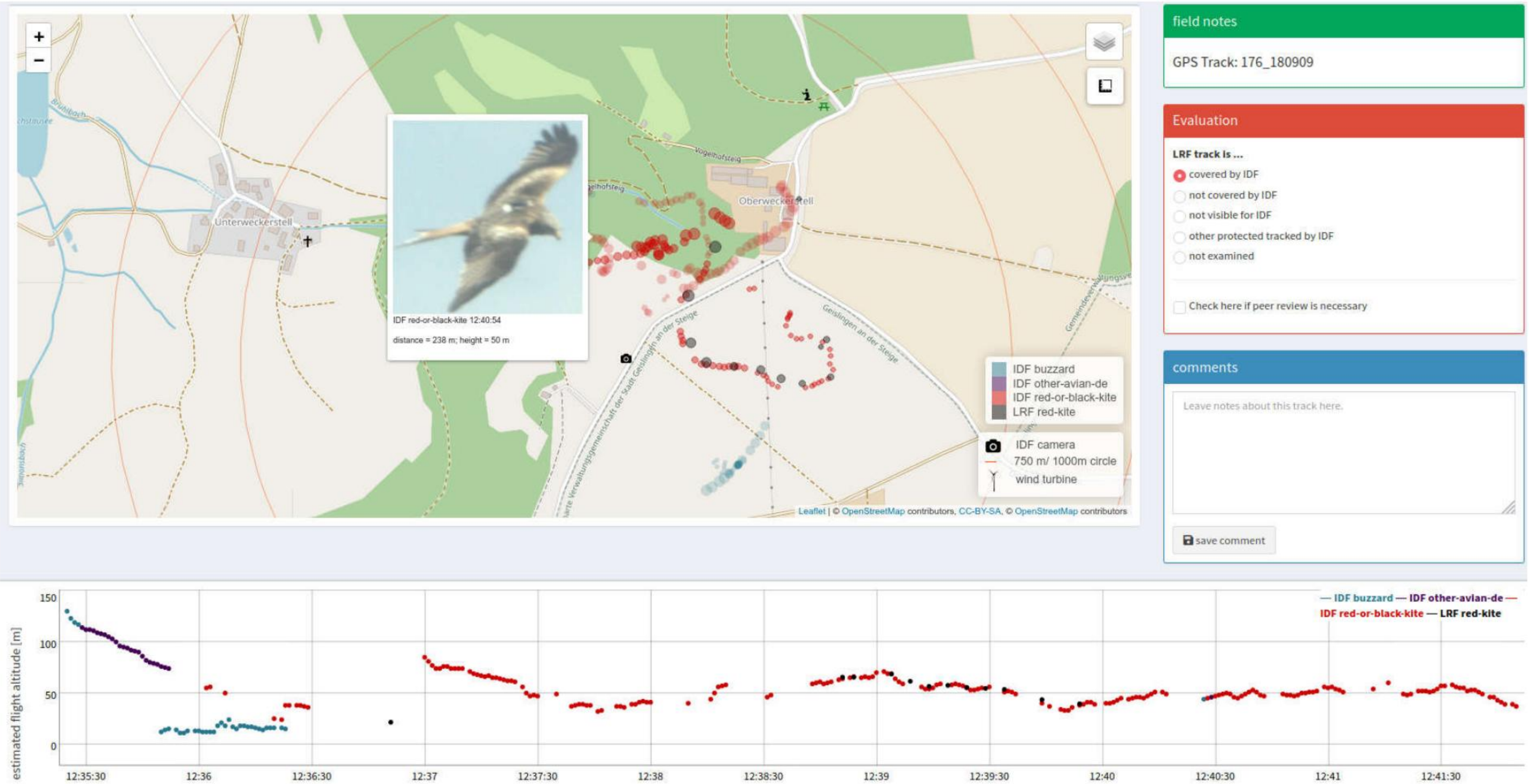

Figure 52: GPS track (gray dots, differently labeled "LRF red-kite" in the illustration) of a red kite that IDF (red dots) has over approx Minute was recorded. The GPS transmitter on the red kite's back is easy to see. Geislingen site, April 19, 2020.

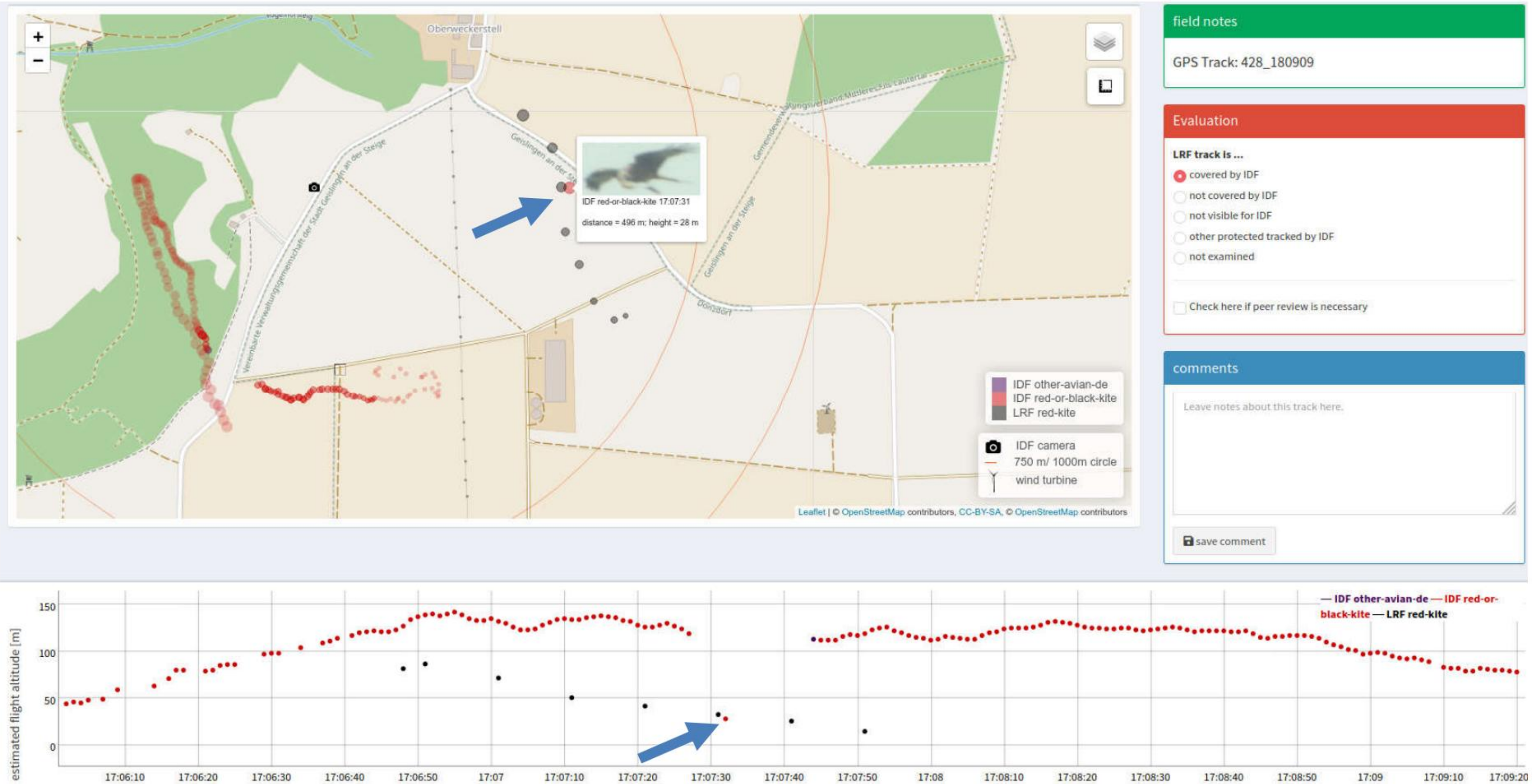

Figure 53: GPS track (gray dots, differently labeled "LRF red-kite" in the illustration) of a red kite, which is also briefly recorded by IDF (red dots) became. "Donzi" was recorded with a point during the detection of another red kite (blue arrows) before IDF pans back to the original bird. Geislingen site, April 24th, 2020.

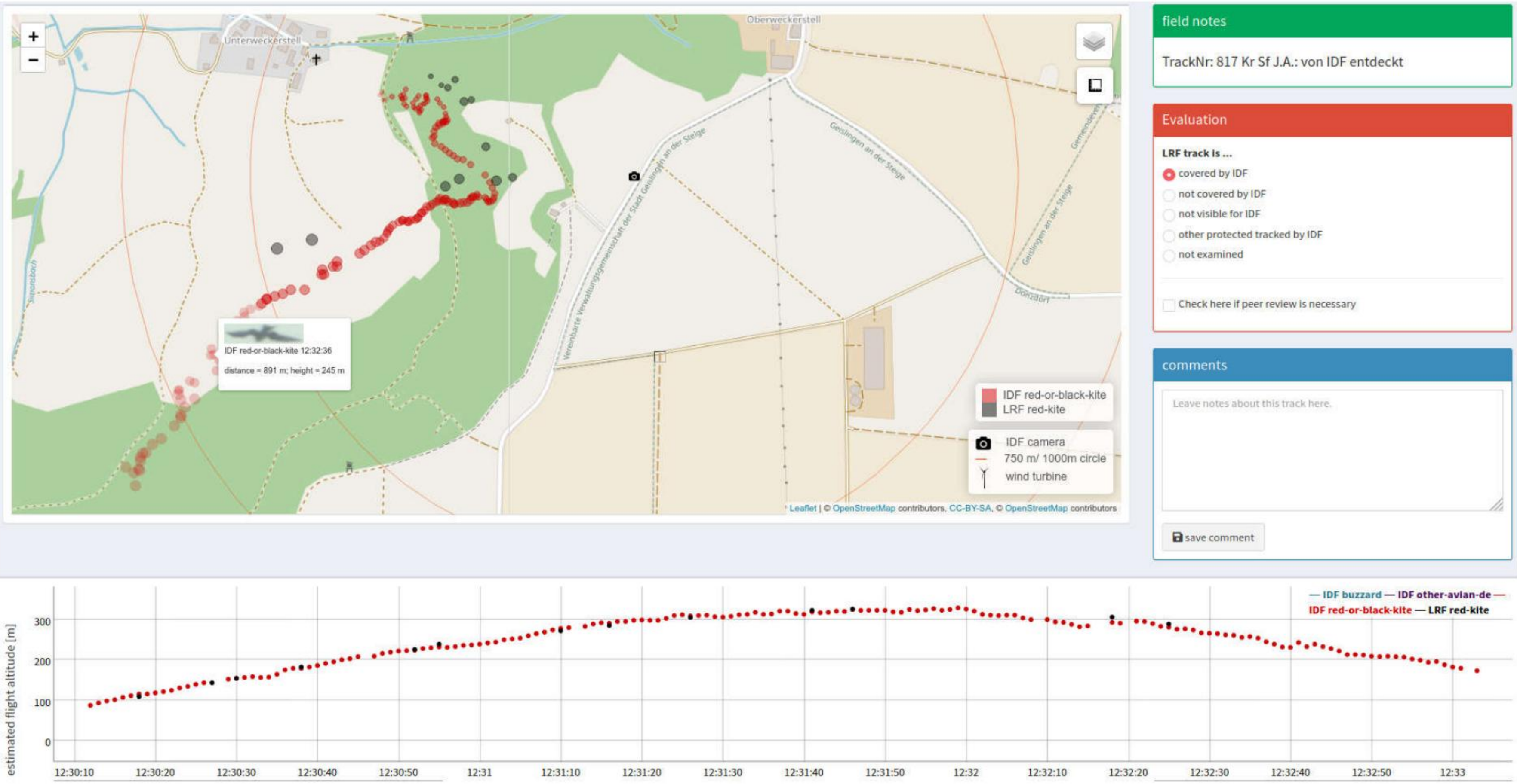

Figure 54: Examples of red kite trajectories at the Geislingen site, which were recorded by both the IDF (red points) and the LRF (gray points). Location Geislingen, April 24th, 2020.

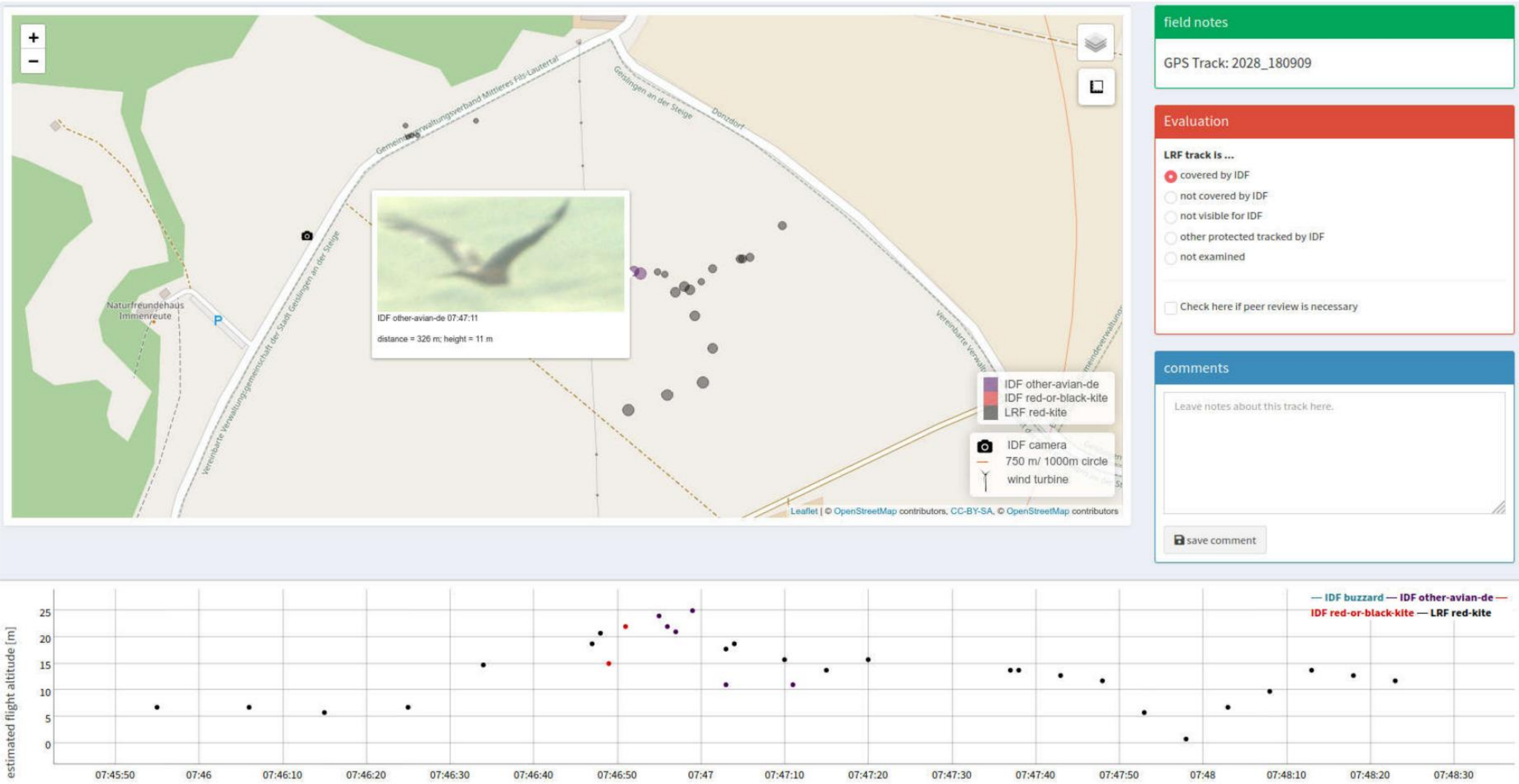

Figure 55: Low-flying red kite "Donzi" (GPS data, gray dots; deviatingly marked with "LRF red-kite" in the figure), the one from the IDF Background was recorded (red dots), but was sometimes not correctly classified as a red kite (purple dots). Geislingen site, May 6th, 2020.

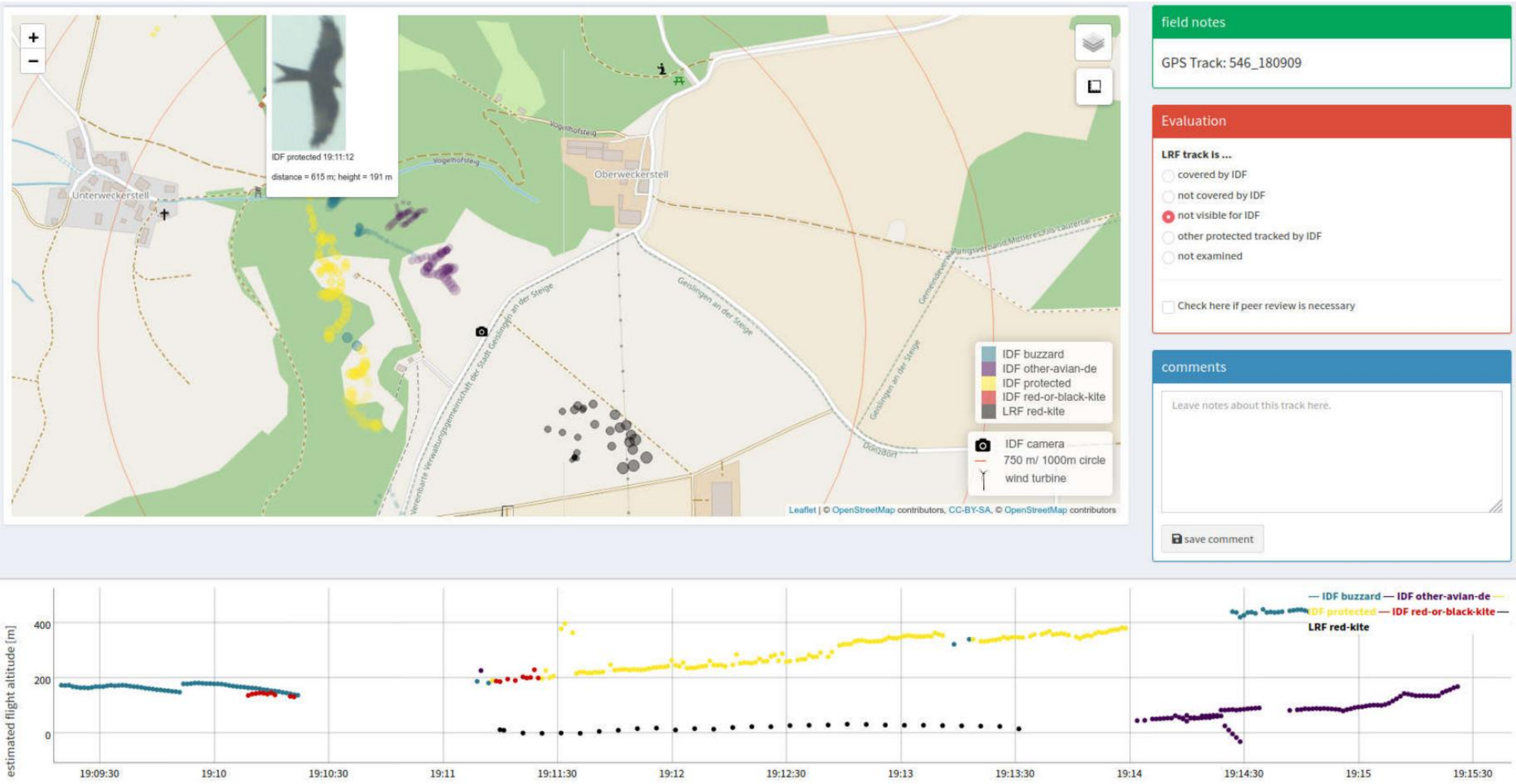

Figure 56: Low-flying red kite "Donzi" (GPS data, gray dots; deviatingly marked with "LRF red-kite" in the figure), which is not recorded by the IDF became. At the same time, IDF recorded another red kite (red and yellow dots). Geislingen site, April 27, 2020.

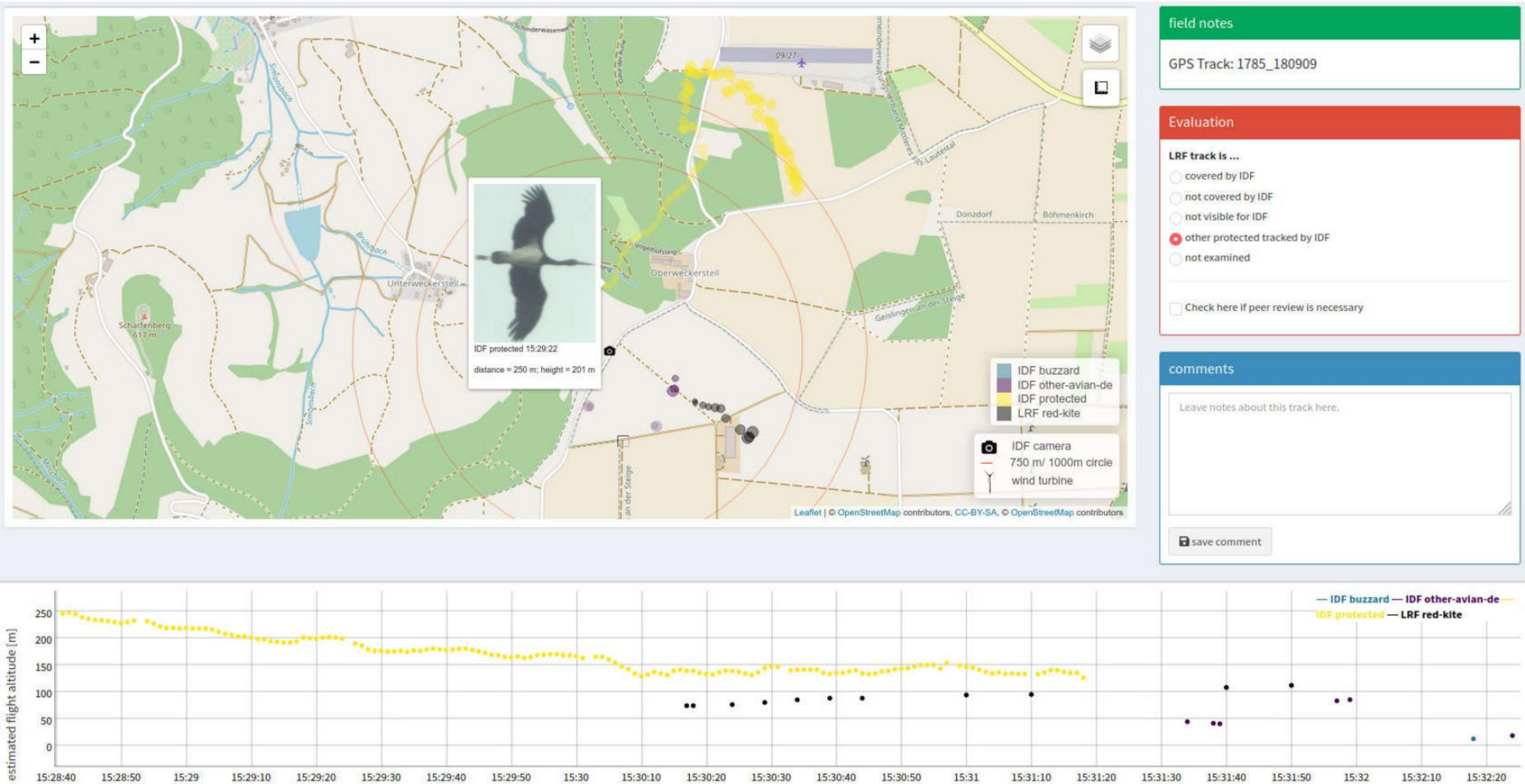

Figure 57: GPS track (gray dots, differently marked with "LRF red-kite" in the figure) of the red kite "Donzi", clearly more visible for the IDF Flight altitude above the horizon. In this case, "Donzi" was not recorded by IDF, because at the same time a black stork, recognized as "protected" (yellow dots), was recorded by IDF. Geislingen site, May 29, 2020.

