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Eagle Utilisation Surveys Bashan Wind Farm Tasmania Australia

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Goldwind

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Executive Summary

The following report was produced by Wildspot Consulting PTY LTD for GoldWind Capital (Australia) PTY LTD Projects. Eagle Utilisation Surveys (EUS) capture how eagles use their aerial environment to meet their specific ecological needs and adaptations for survival, growth, and reproduction. The EUS conducted at the proposed Bashan Wind Farm site in Tasmania's Central Highlands aimed to document the baseline activity of the threatened Tasmanian Wedge-tailed Eagle (*Aquila audax fleayi*) and White-bellied Sea Eagle *(Haliaeetus leucogaster*). These surveys are essential for assessing the potential impacts of wind farm development on these threatened species and guiding conservation efforts.

Key findings from the surveys include:

- Dominance of Wedge-tailed Eagles, with a substantial number of flights observed at both South and North Bashan.
- Evidence of at least three active breeding pairs residing on the study site.
- A substantial proportion of eagle flights occurred within the rotor-swept area (RSA) range, highlighting the potential risk of mortality.
- High-density flight areas were identified, indicating critical habitats and active nesting sites within the study areas.
- Behavioural patterns varied across different activity periods, with display behaviour observed across all periods and soaring being the most common behaviour.

The study also identified several limitations, including observer bias, weather conditions, and survey timing, which could influence the accuracy and consistency of the data collected. In summary, the EUS provided valuable insights into eagle flight activity, utilisation areas, and behaviour, serving as a critical reference for evaluating the potential impact of wind energy development on these species. The findings underscore the importance of targeted conservation efforts to mitigate potential impacts and support the survival and recovery of the Tasmanian Wedge-tailed Eagle and the White-bellied Sea Eagle

1 Introduction

Tasmanian Wedge-tailed Eagles (*Aquila audax fleayi*) and White-bellied Sea Eagles (*Haliaeetus leucogaster*) are large birds of prey that are of conservation concern in Tasmania. The Tasmanian Wedge-tailed Eagle is listed as endangered under both the Tasmanian Threatened Species Protection Act 1995 and the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. Meanwhile, the White-bellied Sea Eagle is classified as vulnerable under the Tasmanian Threatened Species Protection Act 1995 and is protected as a marine and migratory species under the EPBC Act.

The survival and recovery of avian species including the Tasmanian Wedge-tailed Eagle and the White-bellied Sea Eagle is jeopardised by several significant threatening processes: habitat loss and fragmentation, collisions with man-made structures, and human disturbances (Settele, 1996; Dennis, McIntosh & Shaughnessy, 2011; Bekessy et al., 2009; Thaxter et al., 2017). Habitat loss and fragmentation, driven by land clearing for agriculture, urban development, industrial projects, and forestry operations, can reduce available nesting sites and hunting grounds, thereby isolating populations. Collisions with man-made structures such as powerlines, wind turbines, and vehicles pose a direct risk. Human disturbances, including recreational activities, construction, and noise pollution near nesting sites, can lead to nest abandonment and reduced breeding success (Mooney & Taylor, 1996). Illegal poisoning and deliberate persecution, despite legal protections, continue to be a substantial threat. Eagles consuming poisoned bait intended for pests or suffering from secondary poisoning by consuming prey poisoned by lead-based shot face serious risks. Additionally, direct illegal shooting and trapping still occur. Changes in land use and agricultural practices may impact prey availability, leading to food scarcity and affecting eagle survival and reproductive success. For the Tasmanian Wedge-tailed Eagle, genetic factors such as inbreeding depression and loss of genetic diversity due to the small and isolated population may reduce fitness and adaptability, making the population more vulnerable to environmental changes (Kozakiewicz et al., 2017). Addressing these threatening processes through targeted conservation efforts is crucial for the protection and recovery of these threatened eagle species.