5.4.2 The influencing factor precipitation

Based on the precipitation data at the Helfta, Plate and Geislingen sites (see Chapter 4.3.2.2), the influence of precipitation on the IDF collection rate was examined.

At the Helfta and Plate locations, there was little overall precipitation during the IDF surveys in 2018. In comparison, it rained significantly more frequently at the Geislingen site in 2020 (Figure 58). Looking at the IDF acquisition data as a function of the recorded precipitation events, it is particularly clear at the Geislingen site that IDF recorded flight activities even when it was raining. In cases with precipitation and no flight activity recorded by IDF, it cannot be said - based on this data - whether a reduced camera performance by IDF could be the reason, or a generally low one until the birds lack flight activity when it rains.

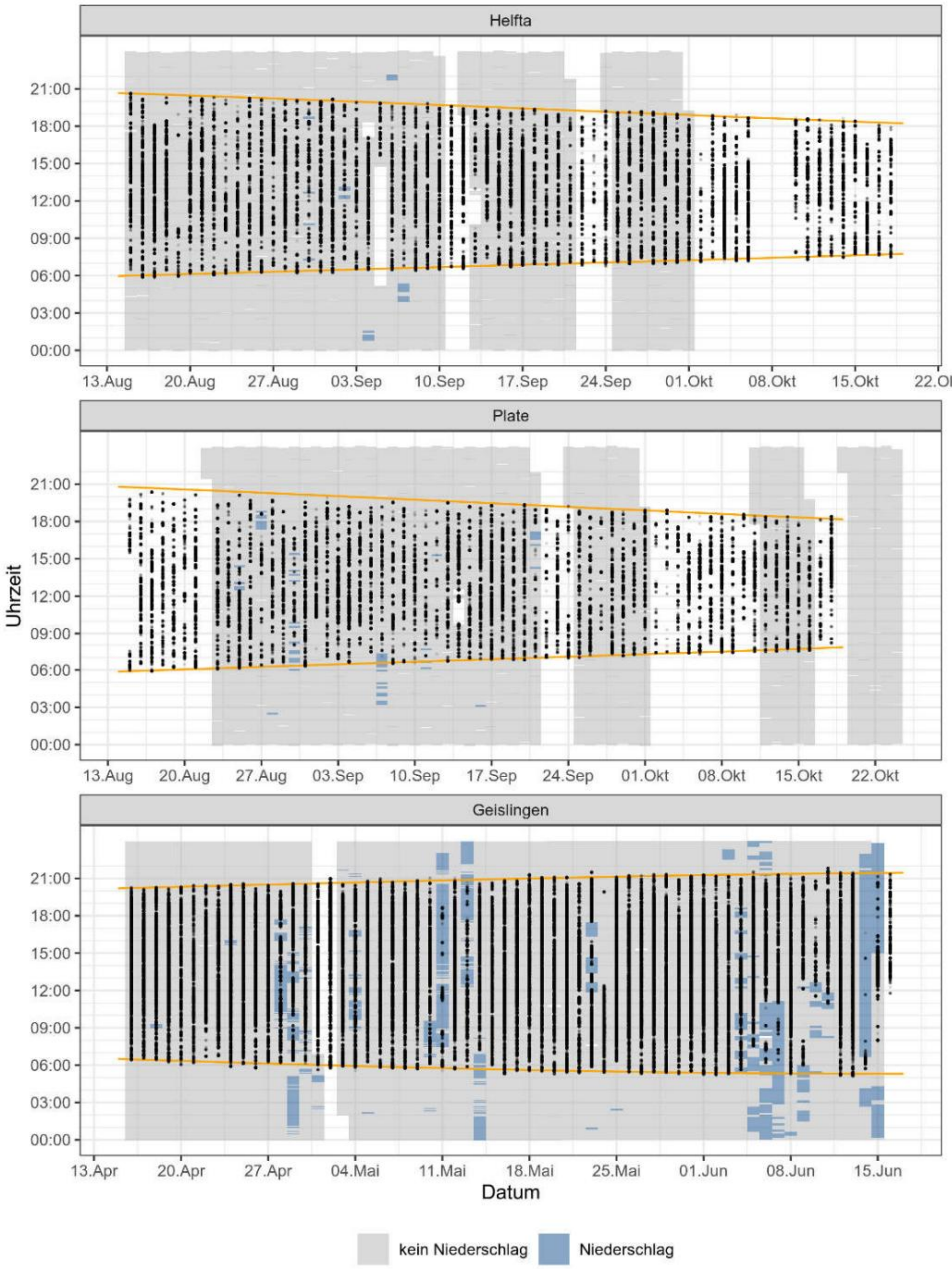

Figure 58: Distribution of all IDF recording points in relation to the precipitation over the respective Data collection period at the Helfta (2018), Plate (2018) and Geislingen (2020) locations. Periods colored gray mean no precipitation, periods colored blue mark precipitation events. No precipitation values are available for unstained areas within the period of the IDF surveys. Sunrise and sunset are each marked with an orange line.

5.4.3 Influence of the position of the sun

Since, according to the manufacturer, the direct view of IDF into the sun through overexposure due to the high brightness leads to a "blind spot" of 15 ° around the sun, the influence of the position of the sun on the detection performance of IDF was investigated.

For this purpose, the minimum difference angle of the respective first point (= detection event) of a trajectory to the position of the sun in different clouded situations was calculated and for differences between the minimum difference angle when it is overcast and when it is clear
Sky explored.

If one considers the distribution of the difference angles of the first location of a flight path by the stereo camera with an overcast and clear sky, it becomes apparent that detection is possible up to a difference angle of <5 ° (almost direct view into the sun) (Figure 59).
A difference between the minimum difference angles when the sky is overcast or clear
cannot be recognized.

Reliable detection seems to be given at least from an angle of 10 °. The area of 10 ° around a point in the sky covers only about 1.5% of the area of the sky dome. A blind spot of 10 ° around the sun would therefore have very little effect on the absolute detection probability of IDF. According to the available data, the blind spot is therefore significantly smaller than according to the manufacturer.

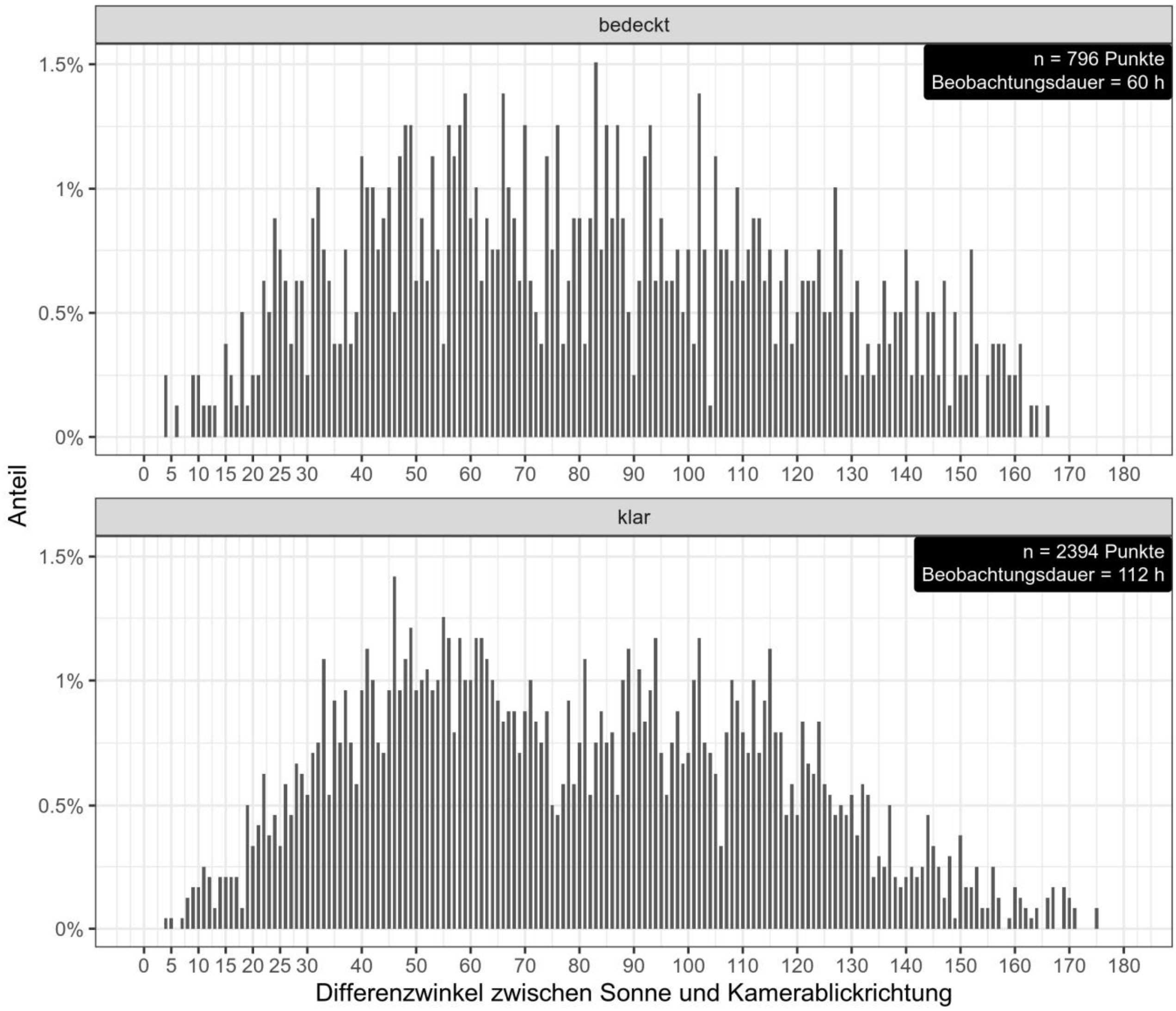

Figure 59: Percentage distribution of the frequency of the respective first track points of the IDF recordings depending on the difference angle between camera and sun for clear and overcast Cloudy situations at the Bütow location in 2020. A difference angle of 0 ° means that the camera was looking exactly at the sun, whereas a difference angle of 180 ° shows that the camera was aiming exactly in the opposite direction to the sun.

5.5 Classification

The classification of a detected flying object by IDF is based on a neural network.
Since the red kite was initially not part of the IDF repertoire, the IDF was first trained in this way in 2018, thus training version 1 of the neural network. Version 1 was used in the data collection years 2018 and 2019. Based on this collected data, version 2 of the neural network was trained and used in data collection year 2020 (see chapter 2.2.2).

The determination reliability with regard to the classification of the red kite was initially between 78% and 84.7% for the four locations (Helfta, Plate, Lübesse and Gerbstedt), which were examined with software version 1, whereby with increasing distance (up to 750 m) the correct classification performance decreased (between 1.1% and up to 6.1%).

With the use of the improved second version of the neural network in 2020 at the

At the Bütow and Geislingen sites, the correct classification rate of IDF was increased to over 97%, with only minor differences in the classification performance with regard to distance (0.6% at the Bütow site) (Table 10).

Table 10: **Correct classifications of red kites (or red and black kites in Bütow and Geislingen) in a 250 m and 750 m radius around IDF. (n = IDF data points of post-determined red kites)**

year	Location	Neural network version	Correct classification up to 250 m in percent [n]	Correct classification up to 750 m in percent [n]
2018	Helfta	1	84.7 [4,557]	83.6 [43,818]
2018	Plate	1	79.7 [1,472]	78.0 [17,084]
2019	Luebesse	1	84.2 [562]	78.1 [12,703]
2019	Gerbstedt	1	84.4 [1,725]	79.4 [21,171]
2020	Butow	2	95.9 [4,338]	96.5 [42,500]
2020	Geislingen	2	97.5 [6,760]	97.5 [60,762]

Accordingly, the false negative rate (target species is classified as non-target species) fell from a range between around 15% and 22% in 2018 and 2019 (NN version 1) to only 2.5% to around 4%. in 2020 (NN version 2). In the case of the false positive rate (non-target species is classified as a target species), on the other hand, there is no comparable trend; the values fluctuate between 2% and around 16% across all locations and years (Table 11).

The false positive rate is primarily interesting from an economic point of view, as it can lead to unnecessary or intended additional shutdowns. The false-negative rate, on the other hand, is relevant from the point of view of species protection law, since any necessary shutdowns are omitted.

Table 11: **Classification error rates for 250 m and 750 m radii around IDF. (n = all post-determined IDF data points)**

Year	location	neural network	False positive Rate (not Target species as target species) in% [n] Up to 250 m	False positive Rate (not Target species as Target species) in% [n] Up to 750 m	False negative Rate (target type as Non-target species) in% [n] Up to 250 m	Not correct Negative rate (Target species as Non-target species) in% [n] Up to 750 m
2018	Helfta	v. 1	2.0 [535]	2.9 [3,287]	15.3 [823]	16.4 [8,596]
2018	Plate	v. 1	1.3 [125]	1.8 [1,119]	20.3 [375]	22.0 [4,819]
2019	Lübesse	v. 1	4.3 [207]	9.7 [2,777]	15.8 [106]	21.9 [3,562]
2019	Gerbstedt	v. 1	10.1 [747]	15.8 [7,265]	15.6 [319]	20.6 [5,493]
2020	Butow	v. 2	6.1 [488]	11.5 [5,220]	4.1 [185]	3.5 [1,541]
2020	Geislingen	v. 2	3.4 [374]	5.8 [2,504]	2.5 [172]	2.5 [1,558]

Figure 60 to Figure 62 show sample images of birds captured by the IDF system.
The original identification by IDF is given for each bird picture. It is noteworthy that the software version 1 already distinguishes between the red kite and the red kite similar species, such as a male marsh harrier recognized as such by IDF and distinguished from the red kite (Figure 60). The correct classification rate was, however, significantly lower in the first version than in the second version (see Table 10), which explains, for example, the incorrect determination of “eagle” instead of the correct red kite in Figure 61. However, as in this example, a

Incorrect determination of a different target species does not lead to an inadequate shutdown, since both species are categorized as "protected".

Figure 62 shows sample images of birds recorded by the IDF at the Bütow site. Version 2 of the classification software has already been used here. All three recorded bird species in this example are correctly classified by IDF, whereby software version 2 no longer distinguishes between red and black kites in order to minimize the risk of confusion.

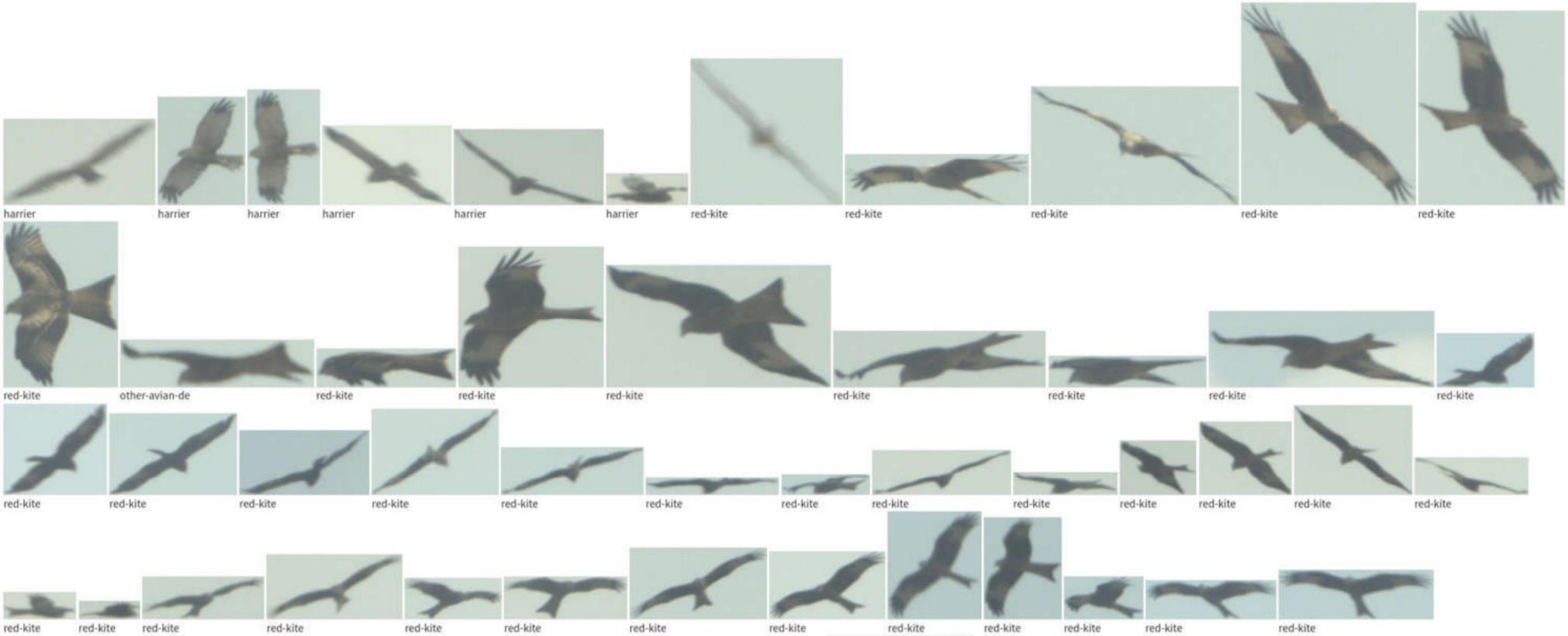

Figure 60: Sample images with the original classification by IDF. Version 1 of the neural network. The male marsh harrier is correctly replaced by the red kite differentiated. Location Plate, 08/17/2018

Figure 61: Sample images with the original classification by IDF. Version 1 of the neural network. The red kite is wrongly identified here by IDF as an eagle ("eagle"). However, both species are designated as target species and are categorized as “protected” by IDF. Location Lübesse, 08/24/2019.

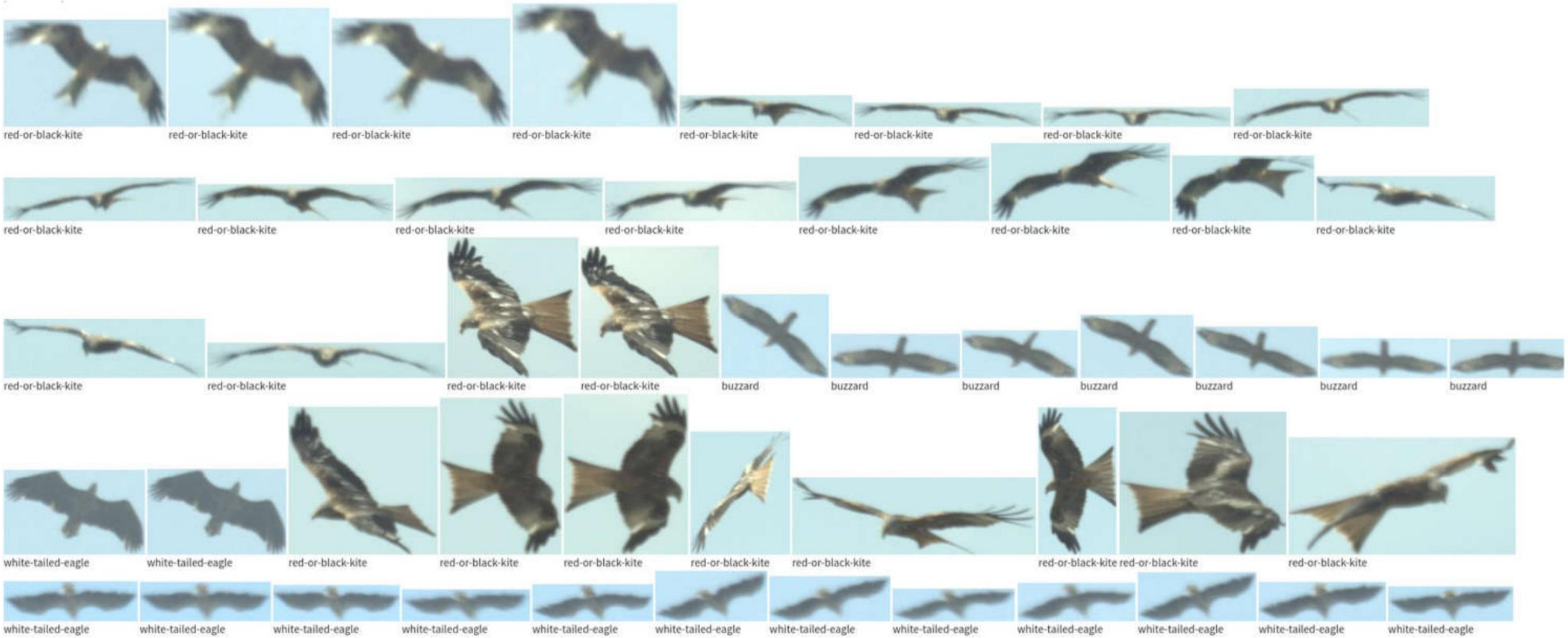

Figure 62: Sample images with the original classification by IDF. Version 2 of the neural network. The three different bird species are correctly identified by IDF. In software version 2, there is no longer a distinction between red and black kites, they form a category. Location Bütow, June 17th, 2020.

5.6 Effectiveness and efficiency of the shutdown

5.6.1 Shutdown triggered by IDF

The shutdown of wind turbines by IDF takes place in stages via two spacer cylinders with different dimensions (see Chapter 2.3). Be in the outer spacer cylinder Target species have already been observed, but a shutdown is only triggered if the bird has a flight direction and flight speed with which it would reach the rotor area of the wind turbine in the time it takes for the wind turbine to go into spin mode (time to collision). When penetrating the inner spacer cylinder, a switch-off signal is triggered in any case.

Examples of flight paths and the resulting shutdowns are shown below. Disconnections in the outer spacer cylinder occurred regularly in different flight situations and at different distances from the inner spacer cylinder (e.g. Figure 63, Figure 64 and Figure 67). Was the airspeed of the detected Vogels was not so high that a shutdown was already necessary in the outer spacer cylinder, the shutdown signal was typically generated when the inner spacer cylinder penetrated (Figure 65). This switch-off signal was generated specifically for the wind turbine and adapted to the flight behavior of the bird (Figure 65 and Figure 66). In some cases, the bird was only detected inside the inner distance cylinder, followed by an immediate shutdown of the wind turbine (Figure 68 and Figure 69).

If wind turbines have already been switched off for a bird by IDF and this bird is no longer at risk of collision, in many cases IDF quickly “focuses” on others, potentially collision prone birds. As a result, for trajectories that have triggered a shutdown, it is not clear whether the bird actually approached the collision area of the wind turbine in the further course of the flight (e.g. Figure 63 and Figure 66). In some cases, however, the bird is followed up and it is shown that an approach has actually taken place to the rotor area (Figure 67) or that the bird turns away again after entering the inner distance cylinder and leaves it (Figure 64).