1.1 Eagle Landscape Utilisation and Behaviour

Analysing eagle utilisation and behaviour within a region is crucial for guiding targeted conservation efforts, especially in areas proposed for wind farm development. The large-scale development of wind farms can cause direct mortality through collisions with turbines and indirectly impact eagle populations through habitat fragmentation and disturbances to hunting and breeding sites (Mooney & Taylor, 1996; Smales et al., 2005). Wind farms are strategically designed and located to harness strong wind resources, optimising conditions for renewable power generation. These same locations can also serve as vital habitats for Wedge-tailed Eagles and White-bellied Sea Eagles, which utilise wind currents for their survival. Just as wind turbines are positioned to maximise energy efficiency, these large birds of prey take advantage of wind currents to fly and soar with minimal effort. By using thermals and updrafts created by wind blowing over hills, ridges, and dense vegetation, eagles can conserve energy and travel long distances without flapping their wings. This behaviour, known as dynamic soaring, is an energy-efficient technique that enables eagles to cover vast areas in search of food and to survey and defend their territory (Alerstam & Hedenström, 1998; Warrick et al., 2002; Olsen, 2014).

The breeding season for both species typically occurs from August to January and is characterised by a gradual increase in aerial displays and interactions between monogamous breeding pairs and territorial conflict and displays towards neighbouring eagles, reaching its peak in August (Brown et al., 2006). This peak in aerial activity is followed by nest occupation, which generally occurs from mid-August to January, with some seasonal variation. Both species build large stick nests in mature or dead trees, cliffs, or islands, designed to accommodate one or two chicks. Both males and females participate in nest building and young rearing. The chicks generally fledge the nest at around 12 to 14 weeks of age in late January to early February (Debus et al., 2007). Although fledged, juvenile eagles often stay close to the nesting site and within their natal territory as their dependence on their parents gradually decreases. Juvenile eagles become independent when their parents force them out of their natal territory as the mature birds prepare for the next breeding season. These nesting sites are often reused for many years and can be passed down through generations, serving as central locations of territorial activity (Pay et al., 2022).

1.2 Eagle Utilisation Surveys

Eagle utilisation surveys document how Tasmanian Wedge-tailed Eagles and White-bellied Sea Eagles use their aerial landscape based on their ecological needs and adaptations. These surveys are mandated by both federal and state law before and after wind farm development in Tasmania. These requirements ensure that the impacts of wind farms on these protected bird species are thoroughly assessed and mitigated, supporting sustainable and responsible wind energy generation. The environmental consultancy group Wildspot Consulting PTY LTD was commissioned by GoldWind Capital (Australia) PTY LTD Projects to conduct eagle utilisation surveys to assess eagle flight activity at the proposed Bashan Wind Farm site. The proposed development site is in the Tasmanian Central Highlands and is planned to include the installation of 56 turbines, each with a capacity of 7.8 MW and a height of 216.5 meters, and the necessary power lines, access tracks, and other infrastructure required for site operations.

1.3 Aim and Objectives

The aim of this study was to document the baseline activity of the Tasmanian Wedge-tailed Eagle and the White-bellied Sea Eagle, to assist Gold Wind Capital in assessing potential impacts of the proposed Bashan Wind Farm on these threatened eagle species. The collected data aimed to provide essential insights into eagle flight activity, utilisation areas, and behaviour, serving as a critical reference for evaluating the potential impact of wind energy development.

Objectives

1. **Document Flight Activity**: Conduct systematic surveys to record the flight activity of the Tasmanian Wedge-tailed Eagle and the White-bellied Sea Eagle across different activity periods.

2. **Identify High-Use Areas:** Develop spatial activity maps for seasonal activity periods to identify high-use areas overlain with the proposed wind turbine layout for context.

3. **Evaluate Flight Heights Relative to Rotor-Swept Area (RSA):** Assess the flight heights of eagles in relation to the RSA of the proposed wind turbine model.

4. **Investigate Activity Variations and Behavioural Patterns:** Examine the variations in eagle flight activity and behaviour across activity periods to identify any patterns or behaviours that may influence their use of the area.

5. **Provide Baseline Data for Impact Assessment:** Establish a comprehensive dataset on eagle flight activity that can inform impact assessments and guide decision-making regarding the proposed wind farm.