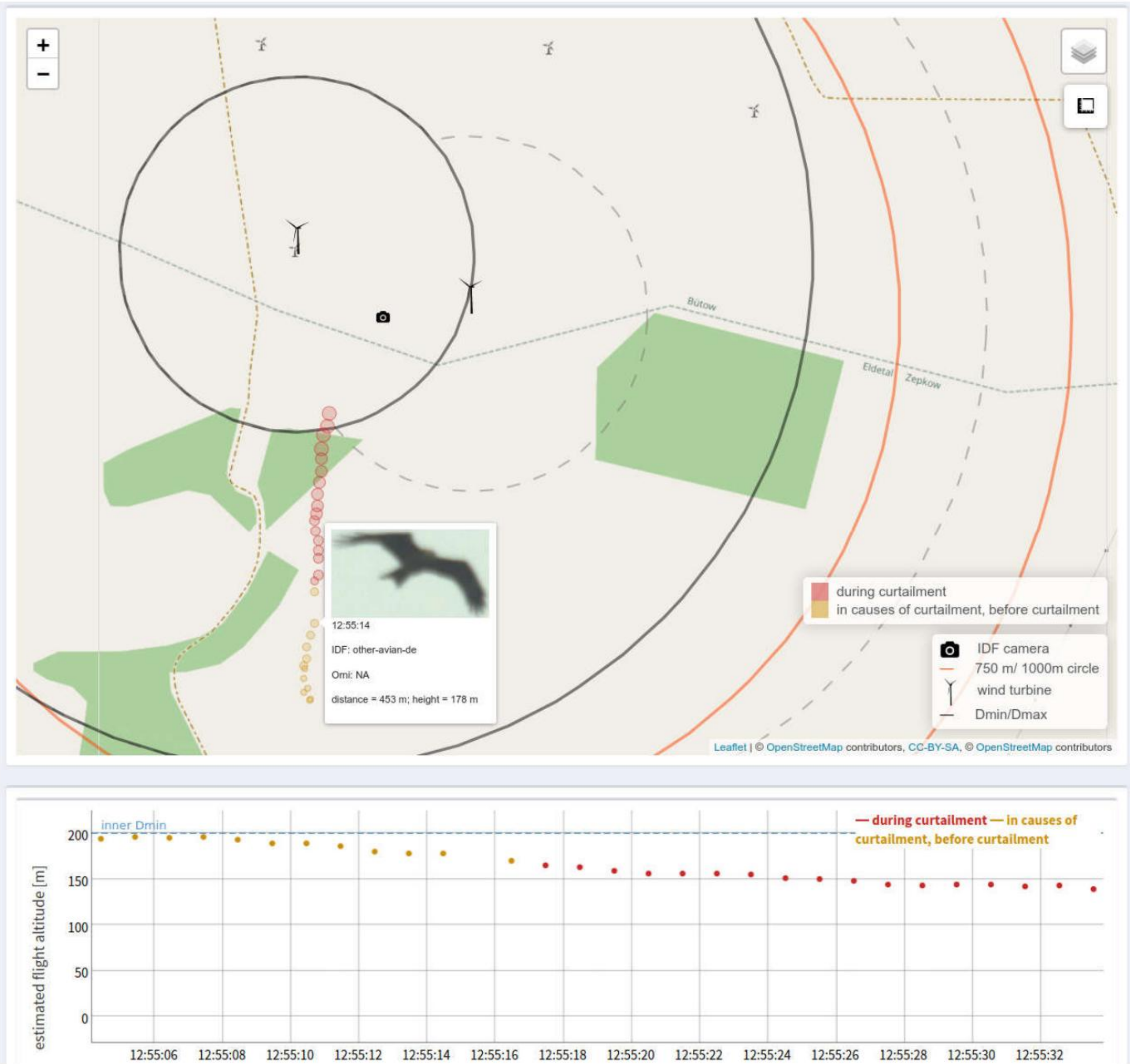

Figure 63: Shutdown in the outer spacer cylinder at the Bütow site. The red kite glides in Descent towards the eastern wind turbine. In this case, the flight vector and the airspeed are so great that IDF already generates a switch-off signal in the outer distance cylinder (outer black line) (change from orange to red dots), approx. 16 s before the red kite enters the inner distance cylinder (inner black line) achieved. Location Bütow, May 18, 2020.

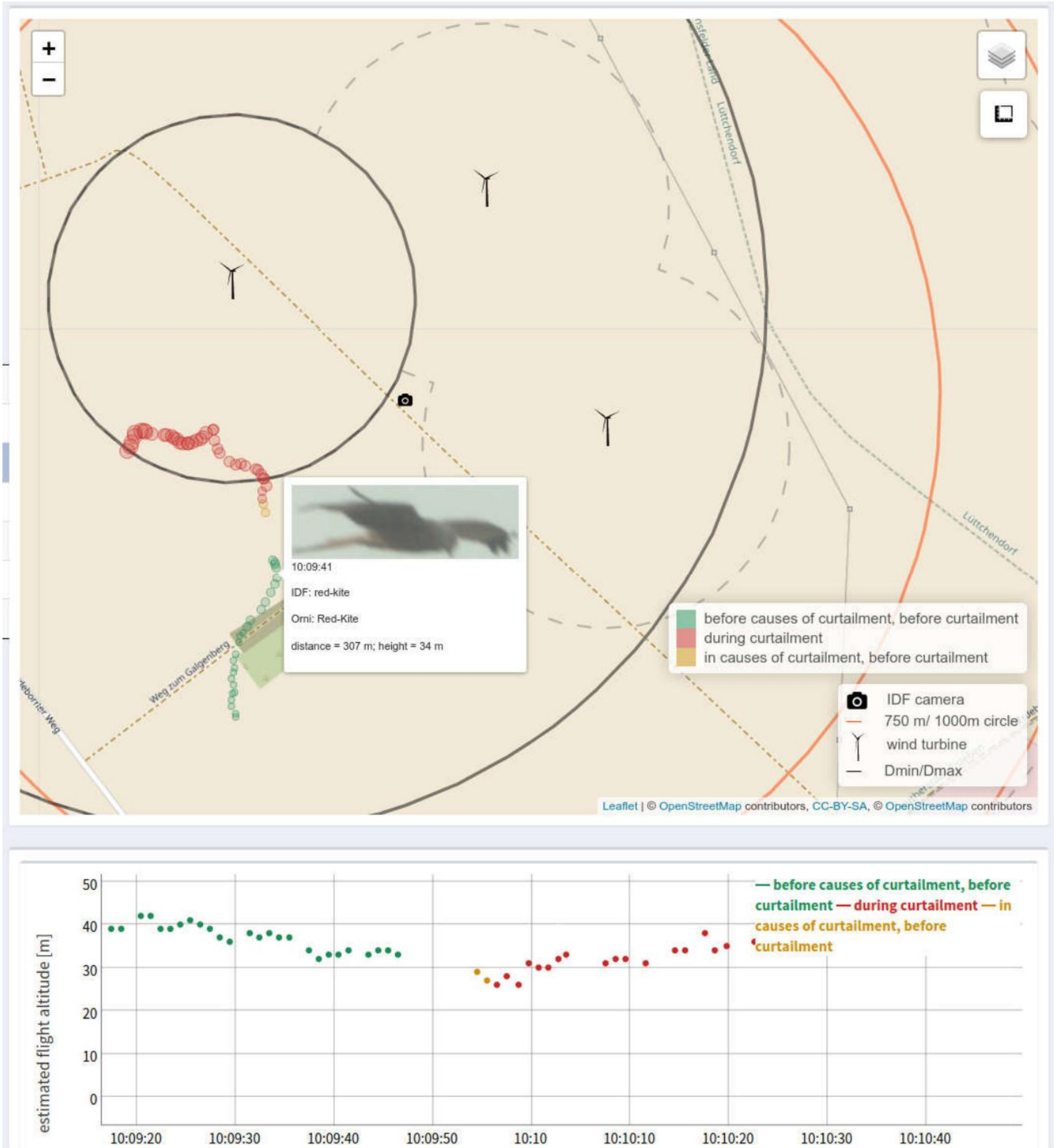

Figure 64: Shutdown in the outer spacer cylinder at the Helfta site. In this case, IDF resolves the Shutdown shortly before reaching the inner distance cylinder (inner black line). Location Helfta, 08/24/2018.

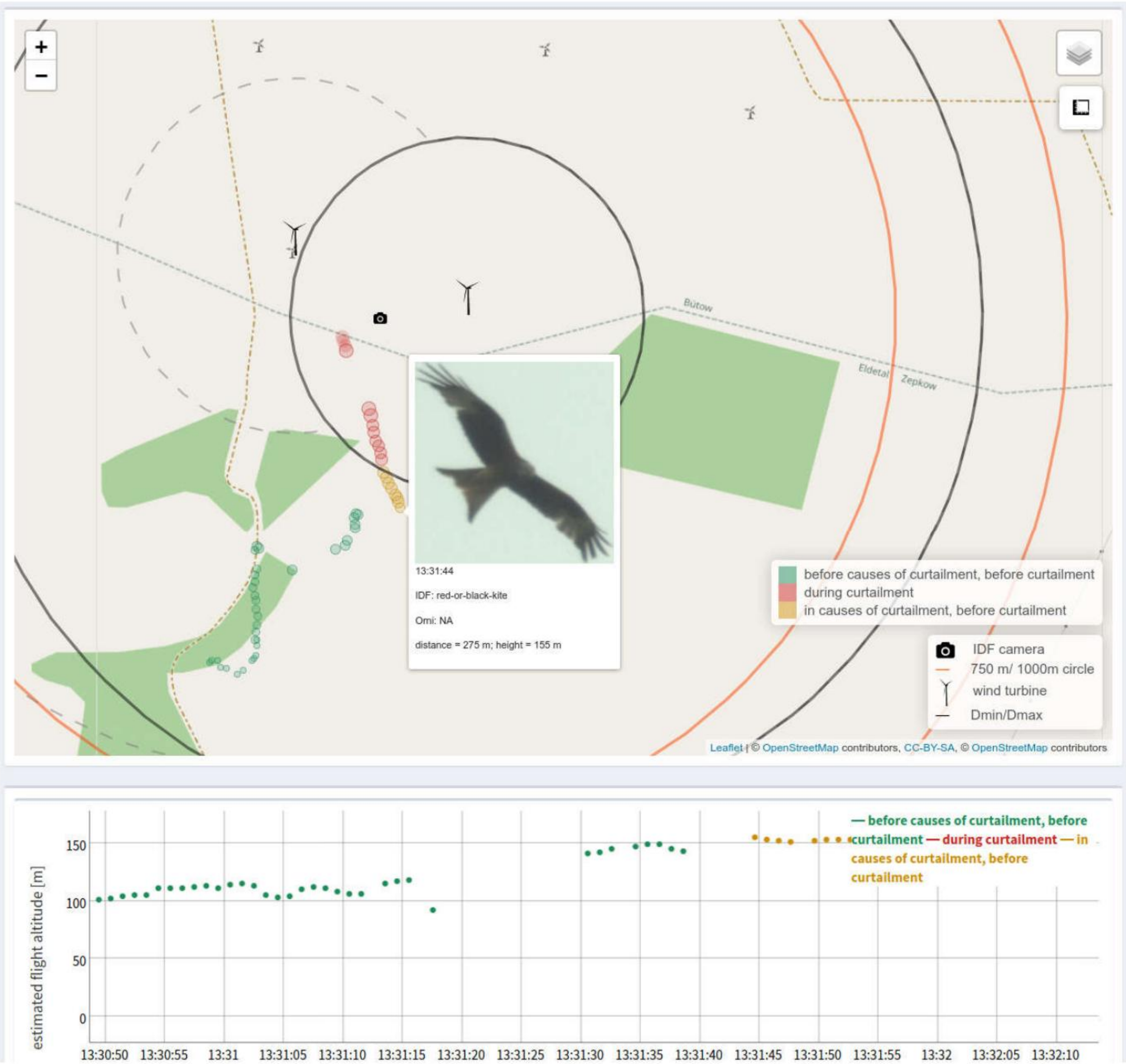

Figure 65: Shutdown when entering the inner distance cylinder (inner black line) of the eastern wind turbine at the Bütow location. The shutdown was triggered with the first point in the inner distance cylinder (red points). Location Bütow, May 18, 2020.

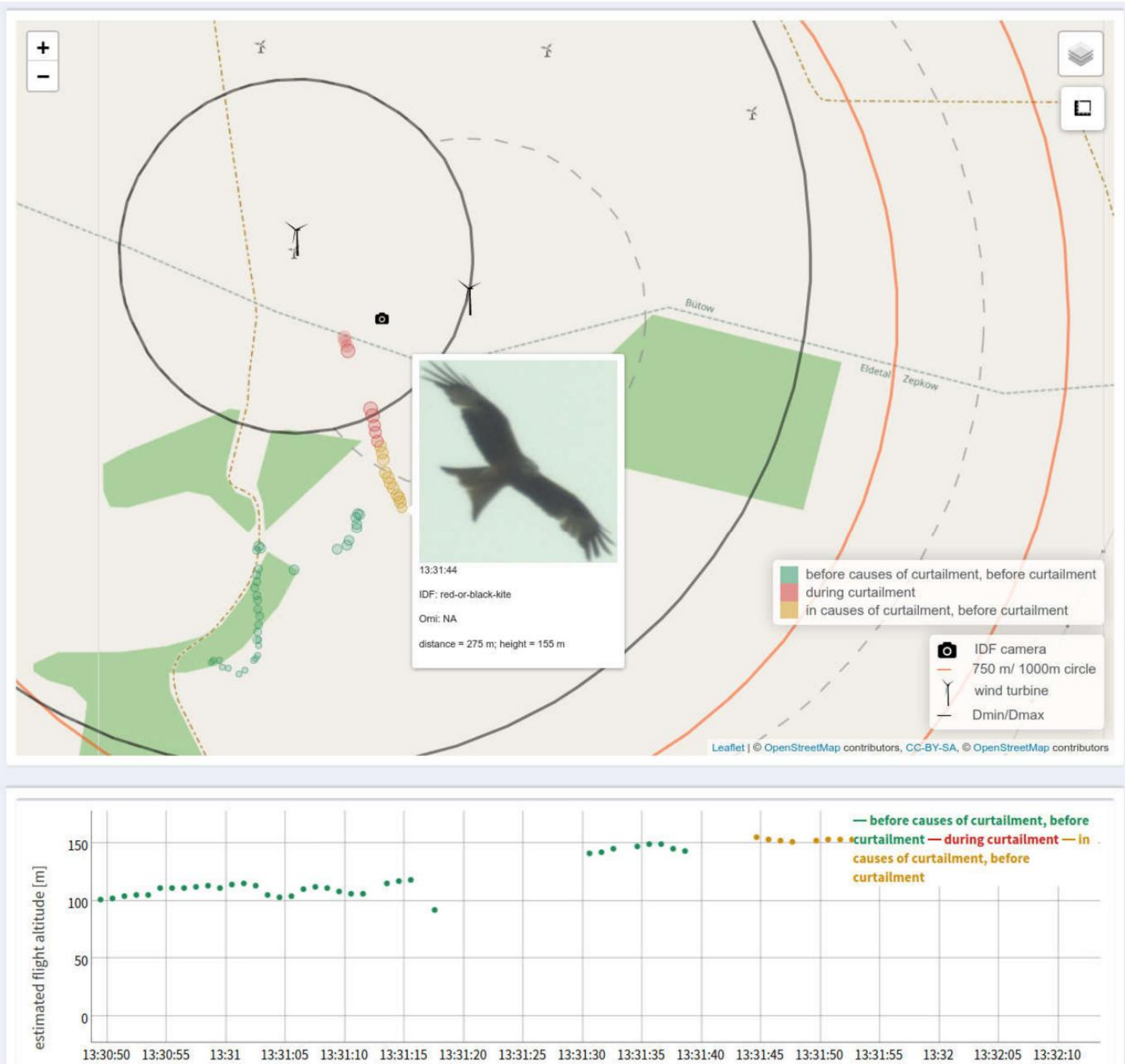

Figure 66: Shutdown when entering the inner spacer cylinder (inner black line) of the western wind turbine at the Bütow site. The shutdown for this wind turbine (red dots) was triggered a few seconds after the shutdown for the eastern wind turbine (see Figure 65). Location Bütow, May 18, 2020.

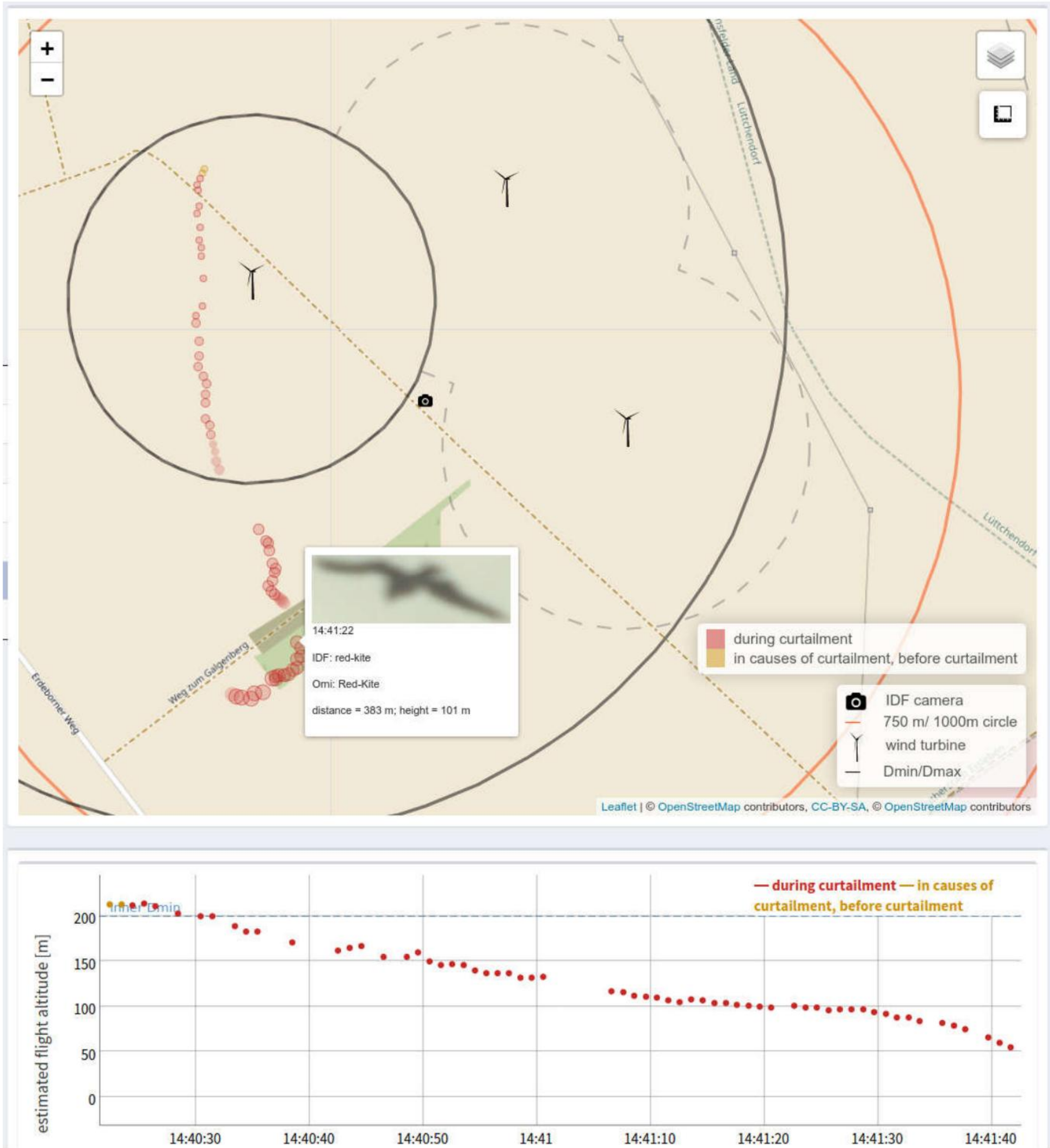

Figure 67: Shutdown above the inner spacer cylinder at the Helfta site. In this case, the bird was detected above the inner distance cylinder (inner black line) and a shutdown was triggered at the beginning of a descent, still above the height limit of the inner distance cylinder (blue line in the height diagram). Location Helfta, September 12th, 2018.

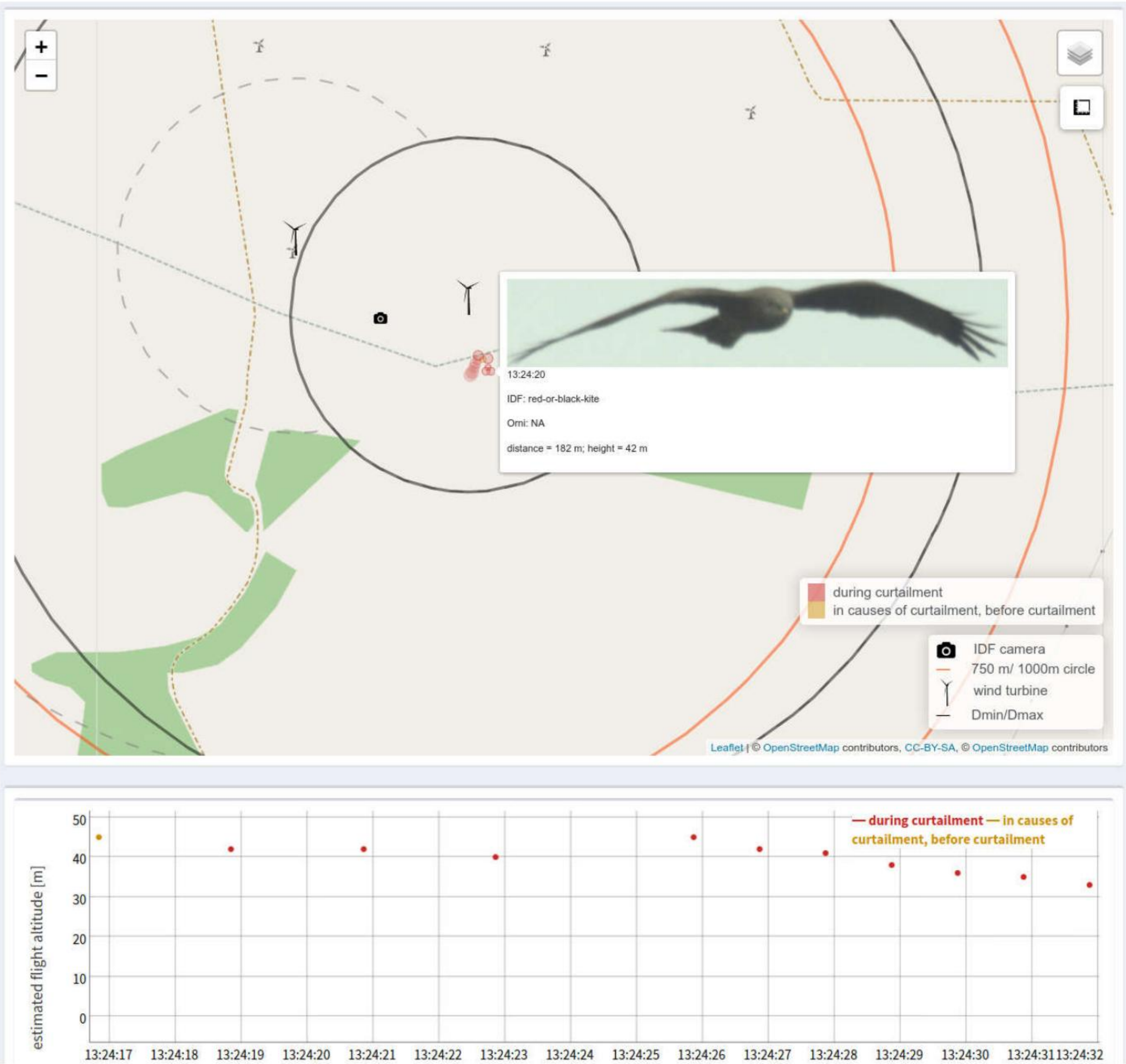

Figure 68: Detection of a red kite in the inner spacer cylinder with immediately following Shutdown at the Bütow site. This red kite was detected near the eastern wind turbine at an altitude of approx. 45 m (orange point), the shutdown was triggered at the next detection point (red points). Location Bütow, May 18, 2020.

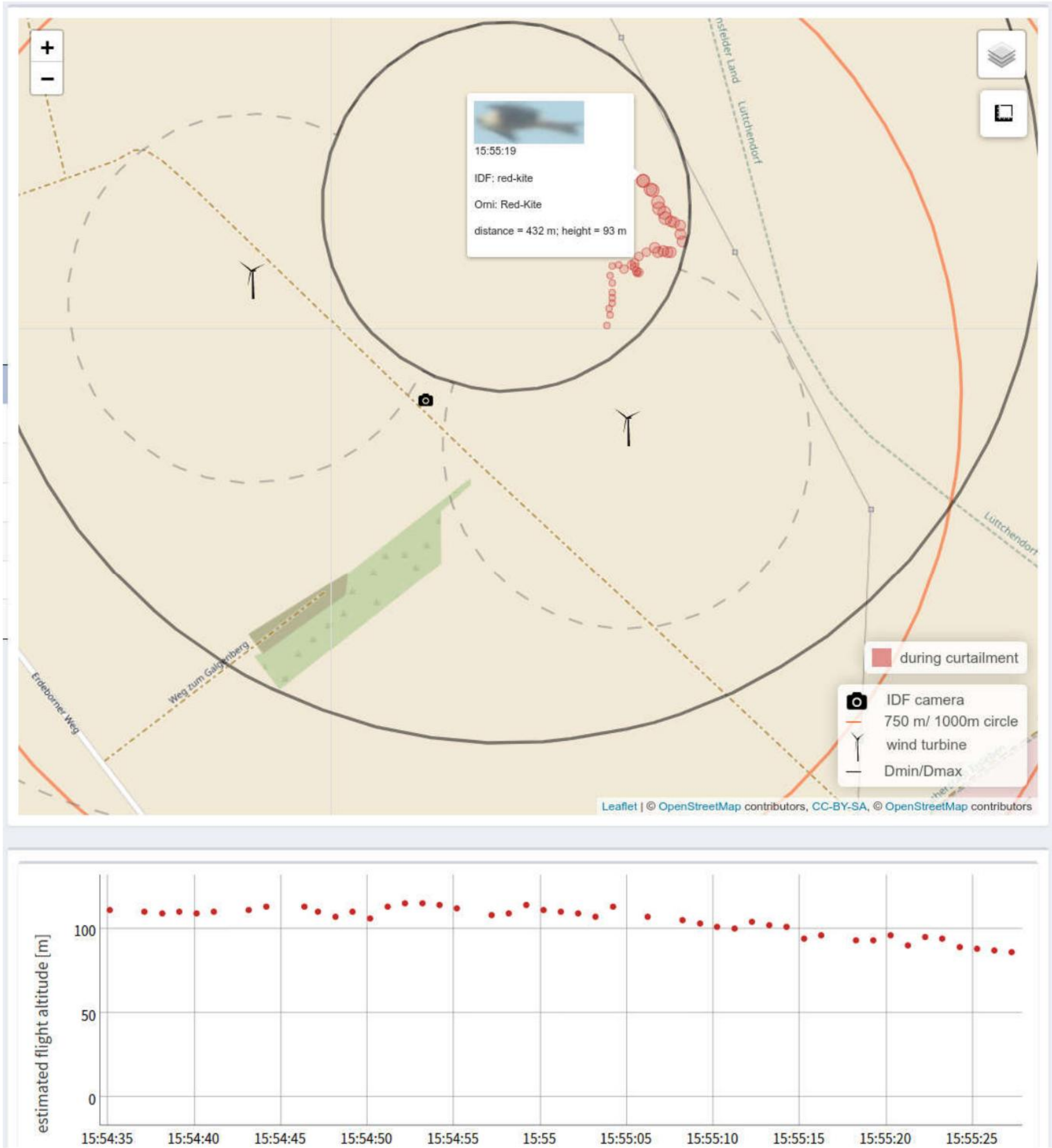

Figure 69: Detection of a red kite in the inner spacer cylinder with immediately following Shutdown at the Helfta site. In this case, a red kite was detected at an altitude of approx. 110 m; the switch-off occurs at the first point of detection (only red dots). Location Helfta, 09/10/2018.

In a number of cases it has been shown that the target species was only detected within the inner spacer cylinder, after which, however, a shutdown signal was immediately generated. Based on these findings, an evaluation was carried out with regard to the distance between the bird and the wind turbine at the time the first switch-off signal was generated. Figure 70 (above) initially shows that shutdowns are triggered at all locations beyond a distance of 600 m from the wind turbine. These are obviously cases in which the bird flies straight towards the wind turbine at high speed. By far the largest part of shutdowns, however, occurs around the area of the boundary of the inner spacer cylinder. However, for a not inconsiderable proportion, the shutdown only takes place within the inner distance cylinder, ie the target species has only been detected at a distance of less than approx. 250 m from the wind turbine.

Figure 70 (bottom) also shows that in the case of shutdowns that only took place inside the inner distance cylinder, low altitudes are represented much more strongly than at the edge of the cylinder including a buffer zone of 25 m. Flights that IDF only takes inside the inner Distance cylinders are detected, are thus predominantly characterized by a low flight altitude. In comparison to flights at greater altitude, such flights are apparently only detected at a shorter distance, that is to say often only in the inner distance cylinder, so that the shutdown can only then be triggered. This difference is particularly pronounced in the two wind turbines in Geislingen, where, due to the local conditions (seating options and hunting activities in a pigsty), there was a high proportion of low altitudes near the two virtual wind turbine locations (see Figure 73).

Overall, the proportion of shutdowns that only took place within the inner distance cylinder is clearly related to low altitudes below 30 m, so that the birds have evidently already flown in low into the inner distance cylinder (Figure 70 and Figure 71). One possible explanation is that they were not visible to IDF (below the horizon line) and / or were blown up in the inner distance cylinder by a seat attendant. Another cause can be the temporal tracking of another bird by IDF, which means that the detection can take place too late or not at all, as has been shown when determining the detection rate at locations with high flight activity (see Section 5.4.1).

The evaluations show that if red kites are detected within the inner distance cylinder, the wind turbines are always switched off immediately, unless the bird is well above the programmed distance cylinder around the wind turbine (Figure 67) and thus in the vertical direction outside of a potential risk of collision. In the sum of all locations, however, it results that approx. 35–59% of all switch-off initiations only take place within the inner distance cylinder and not at its edge (median approx. 48%, Figure 71 A). However, it also becomes clear that the flight altitudes are significantly lower with these shutdowns than with the shutdowns outside or at the edge of the inner distance cylinder (approx. 15–62 m, median approx. 52 m, Figure 71 B).

Shutdowns that only take place well within the inner distance cylinder cannot guarantee that the wind turbine is already in full spin mode if the bird gets into the rotor area while continuing to fly in a straight line. In these cases, however, the flight altitude in relation to the height of the lower edge of the rotor is also decisive for the risk of collision. At the Bütow site, for example, the latter is 98 m (E 101 at a tower height of 149 m) and, compared to the other sites, most closely corresponds to the conditions of modern wind turbines. Figure 72 shows that approx. 80% of the flights of the red kites detected in the inner distance cylinder were below 98 m, ie that at the time of detection the birds were not exposed to a risk of collision. The Geislingen site, which has no wind turbines yet, is characterized by particularly low altitudes for the red kites only detected in the inner distance cylinder. About 80% of all flight altitudes are already reached at a height of 60 m (Figure 73).

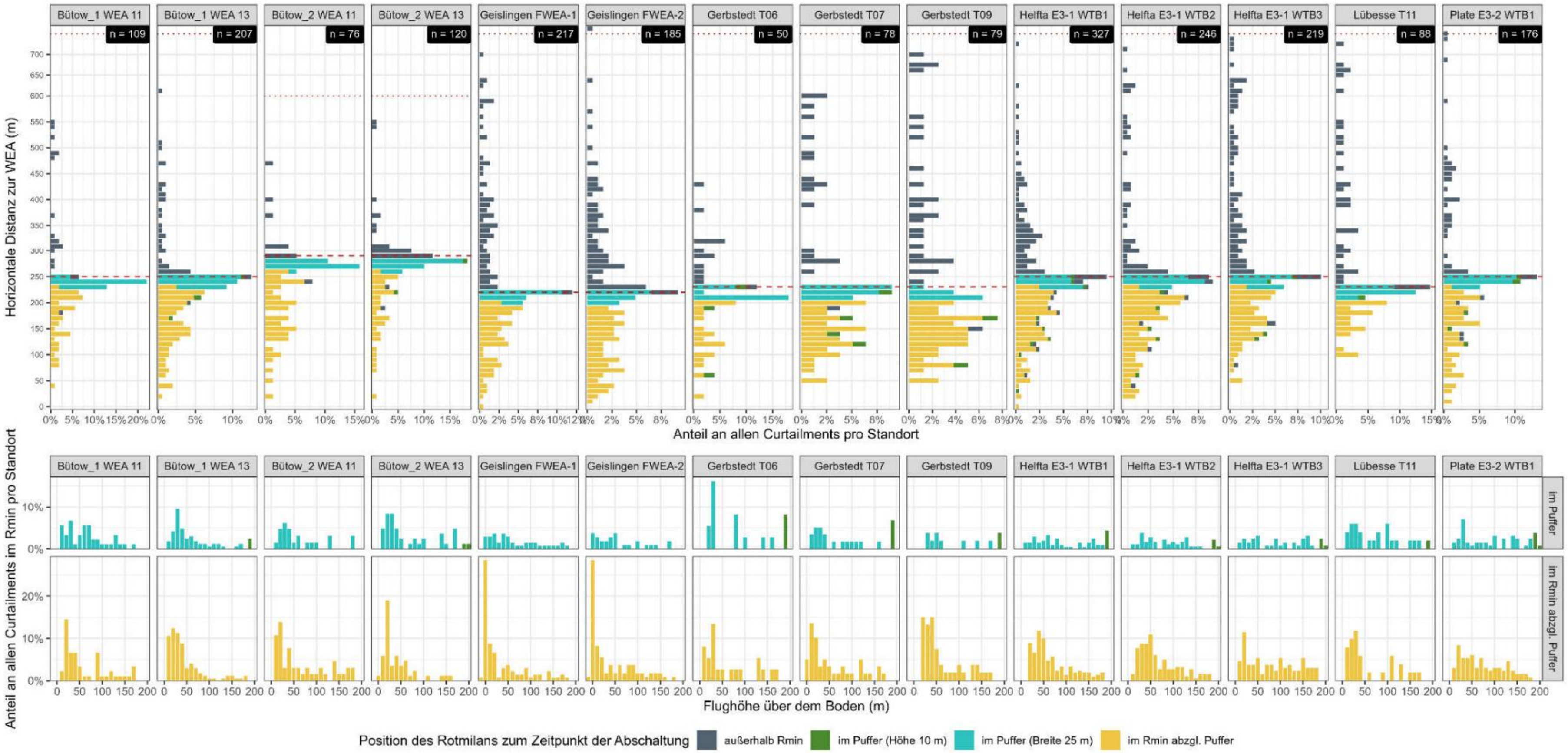

Figure 70: Above: Proportion of switch-off initiations in relation to the distance to the wind turbine. The red dashed lines are Rmin and Rmax.
Below: Proportion of the different flight altitudes at the moment of the shutdown initiations in the totality of all shutdowns in the Rmin, separated for the inside and the edge of the Rmin (including buffer)

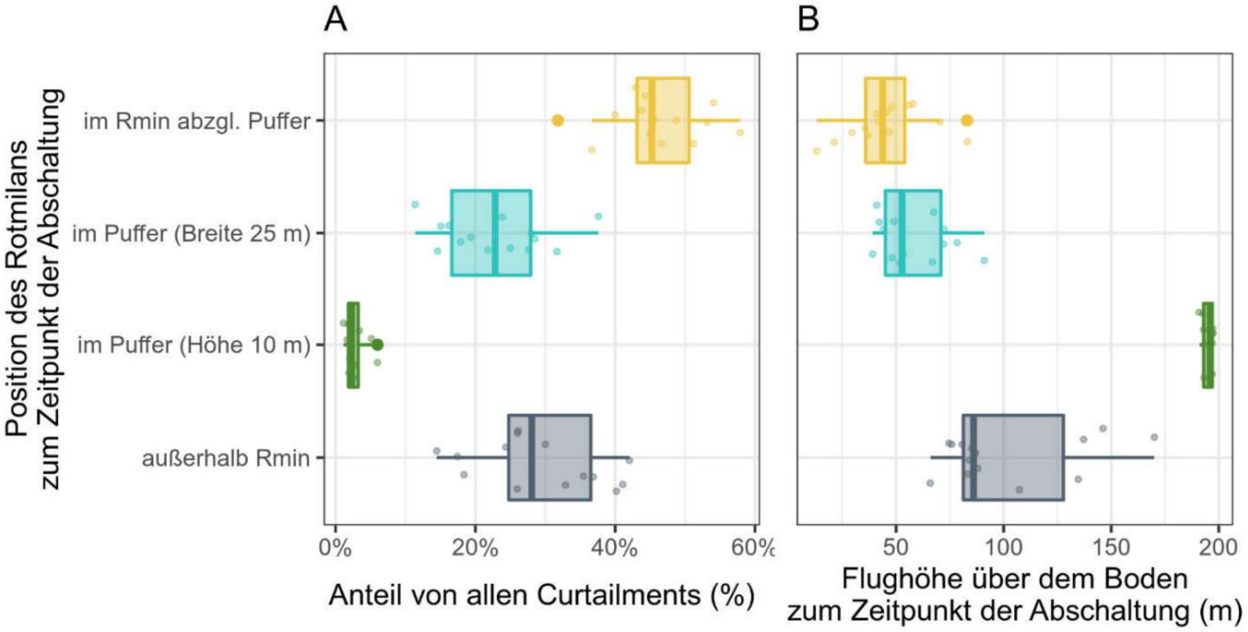

Figure 71: Box plot of the median values of the individual wind turbines in relation to the percentage distribution of the Localization of the shutdown initiation relative to Rmin (left) and in relation to the flight altitude at this point in time (right)

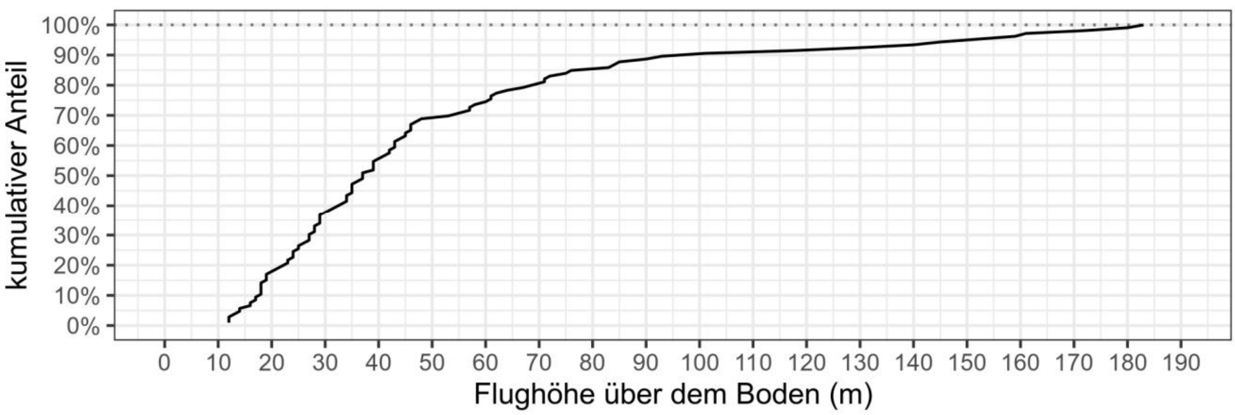

Figure 72: Cumulative display of the flight altitudes of the red kites only detected in the Rmin at the Bütow_1 WEA 13 location.

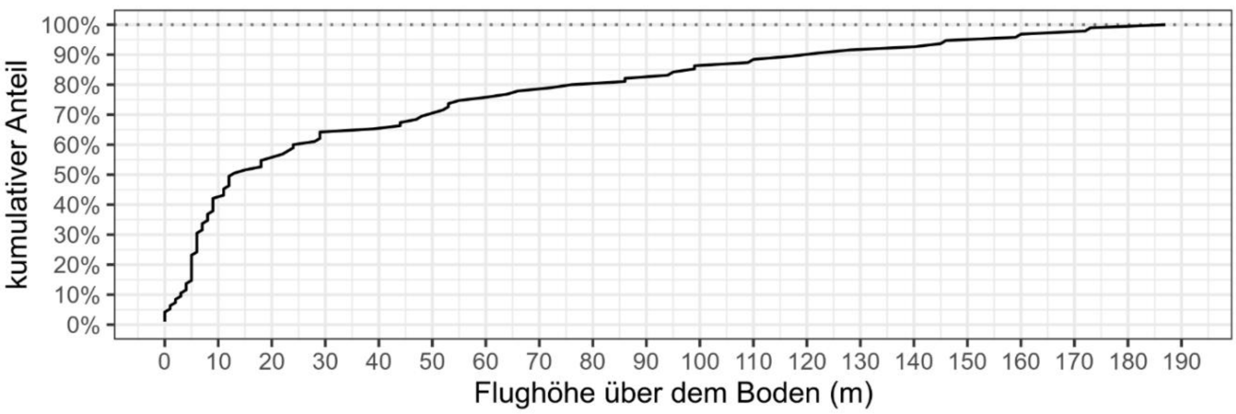

Figure 73: Cumulative display of the flight altitudes of the red kites only detected in the Rmin at the Geislingen FWEA-1 location.

The flight altitude of the red kite obviously has an influence on the detectability by IDF. B. due to local landscape conditions and the local flight behavior of the red kites (Figure 71

to Figure 73). In Table 12, for example, for three different altitudes of 50 m, 75 m and 100 m, it is calculated how many red kites were in the inner distance cylinder at the corresponding altitude at the time of shutdown. This shows that 33% to 69% of the flights, for which the system was only switched off within the inner distance cylinder, took place at a height of up to 50 m. Will all flights up to a height of 75 m included, this value rises to 47% to 84%. At a height of 100 m, this value is between 56% and 91%.

From the flights remaining above these altitudes, the proportion of shutdowns can be calculated in which the birds are only exposed to a residual risk due to the delayed shutdown in the inner distance cylinder. At a limit value of 50 m there is a residual risk for 11% to 34% of all flights for which a switch-off signal was triggered, at 75 m a residual risk of 6% to 23% and at 100 m a residual risk of 3% to 19% .
The residual risk is determined from the ratio of the shutdowns due to flights above the limit value to the total shutdowns. It must be noted, however, that very low-flying red kites are underrepresented by the IDF system, which means that the proportion of low-flying red kites was actually higher. The percentage values given here for the residual risk are therefore to be viewed as conservative and would probably be lower if the total of all flights could have been recorded.

Table 12: **Cut-offs generated by IDF for different heights above mast base.**

			50 m above the mast base			75 m above the mast base			100 m above the mast base		
WEA	Shutdowns total	Shutdown only in Rmin	Flights below	Flights above	Residual risk over all Shutdowns	Flights below	Flights above	Residual risk over all Shutdowns	Flights below	Flights above	Residual risk over all Shutdowns
Bütow_1 WEA11	109	49	55%	22nd	20%	65%	17th	16%	78%	11th	10%
Bütow_1 WEA13	207	106	69%	33	16%	83%	18th	9%	90%	11th	5%
Bütow_2 WEA11	76	44	52%	21	28%	61%	17th	22%	70%	13th	17%
Bütow_2 WEA13	120	44	68%	14th	12%	84%	7th	6%	91%	4th	3%
Geislingen FWEA-1	217	95	69%	29	13%	79%	20th	9%	86%	13th	6%
Geislingen FWEA-2	185	82	65%	29	16%	73%	22nd	12%	84%	13th	7%
Gerbstedt T06	50	20th	55%	9	18%	60%	8th	16%	75%	5	10%
Gerbstedt T07	78	38	58%	16	21%	66%	13th	17%	76%	9	12%
Gerbstedt T09	79	42	55%	19th	24%	69%	13th	16%	76%	10	13%
Helfta E3-1 WTB 1	327	149	39%	91	28%	63%	55	17%	76%	36	11%
Helfta E3-1 WTB 2	246	133	37%	84	34%	63%	49	20%	74%	34	14%
Helfta E3-1 WTB 3	219	94	33%	63	29%	47%	50	23%	56%	41	19%
Luebesse T11	88	28	64%	10	11%	68%	9	10%	71%	8th	9%
Plate E3-2 WTB1	176	82	35%	53	30%	55%	37	21%	67%	27	15%

5.6.2 Reaction of the wind turbine to the switch-off signal

At the Bütow location, an exemplary check of the SCADA data of the wind turbine 13 (Enercon E101) showed that all shutdowns initiated by IdentiFlight were correctly carried out. At this location there was a very high flight activity not only of red kites, but also of numerous other species (see Figure 23).

These included some for which IDF had also generated shutdowns (e.g. sea eagles, ospreys and cranes). In total, this led to a very high number of switch-off signals, the number and time distribution of which are shown in Figure 74 and Figure 75 as an example. The Bütow location is therefore particularly suitable for assessing how well the wind turbine signal conversion has worked on the basis of a large sample of shutdowns. It becomes clear that the number of shutdowns can vary greatly from day to day and between 10 and 90 in the period under consideration

Shutdowns per day fluctuated. Furthermore, it was shown that, according to the daily course of flight activity, an accumulation of shutdowns began from around 9 a.m. and lasted until around 8 p.m.

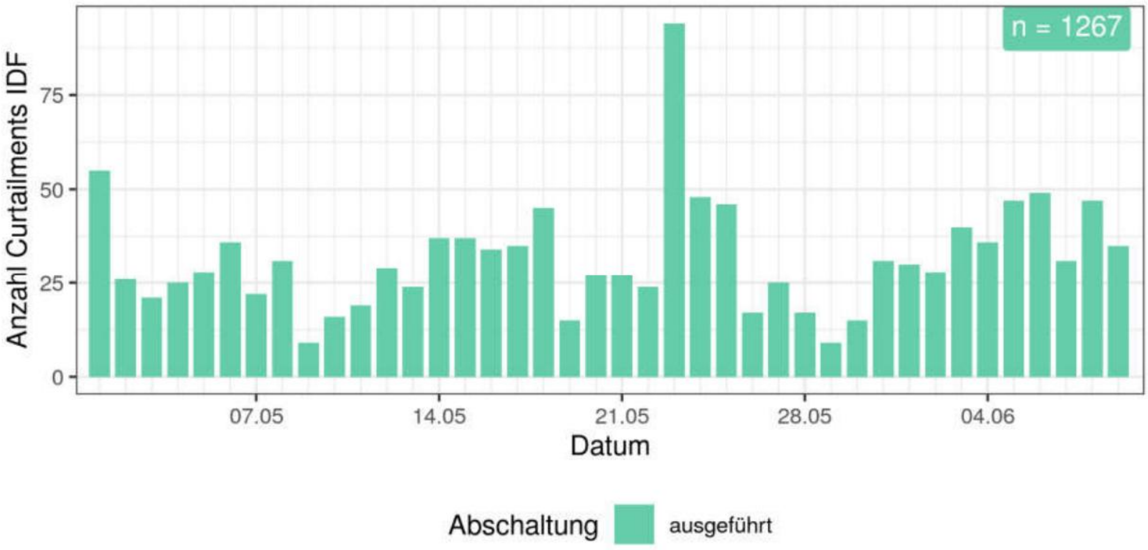

Figure 74: Number of shutdowns initiated by IDF at wind turbine 13 at the investigation site in Bütow. All shutdowns initiated by IDF were correctly carried out by the wind turbine.