2 Methodology

2.1 Site Description

The proposed Bashan Wind Farm development site is in the Tasmanian Central Highlands, Australia, approximately 125 km northwest of Hobart, within the Central Highlands Council area (Figure 1). It is situated near the Waddamana community to the northeast and is adjacent to the Cattle Hill Wind Farm to the north. The development will install 56 turbines, each with a capacity of 7.8 MW and a height of 216.5 m. The study area comprised approximately 8500 hectares, including an additional area that was added approximately one year after the initial study commenced due to the expansion of the planned development area. For ease of description, the initial area is referred to as South Bashan, and the additional area is called North Bashan. The combined study area is located at coordinates 473069 E and 5323845 N.

The elevation ranges from 600 to 900 metres above sea level and features undulating plains and rocky outcrops that support various land uses and vegetation types. The area includes private timber reserves with native eucalyptus forests, plantation forests, permanent timber production zones, grazing lands, modified pastures, and wetland areas. Farming activities such as sheep grazing, cattle production, and hunting are common. The climate is temperate, with cool winters and mild summers. Soil types include peaty soils and alpine humus soils, rich in organic matter with poor drainage, along with sandy loams and clay loams. This diverse soil profile supports a range of sub-alpine and alpine vegetation adapted to the region's cold, wet conditions.

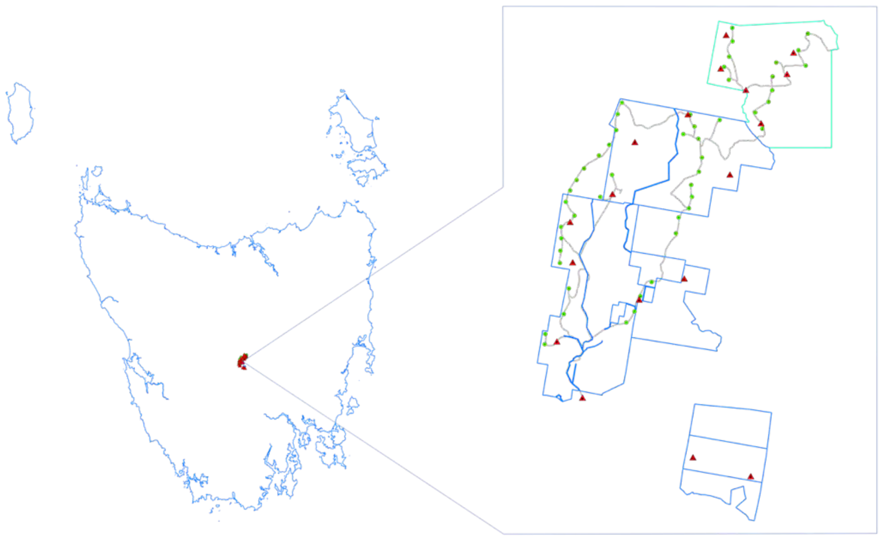

Figure 1. General location of the study area for the proposed Bashan Wind Farm site in the Central Highlands, Tasmania. Boundaries of South Bashan are shown in blue, and boundaries of North Bashan are shown in green.

2.2 Survey Design

The survey design aimed to ensure comprehensive coverage and representative data collection while addressing stakeholder requirements. Recognising that eagles exhibit distinct periods of activity relative to their breeding cycle, the survey timeline was structured around five key activity periods: display, mid-breeding, late-breeding, fledging, and non-breeding (Table 1). The survey strategy for South Bashan involved conducting at least two surveys during each season over two years—two summers, two autumns, two winters, and two springs. In contrast, GoldWind Capital requested that the survey effort for North Bashan, which was a small extension of the study area, be concentrated into a single year. This involved conducting one survey per season—one summer, one autumn, one winter, and one spring. This approach was designed to synchronize the surveys of the northern extension with those already completed in the southern area, ensuring consistent data collection across both regions despite the shorter survey timeline in North Bashan.

Table 1. Description of eagle activity periods

Category	Time (months)	Description
Display	August-September	Focuses on the peak of aerial activity. **Territorial Displays:** Display behaviour to establish and defend territories. **Aerial Displays:** Eagles engage in flight manoeuvres such as soaring, diving, and talon-grappling. Part of courtship rituals where eagles demonstrate their fitness to established and potential mates. **Seasonal Peaks:** Some displaying occurs year-round, but the intensity increases dramatically from mid-June, reaching a peak around egg-laying time in early-spring.
Mid-breeding	October-November	Encompasses the time during breeding season when eagles are actively involved in incubation and raising their offspring. **Incubation:** Parents taking turns incubating eggs until hatching. **Chick Rearing:** Feeding and protecting chick/s and bringing food to the nest. **Nest Defence:** Protecting the nest from potential threats.
Late-breeding	November-December	Encompasses the time when eagles are primary involved in raising their offspring. **Chick Rearing:** Feeding and protecting chick/s and bringing food to the nest. **Nest Defence:** Protecting the nest from potential threats.
Fledging	January-March	Describes the phase when juvenile eagles transition from the nest to accompanying their parents in the greater natal territory, supporting their eventual move toward independence. **First Flights:** Juveniles take their initial flights, improving their flying skills.

		Decreasing Dependency: Young eagles start to hunt and fend for themselves but may still rely on parents initially remaining in their natal territory.
Non-breeding	April-June	Represents a period of reduced aerial activity related to territorial displays. During this time, territorial boundaries for established eagle pairs are more relaxed compared to the breeding season. **Rest and Recovery**: Resting and recovering from the breeding season's demands. **Reduced Displays**: Noticeable decrease in aerial and territorial displays.

Surveys were conducted over a two-year period, from 2022 to 2024, with ten surveys conducted in both South and North Bashan (Table 2). Adjustments were made to align with stakeholder requirements, ensuring that the survey methodology was both scientifically rigorous and practically feasible. Surveys were conducted exclusively during daylight hours to coincide with peak eagle activity times. Care was taken, where possible, to schedule survey dates within periods of clear weather to ensure that results were not heavily influenced by poor visibility due to weather conditions. The South Bashan timeline included data collected across two breeding seasons, whereas the North Bashan timeline included data collected across one breeding season, as this study area was added approximately a year later. It must be noted that within each of the five activity period categories, there is some overlap regarding the time specification in months between the mid and late-breeding season categories. Although there is overlap in the month of November, within the same breeding season, the mid-breeding season survey was always completed before the late-breeding season survey.

Table 2. Eagle Utilisation Survey (EUS) timeline at South and North Bashan

Location	Survey No.	Activity Period	Start Date	End Date	No. Hours
South Bashan	1	Display	29/8/2022	2/9/2022	36
	2	Mid-breeding	1/11/2022	4/11/2022	32
	3	Late-breeding	28/11/2022	2/12/2022	40
	4	Fledging	6/2/2023	10/2/2023	40
	5	Non-breeding	8/5/2023	12/5/2023	40
	6	Display	23/8/2023	27/8/2023	40
	7	Mid-breeding	23/10/2023	27/10/2023	40
	8	Late-breeding	19/11/2023	23/11/2023	40
	9	Fledging	13/2/2024	17/2/2024	40
	10	Non-breeding	23/5/2024	27/5/2024	40
North Bashan	1	Display	4/9/2023	8/9/2023	36
	2	Display	22/9/2023	26/9/2023	40
	3	Mid-breeding	2/10/2023	6/10/2023	40
	4	Mid-breeding	16/10/2023	20/10/2023	40
	5	Late-breeding	6/11/2023	10/11/2023	40
	6	Late-breeding	27/11/2023	1/12/2023	40
	7	Fledging	29/1/2024	2/2/2024	40
	8	Fledging	11/3/2024	15/3/2024	40
	9	Non-breeding	29/4/2024	3/5/2024	40
	10	Non-breeding	31/5/2024	4/6/2024	40
Total					784

Note: The number of surveys conducted in North and South Bashan were equal, with 10 surveys each. However, the surveys in North Bashan were completed in half the time, with two surveys within the same activity period, as this study area was added at the request of GoldWind approximately a year later, starting in September 2023.