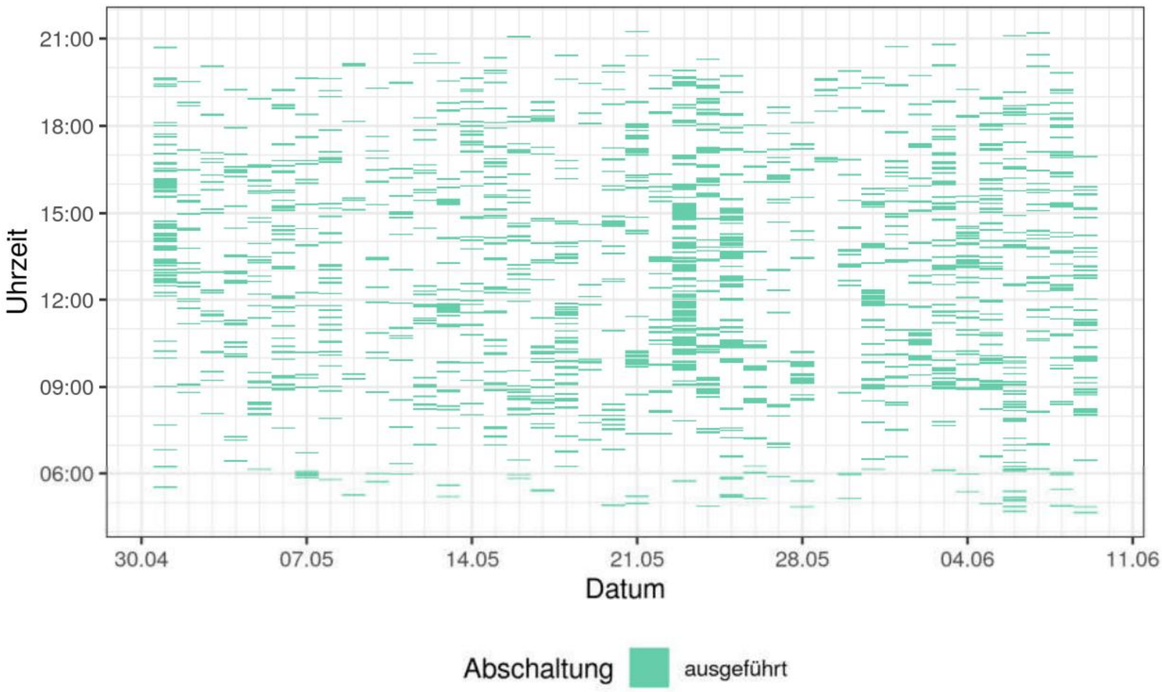

Figure 75: Time-of-day distribution of the shutdown initiated by IDF at wind turbine 13 at the Bütow location.

5.6.3 Relation of flight activity to shutdowns

The frequency and duration of the shutdowns initiated by IDF inevitably depend on the flight activity at the respective wind turbine location. Looking at the entire 750 m radius around the respective IDF, there is a clear linear correlation between the number of recorded tracks per day, with or without birds classified as protected by the IDF, and the number of triggered shutdowns (Figure 76).

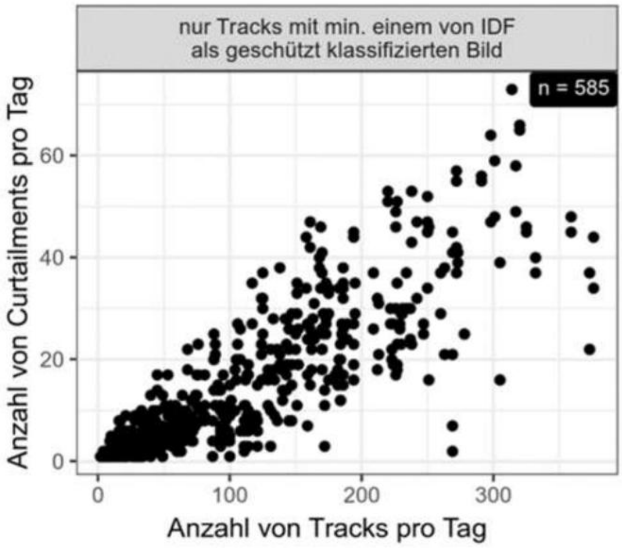

Figure 76: Number of shutdowns (curtailments) per day depending on the number of tracks for which a protected species was classified at least once. n = number of wind turbine days

If the observation is limited to a 350 m radius, which corresponds approximately to the expansion of the inner shut-off cylinder in modern large wind turbines (see Section 6.1.6), it results that almost every second detected flight movement leads to a shutdown with an average duration of approx. 3.5 min (Table 13). The average number of shutdowns per day across the six locations varied from a little over 1 to just under 40
Shutdowns / day, with the highest values in each case in the rearing time of the young, ie from 20.05. until June 30th (Table 14).

Table 13: **Relation of red kite flight activity in a 350 m radius to the number and duration of the IDF for Red Kites triggered shutdowns**

Location	Recorded		Average time of Switch-off signal [s]	relationship Shutdowns / flights
	Flights within a 350 m radius	Shutdowns		
Helfta	641	344	161	0.54
Plate	477	180	155	0.38
Gerbstedt	409	193	217	0.47
Luebesse	325	123	215	0.38
Butow	1,262	392	239	0.25
Geislingen	3,903	1,775	276	0.50
average	**1,385**	**536**	**211**	**0.43**

Table 14: **Average number of daily shutdowns during the different breeding phases on the IDF locations**

Breeding phases	Locations					
	Plate	Luebesse	Butow	Helfta	Gerbstedt	Geislingen
Courtship time 15.03-14.04	1.2	1.7	10.7	5.5	4.8	20th
Breeding season April 15-19	1.5	2.1	13.6	7th	6.1	25.2
Rearing time May 20-30	3.2	4.7	11.5	15.2	13.4	39.4
Post-breeding season 0.1.07.-30.09.	1.5	2.2	5.5	7.3	6.4	18.9

Figure 71 has shown that over 40% of the initiated shutdowns only took place within the inner distance cylinder, but the birds only fly at low altitudes of approx. 15 - 60 m. In order to estimate the effects of the flight altitude on the number and duration of the shutdowns, the Geislingen
all flight movements that remain below 40 m above the ground continuously. For this consideration, a low flight altitude limit was specifically chosen in order to illustrate the effect of including the flight altitude factor with a conservative approach with regard to the height of the lower edge of the rotor.

With such a limitation of the data set to flights above 40 m above ground
At the Geislingen site, there is a significant reduction in the number of flights recorded in a 350 m radius by around 30%. The number of shutdowns is even reduced by almost half (Table 15). Accordingly, the ratio of flights and shutdowns is reduced from 0.50 to 0.36. Only the average duration of the switch-off signal increases slightly.

Table 15: **Relation of red kite flight activity in a 350 m radius to the number and duration of the IDF for Red kites triggered shutdowns at the Geislingen site when taking into account the Altitude**

	Recorded		Average time of Switch-off signal [s]	relationship Shutdowns / flights
	Number of flights in the 350 m radius	Shutdowns		
All flights	3,903	1,775	276	0.50
Only flights over 40 m high	2,731	975	287	0.36

5.7 Flight behavior of the red kite

5.7.1 Altitude

The flight altitudes of red kites, determined from the IDF data, show that the maximum of the flight altitude distribution is around 30 - 40 m, based on the IDF stereo camera, and decreases steadily above (Figure 77). However, there are major differences between the individual locations. While the altitudes in Plate are distributed over a significantly higher altitude range, the altitude at Gerbstedt and Bütow is concentrated most strongly on lower altitudes.

If one considers the cumulative proportions over the height and for the different locations, it can be seen that, averaged over all locations, 55% of the data up to a height of 100 m were recorded, with this value fluctuating between 35% for Plate and 67% for Gerbstedt (Figure 78).

These large differences are presumably due to the site-specific conditions, due to the proximity to breeding grounds or feeding areas that are approached low-altitude or to areas that are mainly flown over or used as thermals. The flight altitudes are therefore site-specific and do not reflect the overall flight altitude distribution of the individuals involved, as is the case with telemetered birds (HEUCK *et al.* 2019). In addition, the prioritization of birds in greater risk of collision by the IDF system and the under-recording of very low-flying red kites lead to a further deviation in the flight altitude distribution compared to

telemetered red kites.

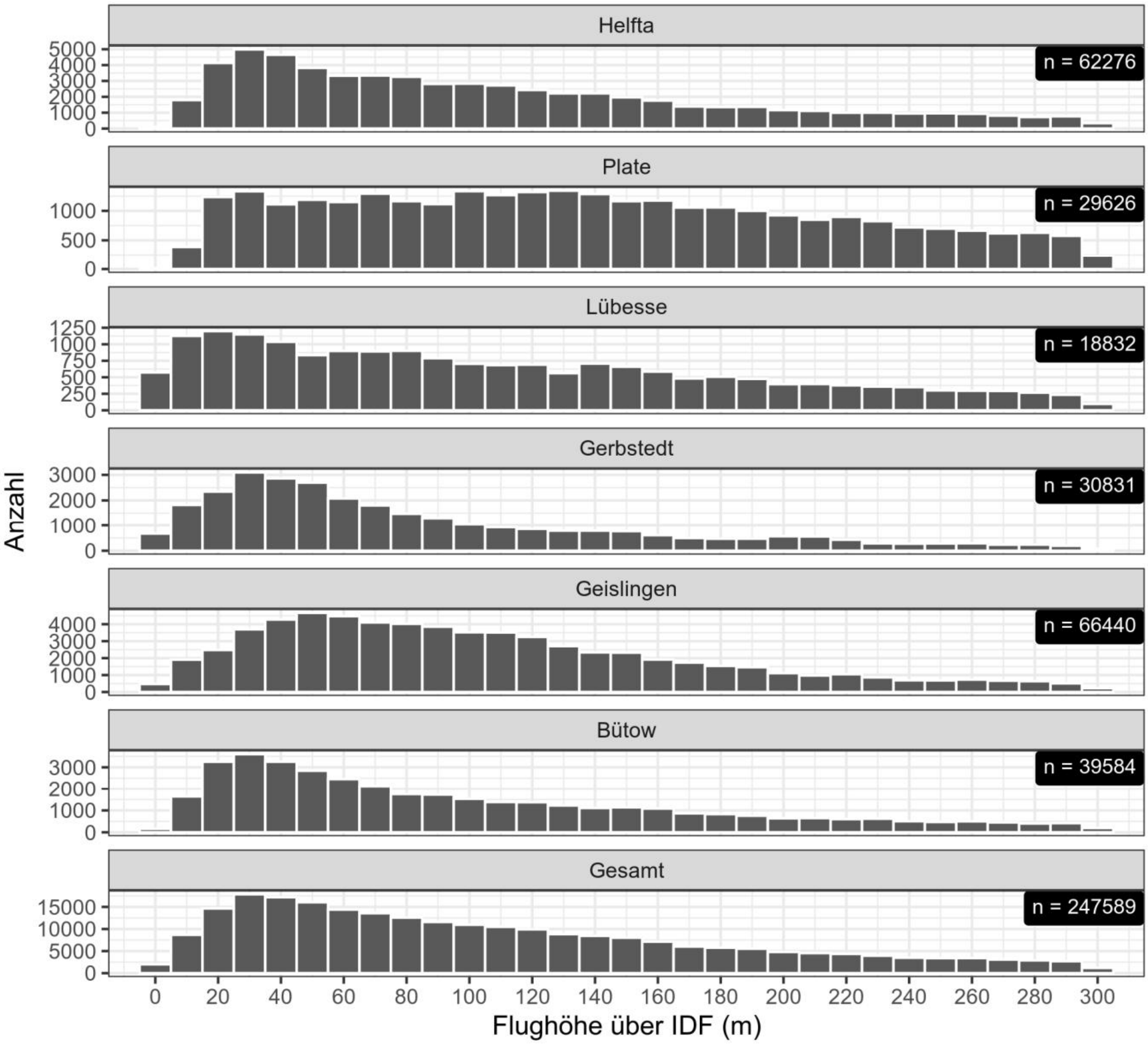

Figure 77: Distribution of the flight altitudes, in 10 m height classes, of subsequently determined Red Kites over all six locations up to 300 m above the IDF.

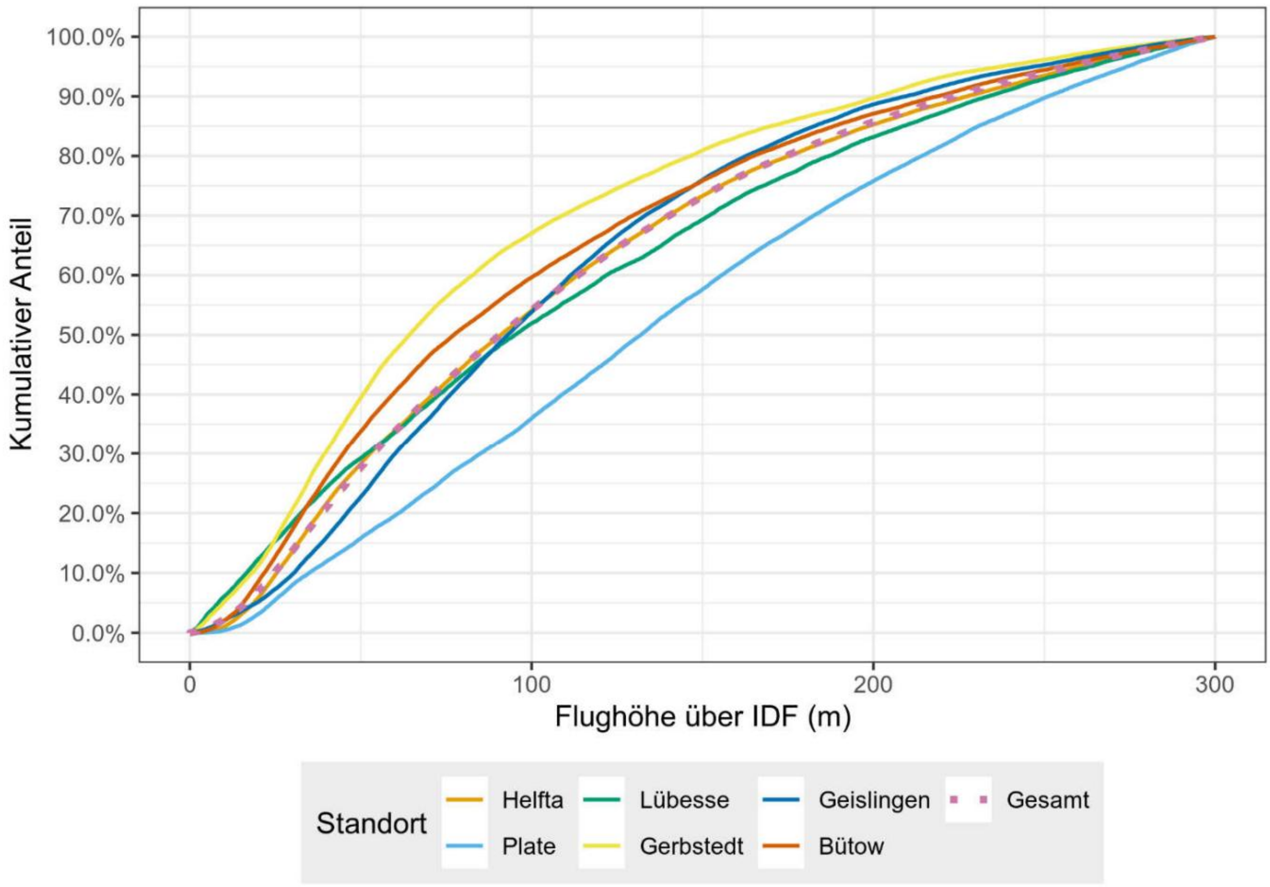

Figure 78: Cumulative proportion of the flight altitudes of post-determined red kites up to 300 m above the IDF.

5.7.2 Airspeed

The flight speed of the target species has a major influence on the required detection range and on the dimensioning of the inner and outer spacer cylinders. Therefore, the following is an evaluation of the data generated by the IDF in this project with regard to the horizontal and vertical flight speeds of red kites.

The median of the horizontal airspeed across all locations based on 76,175 measurements was 8.4 m / s or 30.24 km / h with a standard deviation of 3 m / s (approx. 68% of all values were thus within 8.4 +/- 3 m / s). Between the locations, the medians fluctuate from 7.6 to 9.1 m / s (Table 16).

The median of the vertical airspeed across all locations was -0.8 m / s for the descent and 0.9 m / s for the climb (with a standard deviation of around 1 m / s).
The medians fluctuate only very slightly between the locations (Table 16).

The distribution of the averaged horizontal and vertical airspeeds is largely similar at all locations (Figure 79 and Figure 82).

There is no clear dependence of the horizontal airspeed on the flight altitude, but there is a tendency to fly more slowly near the ground than at higher altitudes
(Figure 80). The median at a height of <50 m is approx. 8 m / s, at a height of 200 to 250 m, on the other hand, it is just under 9 m / s.

Even if very high horizontal velocities were occasionally determined, at a height of up to 200 m approx. 70% of all values are below 10 m / s and approx. 90% below 12.5 m / s (Figure 81).

With regard to the height distribution of the vertical airspeed, a clearer one can be seen
There is a tendency for ascending and descending flights to be faster at high altitudes than low above the ground. At an altitude of <50 m, the median for climb flights is below 0.5 m / s, whereas the median at an altitude of 200-250 m is over 1 m / s (Figure 83), which indicates the general increase in wind speed should be attributed to the height.

Low-flying red kites therefore only gain height slowly. When viewed cumulatively, 90% of the mean rate of climb up to a height of 100 m are below 1.5 m / s (Figure 84).

Table 16: **Flight speeds of red kites determined by the IDF in the horizontal direction as well as in descent and ascent flight.**

	Horizontal airspeed, descent speed						**Rate of climb**		
Location	**Median**	**SD**	**Number of**	**median**	**SD**	**number**	**Median**	**SD**	**number**
Helfta	7.6	2.8	17,960	-0.9	1.0	7,261	0.8	0.9	9,458
Plate	8.4	3.0	5,283	-1.0	1.1	2,486	0.9	1.0	2,500
Luebesse	7.6	2.9	2,296	-0.8	0.8	907	0.8	1.1	1,293
Gerbstedt	8.8	3.0	9,109	-0.7	0.9	3,500	0.8	0.9	5,139
Geislingen	8.8	3.1	29,980	-0.8	1.1	13,460	0.8	0.9	15,802
Butow	9.1	3.1	11,547	-0.9	1.0	5,406	0.8	0.9	5,745
Total / mean	**8.4**	**3.0**	**76.175**	**-0.8**	**1.0**	**33,020**	**0.8**	**0.9**	**39,937**

SD = standard deviation

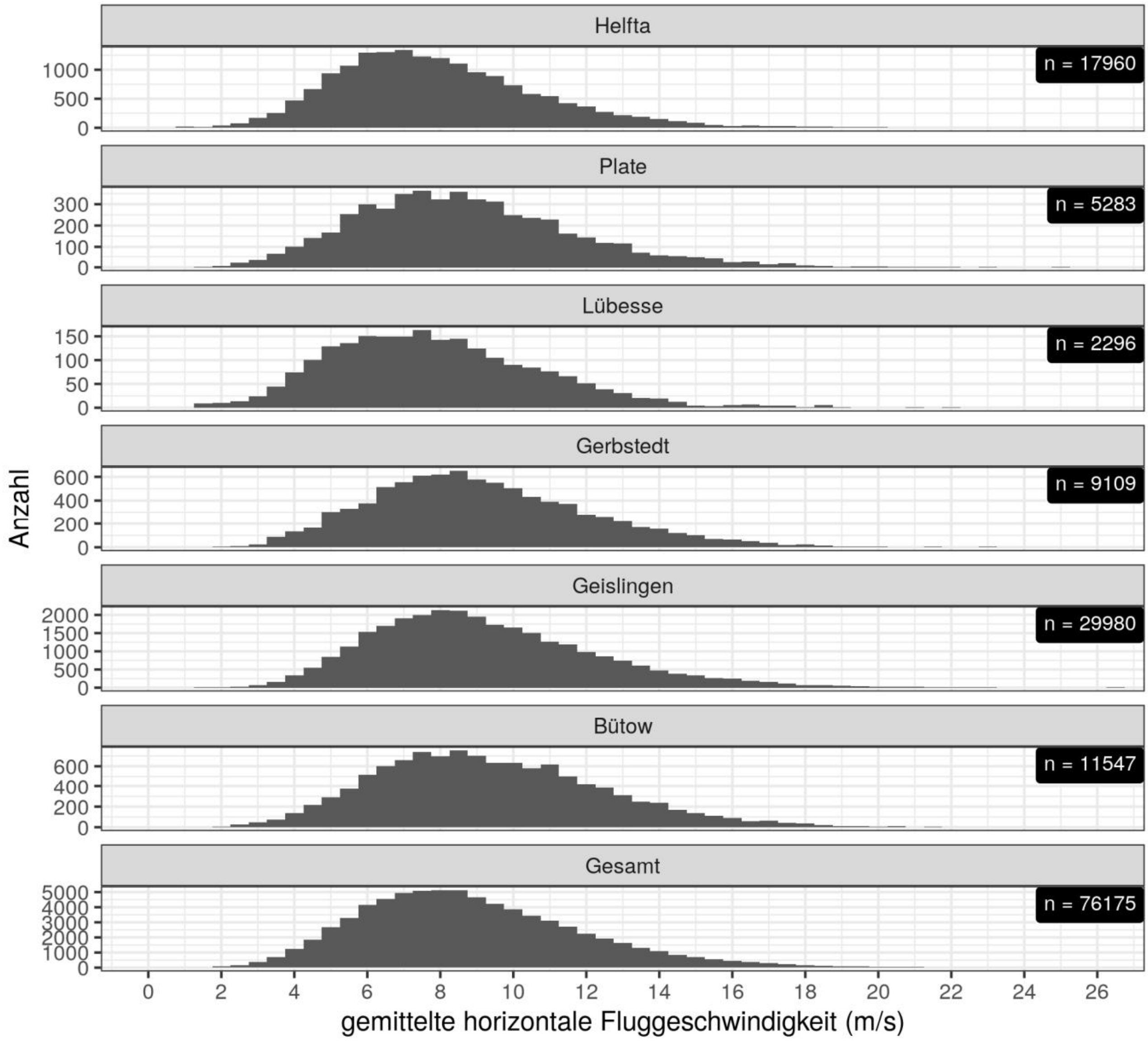

Figure 79: Distribution of the horizontal airspeeds calculated as a moving average of Red kites in all study areas

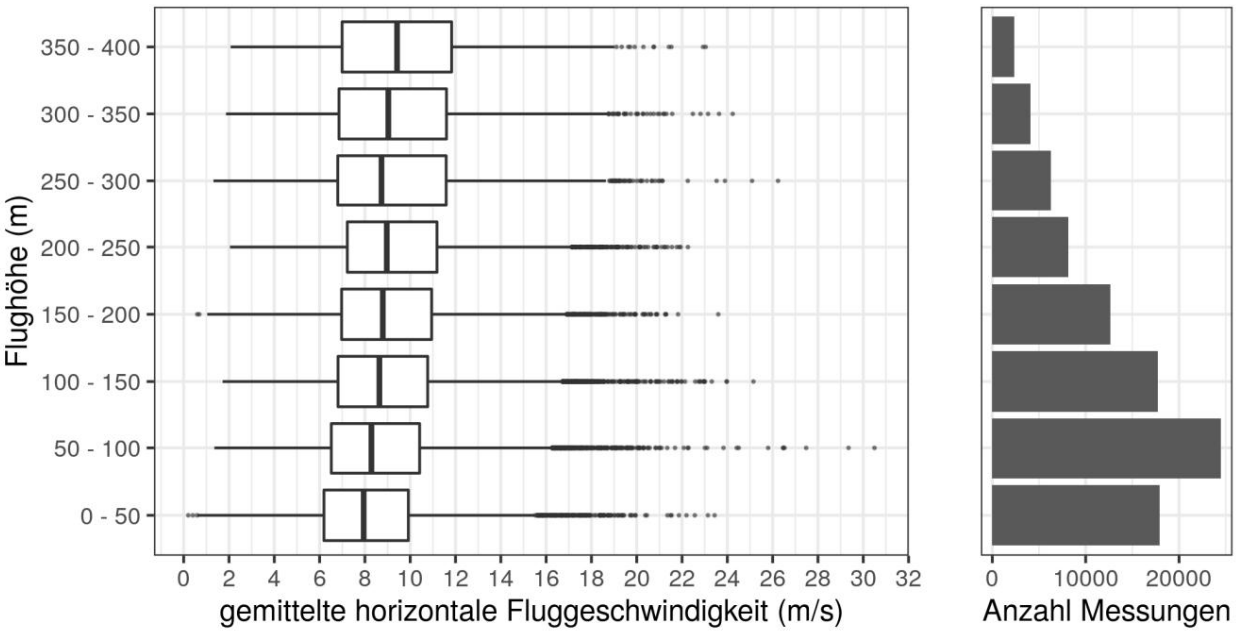

Figure 80: Box plots of the height distribution of the horizontal lines calculated as the moving average Flight speeds of red kites

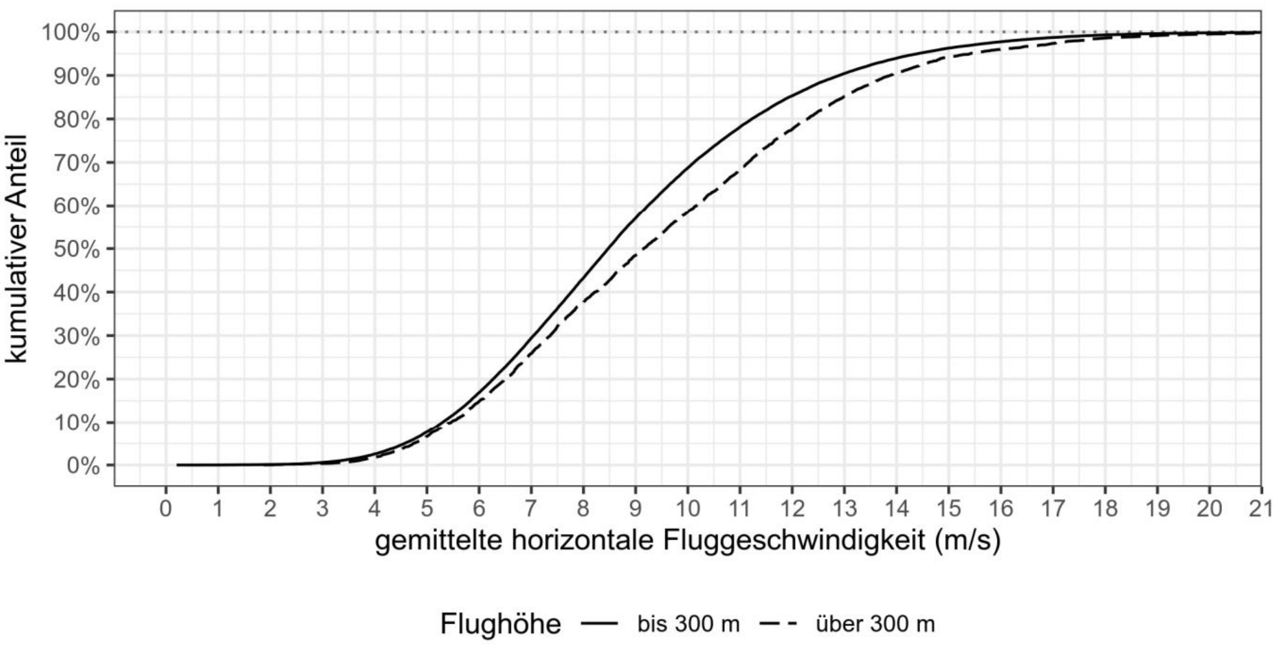

Figure 81: Cumulative representation of the horizontal calculated as a moving average Flight speeds of red kites over all study locations

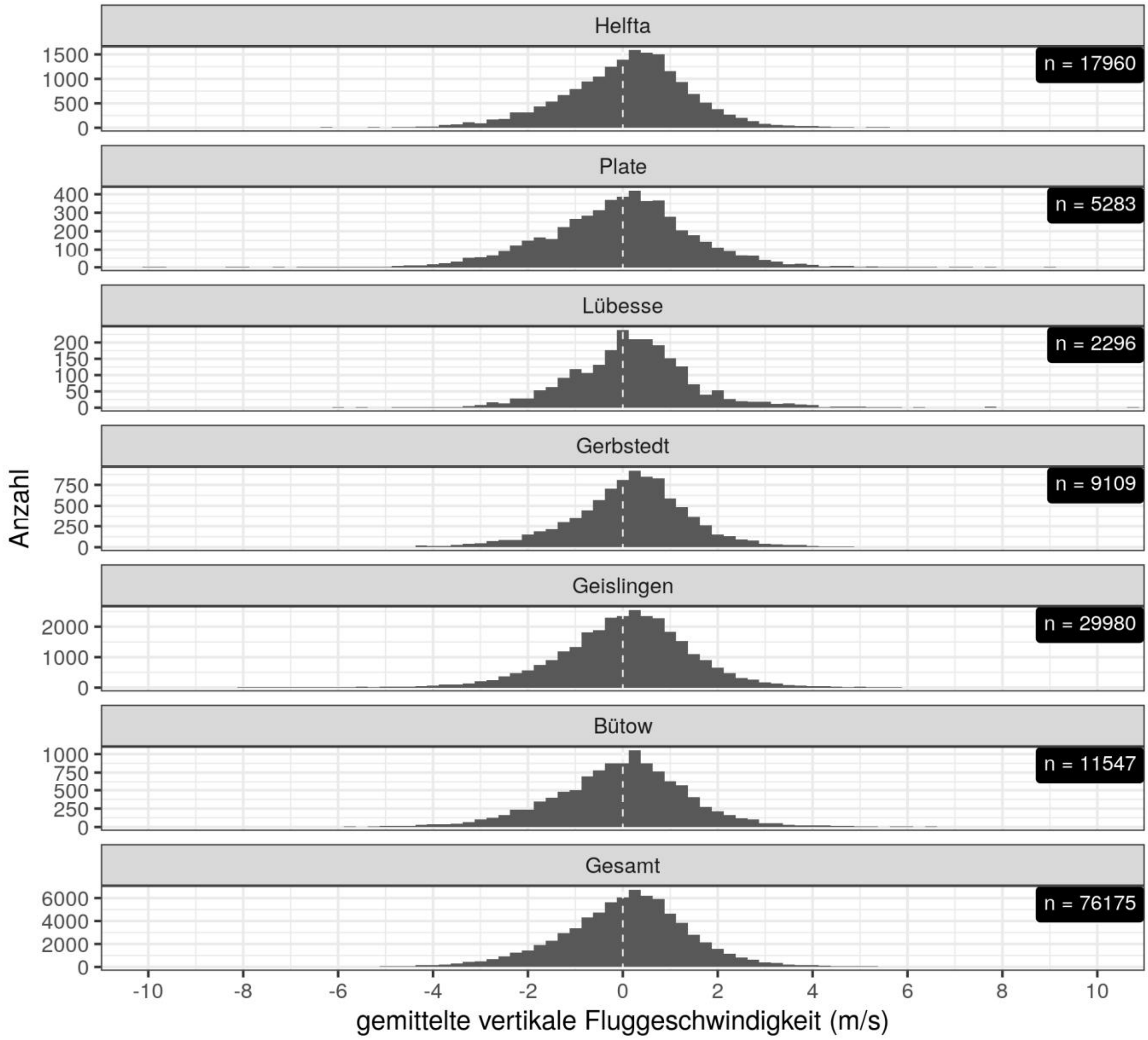

Figure 82: Distribution of the vertical airspeeds calculated as a moving average in all Study areas

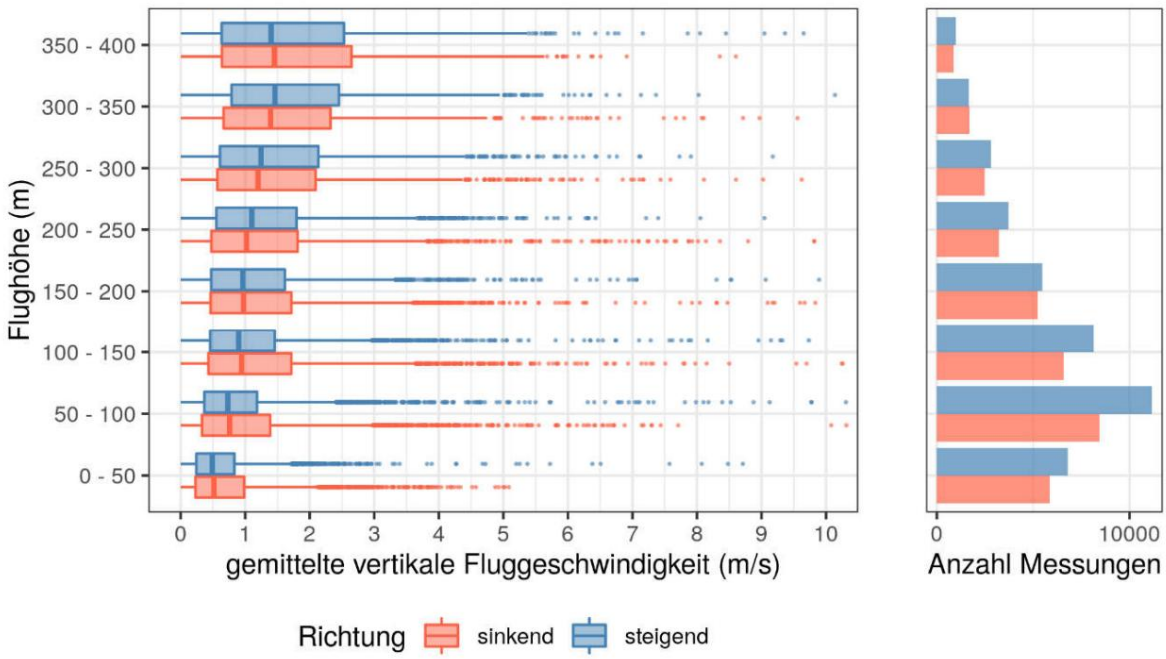

Figure 83: Box plots of the height distribution of the verticals calculated as the moving average Airspeeds

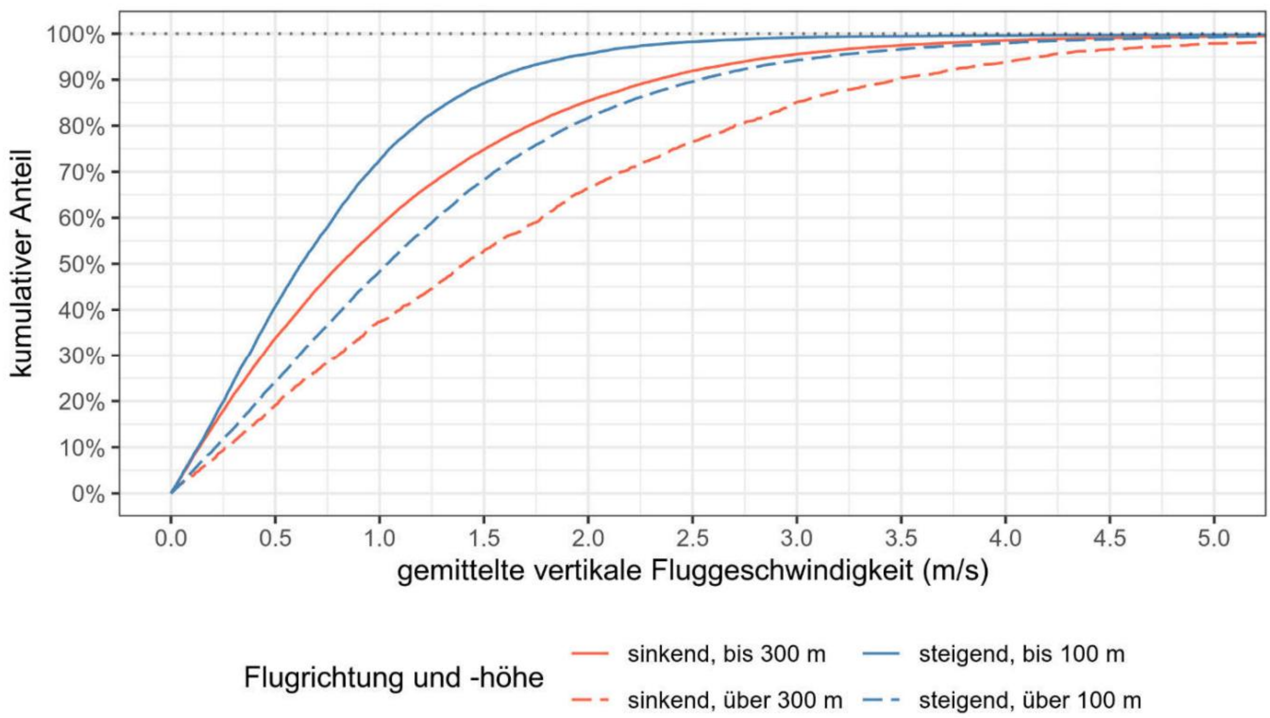

Figure 84: Cumulative display of the verticals calculated as a moving average Flight speeds of red kites over all study locations

6 Assessment of the effectiveness of IDF under species protection law

In the following, in Chapter 6.1 on the basis of the results from Chapter 5, the performance of IDF with regard to the individual criteria from KNE (2019) is discussed and classified.

Then, in Chapter 6.2, these individual results are combined to classify the overall effectiveness of the system.

Then, in Chapter 6.3, the species protection requirements are shown against which this overall effectiveness is to be measured.

In chapter 6.4, the final assessment is made as to whether and under what circumstances IDF is suitable to reduce the collision risk to such an extent that there is no significant increase in the risk of killing within the meaning of Section 44 Paragraph 1 No. 1 in conjunction with Section 44 Paragraph 5 No. 1 BNatSchG is no longer available.

6.1 Characterization of the performance of IDF

The requirements that must be placed on the performance of IDF in order to ensure that the risk of death from wind turbines is not significantly increased in each individual case are considered below using the criteria from KNE (2019). As in chapter 3.1 explained, these are:

1. Spatial and temporal coverage of the location
2. Detection range
3. Acquisition rate (collection of reference data by a so-called second system)
4. Classification rate of the flying object
5. Effectiveness and efficiency of the system response

In addition, the necessary dimensioning of the IDF-specific distance cylinders is considered based on the red kite's flight behavior.

At the BfN colloquium “Nature-Compatible Use of Wind Energy through Smart Technologies in Species Protection” on November 3rd and 4th, 2020, the Swiss Ornithological Institute in Sempach presented its own evaluations of the IDF data from Geislingen (ASCHWANDEN 2020). [9] On the basis of the results obtained, the author concludes that the detection properties of the system (few errors in classification, large range with high detection efficiency) provide a very good starting point for the target species red and black kite to implement a needs-based shutdown. A full project report has now been published on this (ASCHWANDEN & LIECHTI 2020) [10].

[9] https://www.natur-und-erneuerbare.de/aktuelles/details/naturvertraegliche-windenergienutzen-durch-smarte technologies-in-species protection /

[10] https://www.zsw-bw.de/uploads/media/NatForWINSENT_Testbericht_IndentiFlight.pdf

6.1.1 Spatial and temporal coverage of the location

In **spatial** terms, flight paths of red kites were recorded at all six study locations in a 360 ° radius. Only near the ground were areas in which no flight path detection was possible, partly due to shading wood structures or due to masking required by data protection law (e.g. on paths or stables) (see Chapter 4.1.3 and Figure 16 to Figure 24 as well as Figure 42 and Figure 43). However, these areas only take up a very small proportion of the entire camera's field of view and also only affect very low altitudes, which are not relevant with regard to the risk of collision (see Chapter 5.6.1)

With regard to the specific functioning of IDF with the use of an outer and an inner spacer cylinder around the wind turbine to be monitored (see Figure 6), it is particularly important that the inner spacer cylinder around the respective wind turbine can be completely overlooked by IDF. This was the case in all six investigation areas, as there were no visual obstructions in the area of the inner distance cylinder around the wind turbines to be monitored (see Figure 10 to Figure 14). This provided unrestricted spatial coverage of the inner spacer cylinder in each case. With regard to the further reaching outer spacer cylinder, as explained in Chapter 4.1.3, there were only very slight restrictions on visibility close to the ground.

There is an area vertically above the IDF that cannot be seen (see blind zone in Figure 3). However, this range does not affect the detection performance of the IDF system as well as the shutdown processes generated by IDF, since it is completely surrounded by the visibility dome (spatial field of view of IDF). In this respect, a spatial coverage rate of 100% can be assumed at least for the collision-relevant flight altitudes> approx. 20 m.

In terms of **time ,** the combination of all six locations over the recording years from 2018 to 2020 achieved almost complete coverage of the entire breeding season of the red kite; only no data are available from the month of March (total period April 16 to October 18, see Chapter 4.1.4). Out of a total of 393 camera days, 29 days had to be excluded due to complete or partial system failures, so that the total time span is a full year (364 camera days, see Table 3

and Figure 28). According to the data available, this results in a total system availability of around 93% over time (see Chapter 4.1.4). However, this also includes difficulties with the local power supply, especially at the locations with virtual wind turbines. In real use, there will be a reliable power supply via the existing wind turbine to be monitored, so that a technical availability of at least 95% is assumed (see Chapter 4.1.4).

Assessment of IdentiFlight

Due to the combination of six locations, each of which could be easily viewed by IDF, the spatial and temporal coverage rate of the present study can be regarded as extremely reliable with regard to the questions to be investigated.

6.1.2 Detection range

The detection range - based on the location of the wind turbine - must be at least large enough that there is enough time from the time of detection (including classification of the flying object) to when the wind turbine is in spin mode as a result of the system-generated switch-off signal at average airspeed that at expected entry of the red kite into the rotor radius, the spin mode is actually reached.

According to a decision of the OVG Lüneburg (decision of April 29, 2019 - 12 ME 188/18), from a species protection point of view, reaching the spinning operation - in contrast to the complete standstill of the wind turbine - can be regarded as sufficient

On the basis of the current state of information (AMMERMANN *et al.* 2020), it was assumed at the beginning of the investigation that the slowdown process from the arrival of the switch-off signal to the reaching of the spin mode of about 30 s on average was assumed.
This value was confirmed as conservative by shutdown tests at the Lübesse, Gerbstedt and Bütow sites and subsequently accepted (see Section 4.1).

The flight speed of a red kite at a given point in time essentially depends on the flight behavior exercised. From a slow glider to a directed gliding supported by a tail wind to possible nosedive phases, the speed can vary greatly. Assuming approx. 25 km / h (approx. 7 m / s) for gliding and slow gliding (HÖTKER *et al.* 2017), the result is a shutdown time of 30 s

a minimum distance of approx. 210 m from the rotor tip. According to the literature, the airspeed varies by approx. 10 m / s with mixed flight behavior (BRUDERER & BOLT 2001, p. 189: mixed flight behavior from Europe varied around 10.5 or 10.1 m / s). Based on the higher values in BRUDERER & BOLT (2001) (approx. 15 m / s gliding), this results in a distance of approx. 450 m Vogel approaches the facility by the shortest possible route at high gliding speed.

If a certain safety margin is also taken into account for the time interval between the detection of the bird and the onset of the system's slowing reaction (assumption approx. 3 s, see Chapter 4.3.4), this would result in the required minimum detection range of approx. 230 m (at 7 m / s airspeed) or 500 m (at 15 m / s)

plus rotor radius.

[11th] https://www.naturschutz-energiewende.de/wp-content/uploads/20190725_KNE Antwort_233_OVG_Lueneburg_Trudelbetrieb_seT.pdf, accessed on March 4th, 2020

The data on the horizontal flight speed of the red kite (median 8.4 m / s, see Chapter 5.7) collected in the present study with IDF results in a required minimum detection range from the rotor tip of approx. 280 m.
percent coverage of all determined flight speeds (up to approx. 20 m / s, see chapter 5.7), based on the 30 s switch-off time, a detection range from the rotor tip of approx. 600 m is required.

Assessment of IdentiFlight

The available investigations showed a detection and classification range of approx. 750 m for IDF with regard to the red kite (see chapter 5.3). However, it must be taken into account that the IDF system cannot be installed directly on the wind turbine to be monitored, but only at a distance of approx. 100 m to 150 m. This distance is necessary in order to largely exclude the influence of visual shading by the wind turbine tower on the detection performance. This means that the maximum detection range of IDF in relation to a red kite that flies exactly in the extension of the direct line IDF-WEA is limited to approx. 600 m. As shown above, this range is sufficient to detect red kites at almost 100% of all flight speeds in good time and to bring the wind turbine into spin mode before a potential collision. With regard to the red kite, IDF thus fulfills the requirement of a sufficient detection range, also taking into account high flight speeds and taking into account the installation requirements away from the wind turbine to be monitored.

To check the influence of weather conditions on the detection distance, ASCHWANDEN & LIECHTI (2020) at the Geislingen site determined three days with good weather conditions (dry with clear visibility (= 2000 m) and three days with bad weather conditions (wet with partially restricted visibility (<2000 m) m)) and for this purpose the respective frequency distribution of the radial distances at the first point positions identified as the target species of each flight path was formed. It was shown that first detections further away are less common in poor weather conditions. In good weather conditions, 90% of the detections are within a distance of up to up to 750 m and in bad weather conditions, around 91% of the detections are within a distance of up to 600 m (Figure 85). This makes it clear that the weather - especially the visibility -
can have an impact on the detection performance of IDF. However, a large and sufficient detection range is still achieved even under unfavorable weather conditions.

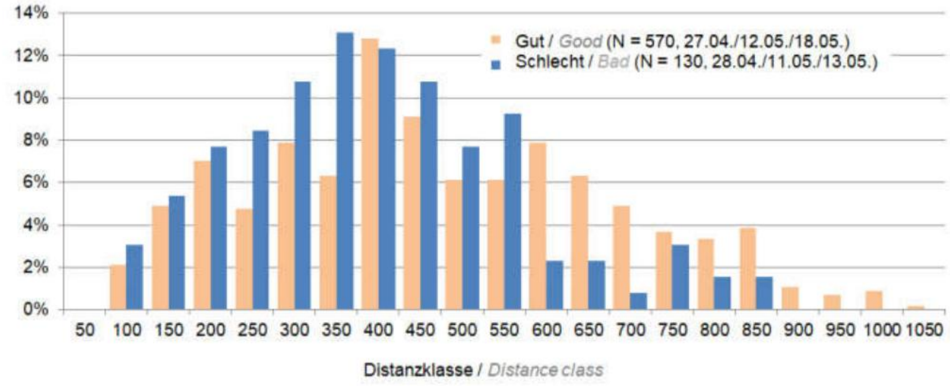

Figure 85: Distribution of the radial initial detection distances of flight paths of the target species as a function the weather (good = dry with a clear view, bad = wet with partially restricted visibility). Source: ASCHWANDEN & LIECHTI (2020)

6.1.3 Acquisition rate

The detection rate indicates how many of the relevant flight objects actually occurring (here red kite) are detected by IDF within the detection range. This is a central criterion for assessing the protective effect of an anti-collision system.

Assessment of IdentiFlight

Overall, a mean acquisition rate of 92% is achieved (see chapter 5.4.1). In general, GPS data as a reference are more accurate than LRF data, so that the acquisition rate at the Geislingen location is based on the telemetry data there (95%). can be viewed as particularly meaningful. The acquisition rate of IDF can thus be classified as very high, which is an essential prerequisite for an effective

Effectiveness to protect the red kite from collisions at wind turbines is fulfilled.

6.1.4 Classification of the flying object

From a nature conservation point of view, the so-called false-negative rate is decisive for assessing the classification performance of a system, ie the extent to which actual red kites are not recognized as such (target species is not recognized as target species). In contrast, the false positive rate at which non-red kites are falsely identified as such by the system does not play a role, as it does not lead to a reduction in the level of protection, but only to additional shutdowns, i.e. a reduction in the availability of the system Operator.

An essential feature of IDF is that the object recognition and the generation of switch-off signals are not carried out comparatively across the board at the level of size classes or species groups, but specifically at the species level, or at least at the species type level (e.g.

Red kite and sea eagle or kite and eagle). However, this high specificity of object recognition represents a further possible source of error, which is described by the false-negative rate. This is a property of the underlying software, the performance of which can, however, be continuously improved to a certain extent through repeated retraining, as could be shown using version 2 of the neural network (see Chapter 5.5).

Assessment of IdentiFlight

In the present studies, the improvement of the software enabled the false negative rate to be reduced from initially 15% to 20% (2018 and 2019, version 1) to 4% to 2.5% (2020, version 2) - based on the Target species red kite or from 2020 on the species group red and black kite. Using version 2, 96% to 97.5% of all red and black kites detected are correctly determined. This classification performance was largely constant up to a distance of approx. 750 m, ie there was no distance-dependent deterioration within the detection distance. Overall, IDF's classification performance can be rated as excellent. ASCHWANDEN & LIECHTI (2020) also come to the same conclusion .