2.3 Observation Points

Before conducting field surveys, potential eagle observation point locations were identified using a desktop Geographic Information System (GIS). The GIS layout was created using publicly available data and adjusted based on a preliminary site visit. On the first day of the initial survey, observation locations were evaluated and refined in the field to ensure optimal visibility and coverage. Vantage points with broad visibility were selected whenever possible and positioned to allow communication between in-field bird observers via radio. To achieve adequate coverage of the site, it was necessary to establish observation points in densely forested areas. Points in open areas allowed for broader visibility, while points in denser vegetation had more restricted views, potentially limiting the detection range of some eagle activity. The observation point locations were finalised to prioritise optimal coverage of the study site. Twelve observation points were established across South Bashan (BE1-BE12) and six were established across North Bashan (BN1-BN6) (Figure 2, Table 3, Figure 3, Figure 4).

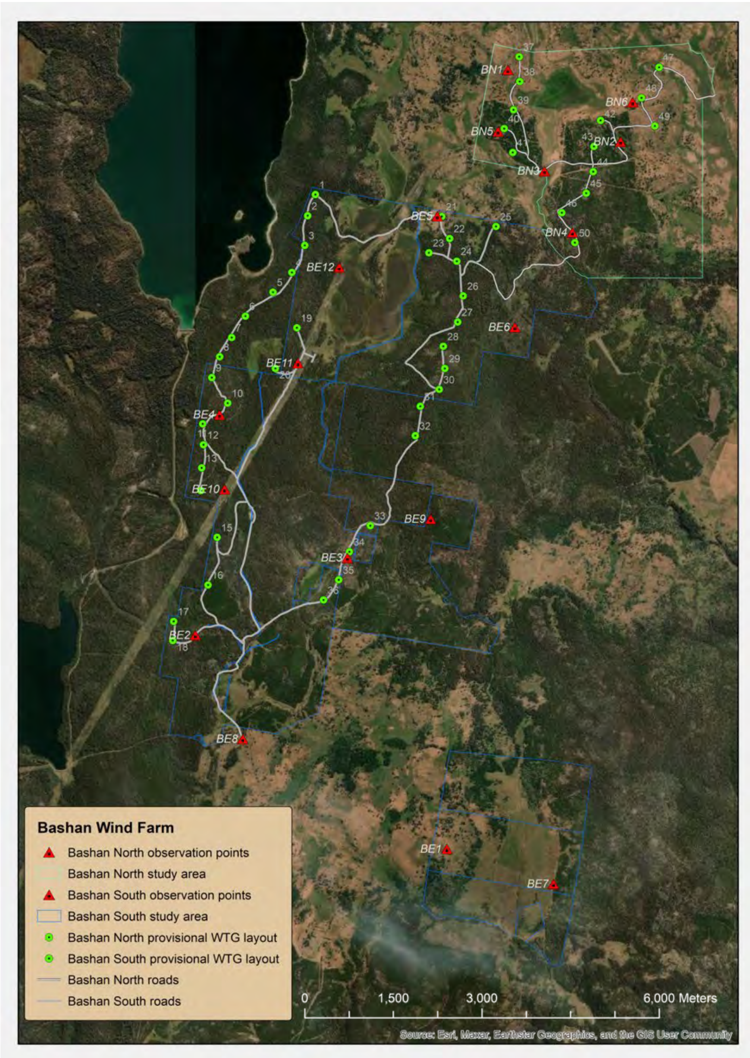

Figure 2. Observation point locations at South Bashan (BE1-BE12) and North Bashan (BN1-BN6) for the proposed Bashan Wind Farm in Central Highlands, Tasmania. Boundaries of South Bashan are shown in blue, and boundaries of North Bashan are shown in green.

Table 3. Description of observation points including geographical coordinates, vegetation types, and visibility range (low: 0-1.5 km, medium: 1.5-3.0 km, high: 3.0-5.0 km).