6.1.5 Effectiveness and efficiency of the system response

The **effectiveness** of the system reaction includes the proportion of those cases in which the stay of a target object (here red kite) within the necessary reaction area correctly led to the generation of a switch-off signal (safe and correct system reaction through switch-off in a risky case according to KNE (2019)). The effectiveness of the system reaction can only be measured in the inner distance cylinder, since a switch-off signal should always be generated in the inner distance cylinder when a target species occurs. The shutdowns in the outer distance cylinder by the TTC (Time-To-Collision) method cannot be included in this evaluation, since it is not possible to determine in detail which flight movement should have caused the shutdown.

There are basically two possible causes for a delayed or missing shutdown in the inner distance cylinder:

1. A target is within a distance that a shutdown will occur but is not recognized as a target object.
2. A target object is within the switch-off distance and is also recognized as such, but does not trigger a switch-off signal or does not trigger a switch-off signal in good time.

Possibility 1 can generally be equated with the collection and classification rate, for which a high resilience has already been determined. With regard to option 2, they show available data that for every red kite that is detected by IDF within the switch-off distance, a switch-off signal is also generated. It turned out, however, that in approx. 48% of all shutdowns, red kites only occur within the inner distance cylinder were detected, so that in relation to the horizontal airspeed or the intended function of the inner spacer cylinder, the shutdown occurred too late in these cases (Figure 71A). With regard to the risk of collision, however, the vertical component must also be included in addition to the horizontal, ie the flight altitude above the ground. In this regard, it has been shown that the median of the flight altitude for the horizontally too late shutdowns is below 50 m (Figure 71B). This low flight altitude is to be set in relation to the height of the lower edge of the rotor at the respective locations. In Bütow, for example, this means that approx. 80% of the flights for which a shutdown was only triggered within the inner distance cylinder took place below the lower rotor edge height of 98 m given there (Figure 72). However, it must be taken into account that a bird below the

Rotor height flies, can get into the collision area by climbing within the shutdown time of 30 s. A median of 0.7 m / s was determined for the speed of such climbs below 100 m (Figure 83 and Table 17), so that flights that are 21 m below the rotor height (ie <77 m), even with delayed shutdown can usually not get into a collision risk within the inner spacer cylinder.

Within the inner spacer cylinder of the wind turbine 13 in Bütow (variant 2), around 70% of the flights that were switched off late took place below 77 m (Figure 72). Thus, actually only about 30% of the flights in the inner distance cylinder were affected by the shutdown, which took place too late. In the case of the WEA 13 in Bütow (variant 2), this comprised 112 flights. In relation to the total number of 919 shutdowns for this wind turbine (Figure 70), the proportion of delayed shutdowns for flights at a level relevant to the collision is around 12%. The effectiveness of the shutdowns, based on the actual collision risk in horizontal and vertical terms, is around 88% in the specific case of WT 13 in Bütow (variant 2).

In each individual case, this value depends both on the height of the lower edge of the rotor and on the heights of the flights in the inner spacer cylinder. That's how they went in Geislingen Flights for which shutdowns were only triggered within the inner distance cylinder, significantly lower than in Bütow (see Figure 73), which further reduces the risk of collision in vertical terms. Overall, the result is that the effectiveness of IDF is greater, the greater the distance between the floor and the lower edge of the rotor. The present results show that IDF has a very high shutdown effectiveness when the lower rotor edge height is large.

The **system efficiency primarily** relates to the question of the extent to which unnecessary shutdowns occur in addition to the necessary, target-type-related shutdowns (Number and duration of the shutdowns carried out as well as the ratio of necessary and unnecessary shutdowns according to KNE (2019)). These are primarily those shutdowns that were not triggered by a target object and therefore are not to be classified as necessary from the point of view of species protection law. A low system efficiency is thus primarily expressed through a high false-positive rate. In the present studies, this rate ranges between 1% and 10% at a distance of 250 m

and in 750 m between 1% and 16% (see Table 11). It should be noted, however, that the false positive rate is not a pure system property, but to a large extent depends on the depends on the conditions occurring at the specific location, ie the frequency with which species occur there that can easily be confused with the target species.

Assessment of IdentiFlight

Effectiveness does not mean that the impairment can be excluded with certainty. An examination based on practical reason is necessary and sufficient in species protection law. However, it is necessary to lower the project-specific risk of killing below the significance threshold (UMK 2020). In the present

Investigation, an effectiveness of the shutdown procedure of 88% was determined as an example for a specific wind turbine at a location with very high red kite flight activity (see Chapter 5.6 and Table 12). In principle, this can be regarded as a high value, which, however, could be better if the detected amount of delayed detection of red kites within the inner distance cylinder had not occurred. According to

According to the manufacturer, the detection performance for flights below the horizon is to be significantly improved in the future. In general, however, there is already a high disconnection effectiveness at present, provided that the lower edge of the rotor is at a sufficiently high height.

In terms of **system efficiency ,** the false-positive rates determined range between 2% and 16%. It must be taken into account that the programming of the neural network tends to favor a slightly higher false-positive rate, since in cases of doubt the flying object is classified as a target species rather than a non-target species (see Section 2.2). This leads to an overweighting of the false-positive error with the aim of minimizing the false-negative rate relevant to species protection law as much as possible.

An essential feature of IDF is that it can be trained very specifically for the target type required in each case in order to limit the absolute number of shutdowns to the necessary minimum as far as possible. Ultimately, the efficiency of an anti-collision system can only be determined by a parallel comparison with other anti-collision systems at the same location in order to determine the absolute number of each triggered shutdown. In this respect, the false-positive rate alone is not a sufficient measure for the system efficiency, as it also depends significantly on the definition of the target object (e.g. red kite versus bird with at least 130 cm wingspan).

It follows from this that the efficiency of IDF cannot be described quantitatively from the data determined in the present study. However, it can be assumed that IDF is an overall very efficient anti-collision system due to its system properties in combination with the low false-positive rates determined.

6.1.6 Dimensioning of the spacer cylinders

As described in chapter 2.3, the generation of shutdown signals by IDF within the outer distance cylinder (with radius Rmax) is based on the method of calculating the time-to-

Collision. If it is detected in the inner distance cylinder (with radius Rmin) , it will always be switched off, regardless of the time-to-collision. The vertical dimensioning of the Spacer cylinder has so far been set from the ground up to specific heights for the inner and outer spacer cylinder.

Due to the determination of the horizontal and vertical flight speeds of red kites made here (Chapter 5.7), the dimensioning of the inner and outer distance cylinder can, however, be adapted to the specific requirements of red kite protection
The vertical dimensioning of the spacer cylinders, under certain conditions (see sample calculation in Table 17 and Figure 87), does not necessarily have to be determined from the ground (Figure 86).

For the definition of the vertical extension of the spacer cylinders, the designations consist of H for height, U or L for the upper (upper) or lower (lower) limit and min and max for the inner and outer spacer cylinder (Figure 86).

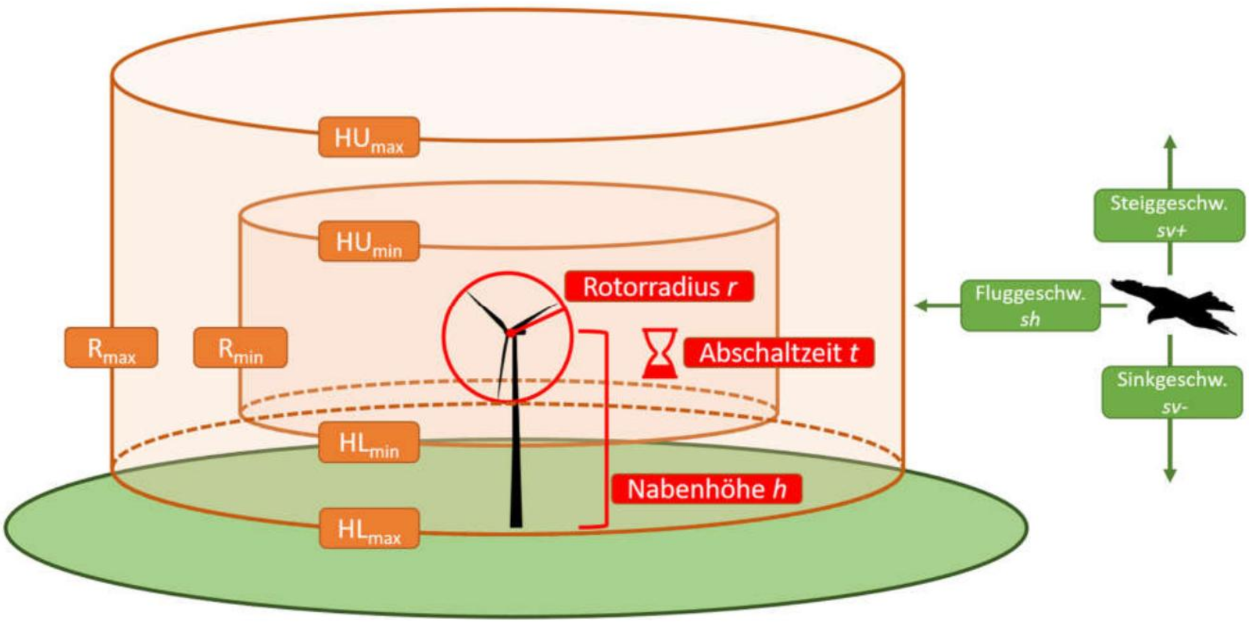

Figure 86: Scheme for dimensioning the inner and outer distance cylinders and the variables required for the calculation.

The calculation formulas below can be used to determine the dimensions of the spacer cylinders according to Figure 86 by using the flight speeds determined by the red kites and taking into account the characteristics of the wind turbine (hub height, rotor diameter and shutdown time).

For the lateral limitation of the inner spacer cylinder Rmin , the middle horizontal Airspeed *shmean multiplied* by the duration for the shutdown (up to the spin mode) of the wind turbine *t* and added to the rotor *radius r :*

r + shmean * t = Rmin

For the lateral limitation of the outer spacer cylinder Rmax , the maximum horizontal airspeed *shmax* to be secured is multiplied by the duration for the shutdown (up to the spin mode) of the wind turbine *t* and added to the rotor *radius r :*

r + shmax * t = Rmax

For the lower limit of the inner spacer cylinder HLmin , the middle one becomes vertical Rate of climb *sv + mean* with the duration for the shutdown (up to the spin mode) of the WEA *t* multiplied and subtracted together with the rotor *radius r* from the hub height *h* of the wind turbine:

h - r - sv + mean * t = HLmin

For the upper limit of the inner spacer cylinder HUmin , the middle vertical Sink speed *sv-mean* multiplied by the duration for the shutdown (up to the spin mode) of the wind turbine *t* and added together with the rotor *radius r* to the hub height *h* of the wind turbine:

h + r + sv-mean * t = HUmin

For the upper limit of the outer distance cylinder HUmax , the maximum vertical rate of descent to be secured *sv-max* with the duration for the shutdown (up to the spin mode) the wind turbine *t* is multiplied and added together with the rotor *radius r* to the hub height *h* of the wind turbine:

h + r + sv-max * t = HUmax

For the lower limit of the outer spacer cylinder HLmax , the maximum vertical rate of climb to be secured *sv + mean* is multiplied by the duration for the shutdown (up to the spin mode) of the wind turbine *t* and together with the rotor *radius r* of the Hub height h of the wind turbine subtracted:

h - r - sv + max * t = HLmax

Using these formulas, the distance cylinders for the Bütow site are calculated as an example, where Enercon E101 wind turbines with a hub height of 149 m were built, resulting in a lower rotor tip height of 98 m and an upper rotor tip height of 200 m above ground. The switch-off time is still assumed to be 30 s. For the flight speeds, on the one hand the medians and on the other hand a 90% coverage of the maximum flight speeds are assumed, in each case for the relevant ones

Height ranges (Table 17). As a result, the inner distance cylinder has a radius of 306 m at a height of 77 m - 236 m, the outer distance cylinder has a radius of 426 m at a height of 50 m - 293 m (Figure 87).

Table 17: **Horizontal and vertical flight speeds of the example calculation from different altitude ranges, each as a median and 90% of all flights.**

Airspeeds	Altitude range	Median *(mean)*	90% *(max)*
Horizontal airspeed *(sh)*	0 - 300 m	8.5 m / s	12.9 m / s
Rate of **descent *(sv-)***	200 - 400 m	1.2 m / s	3.1 m / s
Rate of climb *(sv +)*	0 - 100 m	0.6 m / s	1.5 m / s

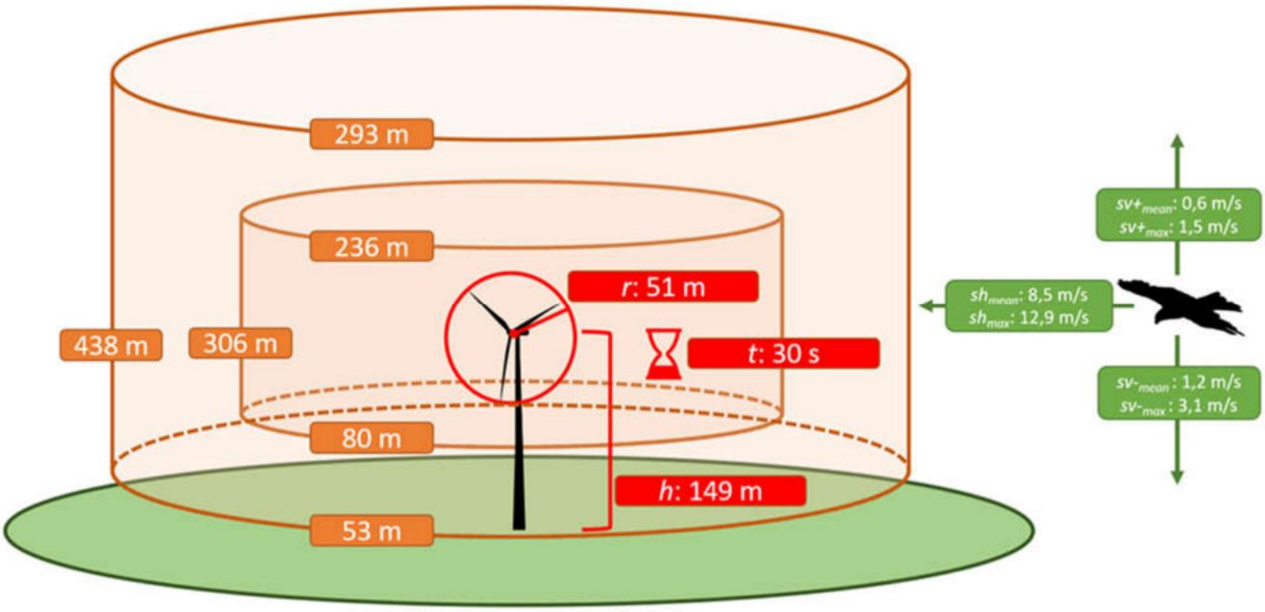

Figure 87: Result of the sample calculation for an Enercon E101 wind turbine in the Bütow wind farm under the assumptions made.

Assessment of IdentiFlight

The above calculation of the inner and outer distance cylinders, taking into account the horizontal and vertical flight speeds determined in this study, shows that the previous dimensioning of the distance cylinders (see Figure 6) should be adapted for the red kite. The dimensions of the application in Bütow (variant 2) were: Rmax of 600 m and a height of 400 m, as well as an Rmin of 291.5 m with a height of 200 m. When determining these dimensions, as in the example calculation, a switch-off time of 30 s

went out.

A direct comparison to the example calculation, in which 50% (median) and 90% of the flights were set for the inner and the outer distance cylinder, shows that the Rmin the example calculation will be larger and the Rmax smaller than previously applied. The vertical expansion shows that the inner spacer cylinder must protrude over the total height of the wind turbine. However, due to the low rate of climb compared to the horizontal airspeed, it is sufficient if the inner spacer cylinder only begins at a height of 77 m, based on the base of the mast. For the height of the outer spacer cylinder, assuming that 90% of all flights are covered, the height is reduced from 400 m to 293 m, with a lower limit of 50 m above the base of the mast being sufficient.

It can thus be seen that the dimensioning of the spacer cylinder is influenced by the following factors:

- the shutdown speed of the wind turbine, which can be determined type-specifically,
- the dimensions of the wind turbine (hub height and rotor radius),
- the proportion of airspeeds that are covered by the distance cylinders should (e.g. median or 90%).

6.2 Overall system performance

The overall effectiveness of the IDF system is relevant in terms of species protection law, understood as the level of protection achieved with regard to the entirety of the flight events of the respective target species that are to be regarded as relevant to collisions based on distance and airspeed. This level of protection results from the combination of:

- spatial and temporal coverage (RA and ZA),
- Acquisition rate (ER),
- Classification rate (CR),

Timely Shutdown Rate (BSR).

These criteria are discussed in summary below and aggregated with regard to the quantification of the level of protection that can be achieved with IDF, with the factors airspeed and altitude in addition to the considerations in Chapters 6.1.1 to 6.1.5

be included. The basis for this is the model developed in Chapter 6.1.6 for dimensioning the two protective cylinders.

The arithmetical combination of the above factors results mathematically by multiplying the respective percentage values:

*RA * ZA * ER * KR * RRA = overall effectiveness*

With a view to better error tolerance and transferability of the results to different locations and types of plant, no fixed individual values are used below for the factors mentioned, but ranges that result from the available data.

Spatial coverage

A complete spatial coverage of the observation radius of an IDF system cannot be achieved, as the presence of elements that obscure the view must always be taken into account. However, the relationship between the shaded area and the collision-relevant flight altitude must be taken into account. Undetected flight events below the horizon line and within visual shadows do not play a role as long as they are clearly below the HLmax remain (see Figure 86), since in view of the very low rate of climb determined, a risk of collision at this low altitude is excluded. The requirement for complete spatial coverage therefore only relates to a height area that is well above tree height and should therefore always be able to be met despite any possible visual shading. Only the existing wind turbines present very narrow obstacles to the view. Otherwise, special attention would only have to be paid to the positioning of IDFs with regard to possible shadows in the topographically highly varied terrain.

On this basis, it is further assumed that the spatial coverage factor has no or at least a negligible influence on the overall effectiveness (RA = 97–99%).

Time coverage

Basically, certain downtimes can always be expected, e.g. B. due to technical failure or as a result of necessary maintenance work. When all six study sites are combined, this results in an availability of 93% after deducting downtimes. However, individual locations also achieve significantly better values, especially those from 2020 (Geislingen 100%, Bütow 97%, see Table 3). However, during longer periods of use over the entire breeding season there may be occasional failures, so that an availability of IDF of 95-99% is assumed in the following.

Acquisition rate

A collection rate of 92% was achieved when the data from the evaluable study sites were combined. Three of the six study sites even achieved a collection rate of at least 95%. In particular, the extensive GPS data from Geislingen can be viewed as a particularly suitable reference sample with regard to the accuracy of the localization, whereas larger deviations between IDF and reference have emerged with regard to the LRF data (see Chapter 5.2.2 and Table 9).

However, the drone data also show a high degree of correspondence between IDF and GPS (see Chapter 5.2.1). In addition, when programming the spacer cylinder
According to Figure 86, only flights from a certain altitude need to be detected.
In this regard, it has been shown that timely detection and deactivation is more successful for higher flights than for lower flights (Figure 71). In this respect, it is further assumed that a coverage rate of 93–96% can be assumed.

Classification rate

In view of the significant improvement achieved by version 2 of the neural network (see Table 10), a correct classification as a red kite (including the black kite) is assumed in 96–98% of the cases. The values achieved with version 1 (79–85%) are no longer included.

Timed Shutdown Rate

Table 12 has shown that the rate of timely shutdown depends to a large extent on the height of the lower edge of the rotor (minus 21 m to take into account climbs) and the local flight activity at low altitudes. For the present consideration, a modern wind turbine with a rotor bottom edge height of 96 m is assumed
(according to the data on altitudes up to 75 m in table 12). This results in a range of 77–91% for the rate of timely shutdowns across all locations considered in this study. In Chapter 6.1.5, a value of around 88% was determined for a specific wind turbine in Bütow. This value results on the one hand from the fact that a larger part of the shutdowns that took place only took place within the inner spacer cylinder and not already at its edge and on the other hand from the consideration of the flight altitudes in the inner spacer cylinder and the ascertained rate of climb. It showed for the

For example, at a location with very high red kite activity, wind turbines observed that only around 12% of those flights within the inner distance cylinder for which the shutdown was delayed were exposed to a potential collision risk. These are those red kites that flew at rotor height or might have been able to fly before the rotor would have reached the final spin mode. It must be taken into account, however, that after the switch-off signal has been generated, there is already a significant reduction in the rotor speed and thus the risk of collision after a short time. In the example shown in Figure 88, the reaction of a wind turbine to a switch-off signal halves the rotor speed after approx. 12 s.

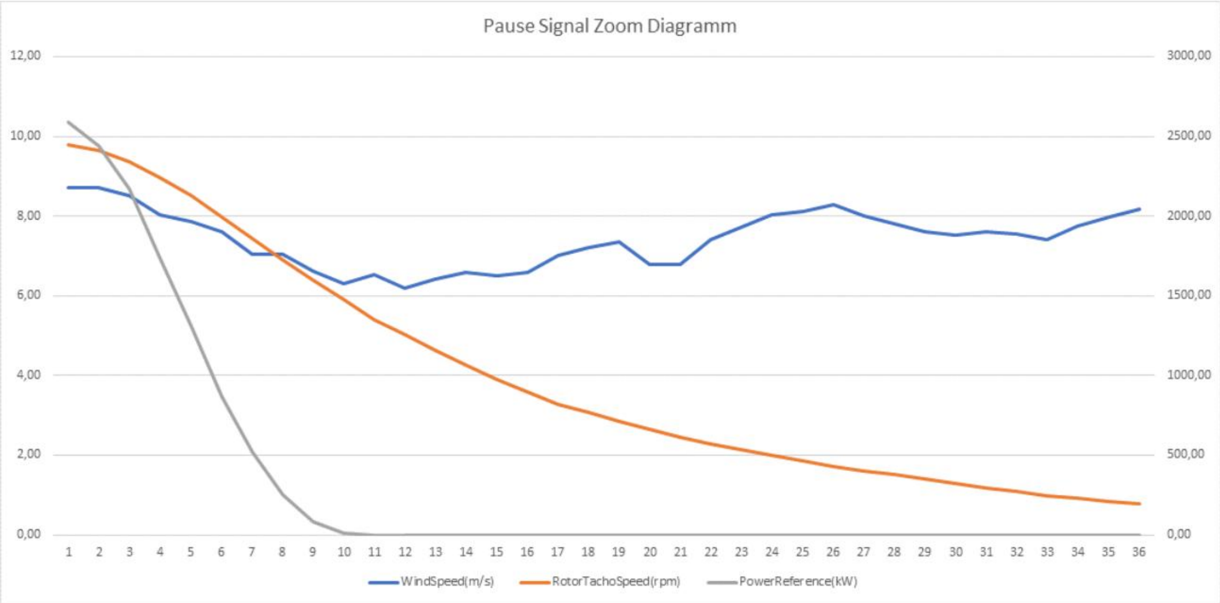

Figure 88: Reaction of a Vestas wind turbine of the 4 MW class to a shutdown signal.
x-axis: time in seconds after the switch-off signal; left y-axis: number of rotor revolutions per minute, right y-axis: power in kilowatts; Source: Vestas, provided by e3

Overall performance

The following calculation results from the previously determined values for the overall system performance:

*0.97 - 0.99 (RA) * 0.95 - 0.99 (ZA) * 0.93 - 0.96 (ER) * 0.96 - 0.98 (KR) * 0.77 - 0, 91 (RRA) = 0.63-0.84*

According to the available data, the IDF overall protection level for the Red Kite for a fictitious wind turbine with a rotor bottom edge height of 96 m is in a range of 63-84%.
within the detection range of approx. 750 m.

If the same calculation is carried out for a wind turbine with a lower rotor edge height of 71 m, the result is a BSR range of 67-87% (according to the data on flight height up to 50 m,
Table 12) and an overall protection level of 55-81%.

These values can be compared in detail with the requirements that were developed by the KNE 2020 in a series of workshops on technical monitoring and shutdown systems for wind turbines and published in 2021 (Figure 89). This shows that, according to the results available, IdentiFlight meets or even exceeds these requirements, in particular with regard to the detection range as well as the detection and classification rate (Table 18). Accordingly, IDF was declared “ready for practice” in a press release on July 8th, 2021 by the KNE

[12th] https://www.naturschutz-energiewende.de/kompetenzzentrum/presse/pressemitteilungen/erstes-kamerasystem zur-avoid-von-vogelkollisionen-an-wind-energieanlagen-reif-fuer-die-praxis /, accessed on September 20, 2021

Figure 89: Checklist regarding the performance of technical anti-collision systems (KNE 2021)

Table 18: Comparison of the KNE requirements and the achieved performance values for IDF

Erprobungskriterium	KNE	IDF
Räumliche Abdeckung	> 80 %	97-99 %
Zeitliche Abdeckung	> 95 %	95-99 %
Erfassungsreichweite	> 500 m	750 m
Erfassungsrate	> 75 %	93-96 %
Klassifizierungsrate	> 75 %	96-98 %
Rate der rechtzeitigen Abschaltungen	k. A.	77-91 %

It should also be noted that the order of magnitude of the species protection requirements for the protection level (approx. 75%) of IdentiFlight developed in Chapter 6.3.2 is achieved. It turns out, however, that depending on the relevant factors of the individual case (rotor height and flight activity at low altitudes), a not inconsiderable part of red kite flights remains without 100 percent protection of an event-related timely shutdown. This value is mainly due to the fact that in the present study a larger part of the shutdown events induced by red kite flights only took place within the inner distance cylinder, i.e. at a smaller horizontal distance than would be required according to the determined average flight speed with a shutdown duration of 30 s. the
corresponding dimensioning of the inner spacer cylinder is based on the worst

Case assumption that all flights from this distance are straight at this speed to the Run the rotor. However, this in no way corresponds to reality. An inner distance cylinder with a radius of 306 m (see Figure 87) covers an area of around 29 ha, within which a star-shaped flight path towards the center cannot be assumed, but a basically even distribution of directions and courses. In fact, in the vicinity of the rotor there is, compared to a random distribution,

reduced traffic in the center. The reason for this is the natural evasive or avoidance behavior of the animals, which search for food within wind farms, but perceive the rotating rotor as an obstacle and adjust their flight behavior on a small scale (so-called micro-avoidance).

13th

Accordingly, in the PROGRESS project, on the basis of collision victims in 55 wind farm seasons of 12 weeks each (46 different wind farms, some of which were examined several times), it was found that collisions are very rare events in absolute terms (GRÜNKORN *et al.* 2016). Only with a relative consideration on the basis of the population sizes does the red kite, in comparison to other bird species, be particularly affected by collisions with wind turbines (SPRÖTGE *et al.* 2018).

In this respect, it should be emphasized with regard to the level of protection determined by IDF that

- Flights within the Rmin with the rotor still running are generally not necessarily closed Cause collisions,
- Delayed shutdowns also lead to protection, as food seekers Red kites only rarely fly in a straight line towards the rotor and, moreover, already a few seconds after the switch-off signal, a significant reduction in the Rotor speed takes place,
- the assumption of a constant climb of over 30 s of birds that fly low into the inner distance cylinder is only a rare worst case.

In order to achieve a sufficient probability of effectiveness in each individual case, various protective measures can also be combined with one another (UMK 2020).
For this purpose, in addition to the use of IDF, the height of the lower edge of the rotor as high as possible (at least 80 m) and, above all, compliance with a sufficient minimum distance from the eyrie must be mentioned. The reference point for this is the derivation of the extension of the outer spacer cylinder (see Figure 86 and Figure 87), which results in a size of around 450-500 m for large wind turbines with a rotor radius of approx. 60-100 m. The principle should apply that the eyrie should always be outside the outer spacer cylinder,

13 See also data in Sprötge & Reichenbach (2020): Significantly increased risk of death - aspects of Assessment of the individual risk of collision. Lecture at the round table on prevention measures of the FA Wind; https: //www.fachagentur windenergie.de/fileaRmin/files/Veranstaltungen/Runder_Tisch_Vermeidungsmasshaben/6_Runder_Tisch_05-02-

2020 / Signifikant_erhoehtes_Toetungsrisis_Reichenbach-Sproetge_2020-02-05.pdf, accessed on March 5th, 2020 so that the numerous flights in the vicinity of the breeding site do not have to be detected and also do not have to be protected by shutdowns.

However, it should be emphasized that in cases of very high red kite flight activity at a specific wind turbine location, the performance of IDF is limited, since for technical reasons it is not possible for a single IDF system to track several birds at the same time.
Precise tracking by the stereo camera can only ever be done for a single red kite
the camera can switch between different red kites in a short time (see Figure 53). However, if IDF causes more or less permanent shutdowns anyway due to the simultaneous prolonged presence of several individuals, detailed and permanent tracking of all individual flights is not necessary for the necessary protection. It is possible that an improvement can be achieved in this regard by using several IDF systems that are coupled to one another. However, this could not yet be investigated in the present study.

6.3 Species protection requirements

6.3.1 Case Law

From the point of view of species protection law, the requirement for the effectiveness of IDF is to reduce the risk of killing by collision with wind turbines for the respective bird species to such an extent that it no longer fulfills the prohibition of Section 44 (1) No. 1 BNatSchG. This is the case if, in accordance with Section 44 (5) No. 1 BNatSchG, the risk of killing and injury is no longer significantly increased by the project for specimens of the species concerned.

From this it follows first of all that the need to use IDF - and also other potential protective measures - is only given if the risk of death and injury is otherwise significantly increased. A prior determination is therefore required in each individual case that this is the case at all.

Furthermore, the question of the level or definition of the level of significance inevitably arises. Without this knowledge, there is no assessment basis for the protective effect IDF has to develop in order to lower the risk below the so-called significance threshold.

The term “significance” is an indefinite legal term that requires legal interpretation (SPRÖTGE *et al.* 2018). In this regard, it can be inferred from the case law of the BVerwG that there must be a “significant” increase in the risk of death in any case. It is therefore not sufficient for individual specimens of a species to be damaged by collisions *(BVerwG,* ruling of July 9, 2009 - 4 C 12/07 -

No. 42). This applies to both bat species and bird species *(BVerwG,* ruling v.
08/12/2009 - 9 A 64/07 - Rn. 60). If it is only about the loss of individual copies, the threshold of the "general life risk" is not exceeded *(BVerwG,* ruling of August 12, 2009 - 9

A 64/07 - marginal number 63). Specimens of the species in question must therefore be present in the area of intervention in an "extent relevant to species protection law" (BVerwG, ruling of July 9, 2009 - 4 C 12/07 - Rn. 46), although it is questionable what is meant by “scope relevant to species protection law” (SPRÖTGE *et al.* 2018).

The latest case law of the BVerwG has clearly sharpened the contours of the concept of significance (BVerwG 9 A 8.17 of November 27, 2018, Rn 98):

> *According to the established case law of the Senate, the offense of the prohibition of killing (Section 44 (1) No. 1 BNatSchG) with a view to the risk of collisions between protected animals and motor vehicles, which can never be completely ruled out in a building project, is only fulfilled if the project has this risk in a for the affected species increased significantly. The criterion of significance, which has to be filled in on the basis of an evaluative consideration, takes into account the fact that there is a general risk of killing animals regardless of the project, which not only results from general natural occurrences, but can also be socially adequate and must therefore be accepted if it is from humans is caused, but only affects individual individuals. This follows from the consideration that the habitats of the endangered animal species are not untouched nature, but natural spaces designed by human hands, which, due to their use by humans, harbor a specific basic risk, not only with the construction of new traffic routes, but For example, it is also associated with the construction of wind turbines or high-voltage lines. Therefore, it cannot be disregarded that traffic routes are part of the equipment of the natural habitat of the animals and therefore special circumstances must arise so that a significant risk from a new traffic route can be spoken of (BVerwG, rulings of July 9, 2008 - 9 A 14.07 - BVerwGE 131,274 Rn. 91 and from April 28, 2016 - 9 A 9.15 - BverwGE 155, 91 Rn. 141). Circumstances that play a role in assessing the significance are, in particular, species-specific behaviors, frequent use of the cut-through area and the effectiveness of the intended protective measures, as well as other criteria in connection with the biology of the species. The significance approach does not only apply to the operational level Risk of collisions with the route, but also for construction and system-related risks (BVerwG, decision of March 8, 2018 - 9 B 25.17- UPR 2018, 382 Rn. 11). The other senates of the Federal Administrative Court dealing with planning law have subscribed to this case law (judgments of February 9, 2017 - 7 A 2.15 - BVerwGE 158, 1 marginal number 466, of April 6, 2017 - 4 A 16.16 - NVwZ-RR 2017.768 marginal no . 73 and from November 9, 2017 - 3 A 4.15 - BVerwGE 160, 263 Rn. 58, 62 and 67).*

From this and in particular from the judgment of the BVerwG of April 28, 2016 - 9 A 9.15 - Rn. 141, the following principles can be derived (see SPRÖTGE *et al.* 2018):

- Protective measures only need to ensure that the risk of death is below the "Significance threshold" is lowered. A zero risk is not required (also UMK 2020).

- The fact that individual specimens of a species may be damaged by collisions is not sufficient for the significance criterion to be fulfilled.
- The project-related risk must remain below the risk threshold that is always associated with such a project in the natural area if the significance criterion is not fulfilled.
- The reference value is the specific basic risk in a human-designed environment. The risk of the new project must therefore clearly exceed the specific basic risk to which animals are usually exposed by wind turbines.
- Evidence for this are special circumstances through which the new project clearly stands out from other wind energy projects as a normal part of the natural area.
- A correspondingly increased activity density of the Project endangered animals at the project site. This must be significantly higher than normal use of the natural area by the animal species concerned.
- In this respect, not every - even slight - transgression of the specific Basic risk represents a significantly increased risk of death. The specific basic risk must rather be clearly exceeded.
- If there are no special circumstances of corresponding weight, are Protective measures are not required under species protection law.

In addition, SPRÖTGE *et al.* (2018) on the basis of a comprehensive evaluation of the case law of species protection law:

- The assessment of the risk of killing must be based on a sufficiently secured Factual basis and take into account the current state of ecological science.
- The realization of a significantly increased risk of killing must be accompanied by sufficient Probability to be expected. The mere possibility of success is therefore not sufficient. The determination that the loss of individual specimens cannot be ruled out in principle does not justify a significantly increased risk of death.
- Falling below the minimum distance or the test radius 1 of the respective Guidelines of the federal states justify the initial suspicion of a significantly increased risk of killing (so also UMK 2020). However, it is not a taboo zone, ie falling below the minimum distance or the test radius 1 does not necessarily mean that approval is not ineffective.

The evaluation of the case law thus makes it clear, among other things, that IDF does not must develop one hundred percent protective effect in order to ensure that the risk of death is no longer significantly increased. On the other hand, the question arises as to how effective such a system must be in this regard.

AMMERMANN *et al.* (2020) assume that technical systems for event-related, needs-based shutdown, as soon as they are technically mature and their performance has been proven by tests, are suitable for minimizing conflicts under species protection law.
However, further requirements for the assessment criteria for the performance are not mentioned. It is only pointed out that it is necessary to determine which uncertainties are tolerable in the context of the significance assessment. SPRÖTGE *et al.* (2018)
emphasize the species-specificity of the special circumstances required by case law as a prerequisite for the existence of a significantly increased risk of killing.

However, the current efficacy study by IDF only relates to the red kite.
In this respect, the requirements for the level of protection to be achieved in order to remain below the significance threshold are only discussed with regard to the red kite. The requirements may differ for other species.

Legal aspects of approval when using detection systems are also dealt with by WEISS
(2019) discussed: 14

"The standard of the protective measure must be that on the one hand there is no zero risk and therefore no 100 percent security of avoiding collisions is required by the protective measure.
On the other hand, a positive prognosis of the effectiveness of the protective measure is required. If one tries to approach this standard, the question can be asked: What probability of stay is generally tolerated without assuming a significant increase in the risk of killing? Or based on the case law of the Federal Administrative Court: When is a species still on the move in a natural area designed by human hands? Both the technical papers of the individual federal states (e.g. also on room use analyzes) and the so-called Helgoland paper make assumptions as to when no protection and restriction area is affected, whereby the probability of stay outside the so-called homerange or regularly used flight corridors is tolerated. Insofar as a detection system with needs-based operational regulation ensures that shutdown takes place to the same extent as the probability of staying in the homerange or regularly used flight corridors, this means that no matter where the wind turbine is located with this protective measure, a natural area designed by human hands or a location outside of protection - and restriction area simulated. This could represent an approximation of the threshold value to be developed. "

This standard - ensuring a level of protection at which the remaining residual risk corresponds to the probability of staying outside of protection and restriction areas -
will be further elaborated from a technical point of view below.

[14th] https://www.naturschutz-energiewende.de/wp-content/uploads/Dokumentation_zur_KNE Fachkonferenz_Vogelschutz_an_Windenergieanlagen.pdf, accessed on November 25, 2020

6.3.2 Technical requirements

Based on the plausible assumption that the collision risk depends on the extent of flight activity - which is also the basis for the derivation of the distance recommendations of the LAG VSW (2015) - it follows from the above that a certain low level of

Red kite flight activity at the location of a wind farm does not yet imply a significant increase in the risk of killing, ie does not yet indicate any special circumstances that would go beyond the specific basic risk. The performance of the system must therefore be judged on whether its effectiveness is so good that only such a small amount of flight activity remains without protection. This low level is based on the likelihood of staying outside of protection and restriction areas.

In order to derive the necessary protection level of IDF in relation to the red kite, various guidelines and recommendations for action are evaluated below, the corresponding percentage information on flight activity or

Make the probability of your stay. These are guidelines from the federal states

Rhineland-Palatinate, Thuringia and Hesse, as well as recommendations from the state working group for bird sanctuaries.

Rhineland-Palatinate:

According to the Red Kite Guideline Rhineland-Palatinate (ISSELBÄCHER *et al.* 2018), depending on the location of the planned wind farm in relation to specified test areas, a brood pair-related room use analysis must be prepared. This aims at a quantitative determination of occupancy rates in the danger area of the planned wind turbine locations in relation to the rest of the action area.

In the species protection assessment, areas or grid cells within a usage frequency of <20% of the flight activity determined in standardized space use observations are viewed as low in conflict (low and below average red kite activity). Areas with an increased presence of red kites in the action area used during the breeding season are demarcated from areas with low activity by means of a threshold value that describes the 70% use of space. For the 70-80% range

Use of the space requires a case-by-case consideration including avoidance measures.

Accordingly, in Rhineland-Palatinate, in areas with a frequency of use <20% (or <30% when using preventive measures), the prohibition under Section 44 (1) No. 1 BNatSchG is not met, ie there is no significant increase in the risk of killing.

This is apparently based on the assumption that keeping> 80% (or> 70% in the case of preventive measures) of the flight activity of the red kites within their area of activity used during the breeding season is sufficient to ensure adequate protection in terms of species protection according to the case law (no need for a zero Risks, no existence of special circumstances with only little flight activity).

However, this regulation is supplemented by the requirement to keep a 500 m zone around the breeding site free, since a high level of flight activity is concentrated here in a small space. Such a proposal can be found in a similar manner in SPRÖTGE *et al.* (2018) and is also provided for in the current guidelines in Baden-Württemberg and Hesse, for example.

Thuringia:

The avifaunistic article in Thuringia15 provides for a threshold value formation in which 75% of the total flight activity is used in each individual case. For areas that are within this 75% range, an above-average amount of flight activity is assumed, which causes a significantly increased risk of death. The planned grid analysis of location-related land use maps equates 75% of the flight activity of red kites found in the investigation area with a significant increase in the risk of killing.

Hesse:

The current administrative regulation16 provides that a significantly increased risk of killing of collision-sensitive breeding bird species in wind turbine priority areas is usually not given if the project is in an area with less than 25% (osprey), 40% (red kite) or less than 50% (all other collision-sensitive bird species) of the flight activity is around the nest site.

State working group of bird protection centers:

The recommendations for minimum distances of the so-called "Helgoland paper" "... represent the area around the nest location in which the majority of the activities take place during the breeding season (more than 50% of the flight activities)" (LAG VSW 2015, p. 19). In the case of the red kite, this value has been increased to 60%. "The use of the distance recommendations in the approval process generally leads to the avoidance of conflicts under species protection law" (ibid. P. 17).

In the recommendations for avifaunistic surveys and evaluations (LAG VSW 2020) it is stated that when evaluating space use observations, the area which comprises 75% of the flights observed is characterized by a “significantly increased flight activity”.

The distance recommendations of the LAG VSW (2015) as well as the various guidelines of the federal states always only take into account the two-dimensional distribution of red kite activity, but not its distribution over the height. With regard to the design of

15th https://tlubn.thueringen.de/fileaRmin/00_tlubn/Naturschutz/Dokumente/1_zool._artenschutz/2017_Fachbeitrag_WEA_17.pdf, accessed on November 25, 2020

16 https://www.staatsanzeiger-hessen.de/dokument/?user_nvurlapi_pi1[pdf]=StAnz-Hessen-Ausgabe-2021-01.pdf # page = 13, accessed on March 21, 2021

Operating hours regulation to reduce the risk of death, the current Hessian administrative regulation also includes the rotor-free zone above ground.

This is based on more recent telemetry data from red kites in Hesse using transmitter types that enable a very precise resolution of the flight altitude (HEUCK *et al.* 2019).
These show that 81% of the recorded location points in flight had an altitude of less than 100 m, 72% an altitude of less than 75 m (Figure 90). From this it follows that in the case of modern wind turbines with heights of the lower rotor edge of approx. 80-90 m, about 3/4 of the flight activity remains below a height that is prone to collision.

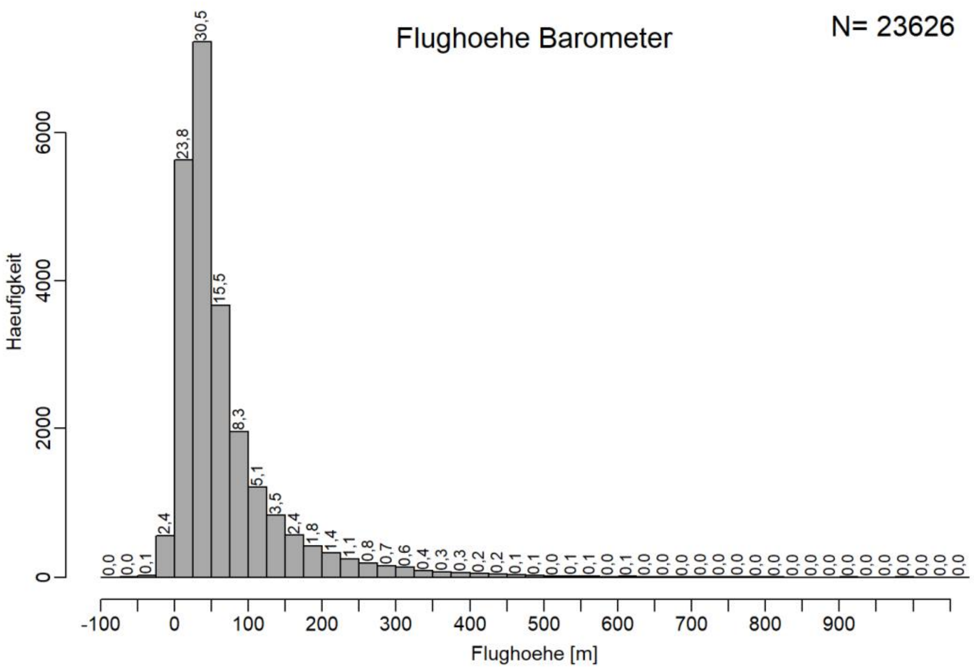

Figure 90: Histogram of the flight altitudes in 25 m classes with information on the respective percentage of the Frequency (data from five red kites with transmitters, only locating points in flight). From Heuck et al. (2019)

6.3.3 Resulting requirements for the performance of anti-collision systems

On the basis of this evaluation of existing recommendations and the framework conditions under species protection law (see Chapter 6.3.1), a level of> 75% is derived as a requirement for the overall protective effect of a camera system while at the same time keeping a radius of approx. 500 m around the eyrie. Such a minimum distance makes sense for the use of a camera system anyway, because otherwise all flight movements directly at the eyrie would lead to the generation of switch-off signals, which would accordingly result in a very high number of switch-offs. Second, it becomes the fact

Account is taken of the fact that in areas of particularly high flight activity (such as near the nest), 25% flight activity - in absolute terms - corresponds to a high number of flights that would still be subject to a risk of collision. An IDF-related derivation of this minimum distance based on the dimensioning of the outer spacer cylinder is given in Chapter
6.2 in connection with chapter 6.1.6.

6.4 Assessment of the effectiveness of IdentiFlight

The results from Chapter 6.2 have shown that IDF is very well able to do what is to be applied
A level of protection of 75% can be achieved or significantly exceeded, especially when the flight altitude is included in relation to the height of the lower edge of the rotor.

It can thus be stated that IDF reduce the risk of killing red kites through collisions with wind turbines below the significance threshold in accordance with the legal and technical requirements
can. The use of this system to protect the red kite from collisions with wind turbines is particularly suitable if a certain minimum distance to the breeding site is maintained
(see Section 6.3.3), the lower edge of the rotor is sufficiently high, the terrain is only moderately moved and IDF can be positioned so that the lower extension of the outer spacer cylinder (HUmax) runs above the horizon line.

7 Outlook

For the red kite, with the presented study at six locations, extensive bases are now available for assessing the fundamental performance of IDF. Further research should therefore focus on the following areas:

• Expansion of the species spectrum

The possible uses of IDF to avoid a significantly increased risk of killing certain bird species at risk of collision will be tested in further projects in 2021.
The white-tailed eagle is also included as a target species. In view of the previous test results on the effectiveness of IDF in relation to eagles from the USA (MCCLURE *et al.* 2018; MCCLURE *et al.* 2021), a very high level of protection from IDF can be expected for the white-tailed eagle.

• Extension of the landscape spectrum

So far, mainly open land locations with a low proportion of forest have been examined. In the next step, forest locations in low mountain ranges should therefore also be included.

• Monitoring of entire wind farms by coupling several systems

In the present study, only individual IDF systems were tested. The objective of IDF, however, is to monitor entire wind farms by coupling several systems, which, according to the manufacturer, leads to an improvement in the level of protection. Further investigations should therefore look at the interaction of several systems.

• Use in basic research

In addition to its use as a protective measure to avoid collisions, IDF also offers new possibilities for gaining further knowledge about the behavior of birds in the vicinity of wind turbines with high temporal and spatial resolution. On the basis of the very precise location of the flight paths every second, data is generated whose evaluation options go beyond those of GPS and LRF data. In addition, there is the permanent monitoring of a certain area of space with the complete recording of all flight movements taking place in it, whereas GPS telemetry can only deliver data from individual individuals, even if in their entire area of action. To observe the flight behavior in the vicinity of the wind turbine, however, it is necessary to switch off the switch-off programming so that the flights can also be followed up within the inner protective cylinder. Also to check the effectiveness of other protective and preventive measures, such as B. deflection surfaces, IDF can be used for the quantitative determination of flight activity at certain locations.

- Testing of further technical developments

  On the part of the manufacturer, continuous technical developments of the IDF system are planned. These include, among other things, a reduction in the reaction time of the stereo camera when panning between several birds and an improvement in detection performance against a dark background. It can therefore be expected that the results achieved so far, which already demonstrate the effectiveness of the system with regard to the requirements of species protection law, will be improved again in the future.

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