Observation Point ID	Geographical coordinates	Vegetation and Land Use	Visibility Range
BE1	474672 E 5317292 N	Grazing and modified pastures. Native eucalyptus forest.	High
BE2	470416 E 5320913 N	Native eucalyptus forest. Plantation forest.	Low
BE3	472991 E 5322224 N	Native eucalyptus forest. Plantation forest. Marsh and wetlands.	Medium
BE4	470827 E 5324649 N	Native eucalyptus forest.	Low
BE5	474512 E 5328012 N	Native eucalyptus forest. Marsh and wetlands. Grazing and modified pastures.	High
BE6	475826 E 5326131 N	Native eucalyptus forest. Plantation forest.	Medium
BE7	476478 E 5316702 N	Grazing and modified pastures. Plantation forest. Sparse native eucalyptus forest.	High
BE8	471219 E 5319157 N	Grazing and modified pastures. Plantation forest. Sparse native eucalyptus forest.	Medium
BE9	474399 E 5322882 N	Native eucalyptus forest. Plantation forest.	Low
BE10	470911 E 5323388 N	Native eucalyptus forest.	Medium
BE11	472154 E 5325523 N	Native eucalyptus forest. Marsh and wetlands.	Medium
BE12	472852 E 5327147 N	Native eucalyptus forest. Marsh and wetlands.	Medium
BN1	475709 E 5330492 N	Grazing and modified pastures. Marsh and wetlands. Plantation forest. Sparse native eucalyptus forest.	High
BN2	477612 E 5329274 N	Grazing and modified pastures. Plantation forest. Sparse native eucalyptus forest.	Low
BN3	476328 E 5328777 N	Grazing and modified pastures. Plantation forest. Sparse native eucalyptus forest.	High
BN4	476798 E 5327735 N	Native eucalyptus forest. Plantation forest.	Low
BN5	475540 E 5329446 N	Grazing and modified pastures. Plantation forest. Sparse native eucalyptus forest.	Medium
BN6	477818 E 5329946 N	Grazing and modified pastures. Plantation forest. Sparse native eucalyptus forest.	High

Figure 3. Example observer view from observation points BE3 (top), BE5 (middle), and BE4 (bottom) capturing the landscape and location used for collecting bird utilisation data.

Figure 4. Aerial view from observation point BE5 capturing native eucalyptus forest, marsh and wetlands, and grazing and modified pastures.

2.4 Data Collection Methods

Observer Point Rotation

Data collection involved in-field observers at designated observation points, with methods adapted to the distinct site characteristics of South Bashan and North Bashan.

South Bashan

South Bashan, which spanned approximately 7200 hectares, featured dense forestation with high canopy height and varied topography with undulating plains, presenting challenges for visibility and communication. To address these characteristics, six in-field observers were deployed to ensure adequate coverage. These observers rotated from one half of the site to the other once per day, completing two observation sessions of four hours each across twelve unique observation points (BE1-BE12). The strategy focused on maximising site visibility and coverage, distributing observers across points that were close enough to allow for accurate data collection, with varied visibility ranges and vegetation types, to capture substantial eagle activity despite logistical challenges.

North Bashan

North Bashan, covering approximately 1500 hectares, featured grazing and modified pastures, a central marshland, and plantation forests with some native forested areas across relatively flat terrain. This terrain facilitated effective radio communication with minimal interruptions from topography and vegetation. Three in-field observers were deployed, rotating between six observation points (BN1-BN6) once per day to mitigate fatigue, completing two observation sessions of four hours each. Fewer observers were needed to cover this smaller study area adequately, yet three were necessary to accurately capture data via triangulation.

Recording Data

All eagle flight data were recorded electronically using the Fast Field Mobile Forms application. For each observation session, baseline data including the observer point location, date, session start and finish times, and weather conditions (precipitation, wind speed, wind direction) at the start, mid-session, and end-of-session were recorded. Observers used binoculars to scan their designated observation areas. When an eagle was sighted, its flight path was recorded electronically in the mobile application and mapped using landscape features as reference points on an aerial photograph. Accurate recording of flight paths depended on multiple key factors including proximity of the flying bird to an observer, visibility of the bird to both observers, optimal location for bidirectional observation (ideally forming a 90-degree angle to each observer), triangulation, and the availability of recognisable landmarks to aid in geographical positioning on the map. The layout and distance between observation points allowed most flights to be monitored by more than one observer simultaneously. When a bird was first spotted, both observers would attempt to pinpoint its location. The observer who first saw the bird would convey the flight height and compass bearing over two-way radios to the other observers. If two or more observers located the same bird, they would consult landmarks visible to all or identify the specific 30-hectare segment and its location within that segment (see example, Figure 5).

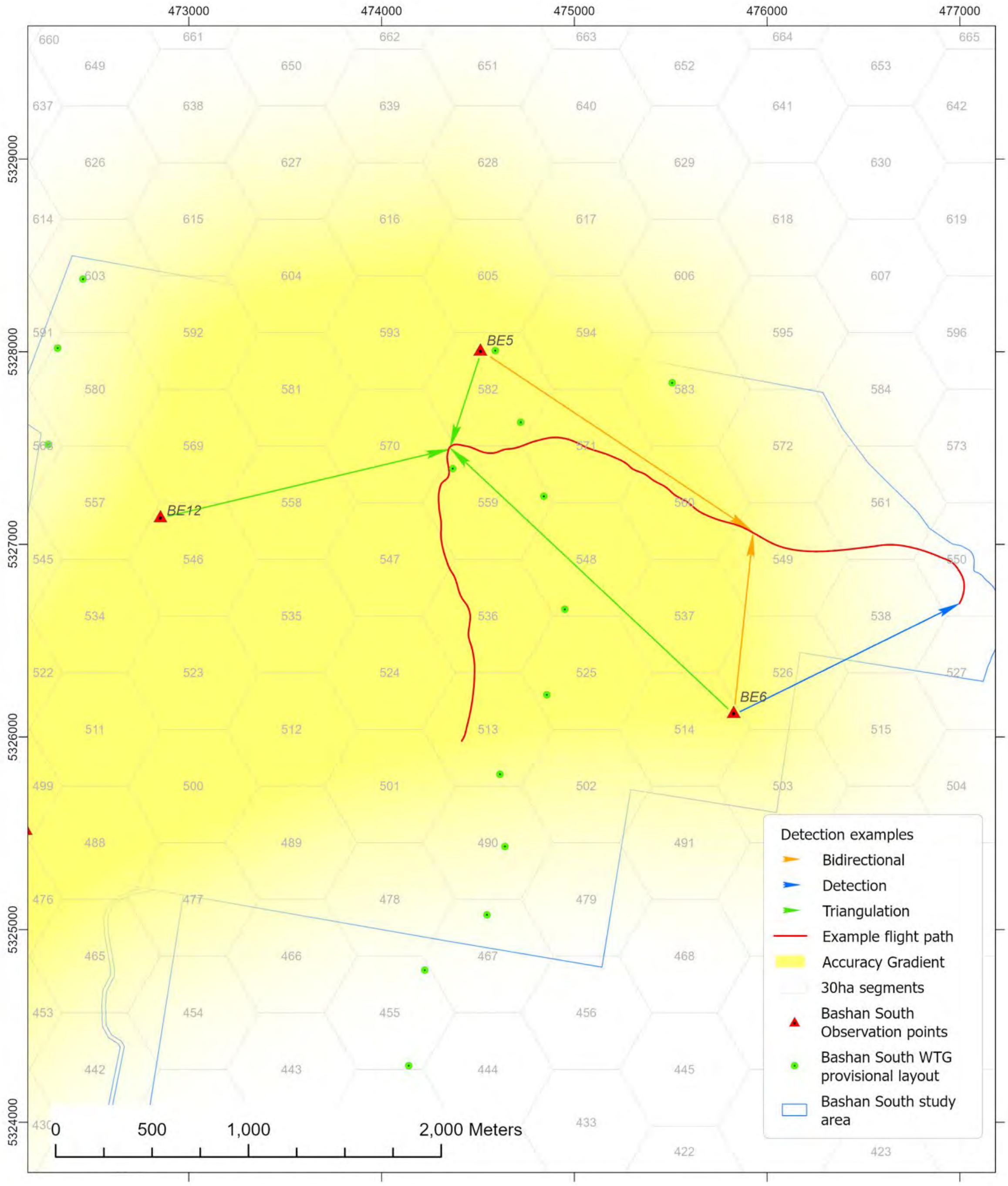

Figure 5. Example of bidirectional interpretation and the estimated accuracy of an eagle flight including its geographical position among three South Bashan observation points (BE5, BE6, and BE11) relative to the 30-hectare segments (grey hexagons). This includes the first detection (blue arrow), bidirectional observation (orange arrow), and triangulation (green arrow). The accuracy gradient is represented by the yellow shading, indicating the spatial accuracy of flight path detections.

Bidirectional interpretation of geographical position and triangulation aimed to ensure accurate flight position recording, though accuracy varied due to inherent biases from the six different observers and the varying in-field visibility at each observation point. Once the eagle's position was agreed upon, observers tracked the eagle's flight as it moved through the observation segments. The observer who first sighted the eagle continued recording until the eagle crossed into another observer's area, at which point the new observer took over. If the eagle perched or went out of sight, the recording was stopped, noting the time and last sector seen. If the eagle resumed flight or returned to view, a new flight record was started. Additional data was recorded to complement the recorded flight path and gain an understanding of eagle behaviour (Table 4).

Table 4. Data type and entry details of observed eagle flights.

Data Type	Data Entry Details
Reference (Ref)	Each flight was given an individual reference number. For each flight a separate flight path was drawn on an aerial map.
Species	Wedge-tailed Eagle (WTE) or White-bellied Sea Eagle (WBSE)
Age	Recorded as adult, immature, juvenile or unknown.
Time first observed	The time at which an eagle was observed
First Seen Flight Location (sector)	The sector in which the eagle was first observed
Last Seen Flight Location (sector)	The sector in which the eagle was last observed
Average Height (m)	The average distance of the eagle above the ground
Flight behaviour	There were three categories of flight behaviour, namely soaring, displaying, flying, and conflict. Multiple behaviours could be recorded for a single flight.
Wind speed (m/s)	Wind speed was measured with a handheld anemometer in metres per second (m/s) three times per session; at the start, middle, and end.
Wind direction (deg)	Wind direction was recorded at ground level using a compass.

Eagle Flight Behaviour

The following table outlines the characteristic flight behaviours observed in Tasmanian WTEs and WBSEs(Table 5).

Table 5. Flight behaviour definitions of the Tasmanian Wedge-tailed Eagle and White-bellied Sea Eagle.

Flight behaviour	Definition
Flying	The direct, purposeful flapping of wings. Often observed when an eagle is hunting or in pursuit of another bird.
Soaring	Minimal wing beats, observed in conjunction with a circling flight pattern. Often characterised by the use of rising currents of air, such as those found on the windward side of hills and thick vegetation, or thermals, which are rising currents of warm air.
Displaying	Eagles perform display flights as a territorial defence behaviour, usually directed towards neighbouring breeding pairs. These flights consist of a series of sharp climbs and steep, semi-closed-wing dives. Display flights are often seen near nesting sites.

2.5 Data Preparation and Analysis Techniques

The data from the EUS surveys were prepared and analysed using Excel version 16.86 and GIS Arc Map Spatial Analyst. Initial data preprocessing involved removing errors and inconsistencies to ensure an accurate and consistent baseline dataset of eagle flight activity. Due to the expansion of the initial study area during the development process, the study was divided into two parts: South Bashan (the initial study area) and North Bashan (the additional area). This separation was crucial because the survey timelines differed between the two areas. Surveys in South Bashan were conducted over two breeding seasons, while those in North Bashan were condensed into a single breeding season, as this area was added approximately a year later (see Site Description). By analysing these areas separately, we aimed to capture and accurately represent the variance in eagle activity within and across breeding seasons collected at different intervals.

Kernel Density Estimation (KDE)

To visualise the spatial distribution of eagle activity and identify high-use areas, contour maps of kernel density estimation (KDE) were created using GIS software. These maps were generated for the combined eagle activity across all surveys in both North and South Bashan, as well as for individual activity periods: display, mid-breeding, late-breeding, fledging, and non-breeding. The initial flight path data, drawn by in-field observers, were converted into points at 50 m intervals. The point density was then estimated per hectare and smoothed using KDE to produce contour maps. These maps were presented alongside flight counts for each activity period and the proportion of observed behaviours: soaring, flying, and displaying.

Flight Height Analysis

Flight height data were analysed and presented relative to the rotor-swept area (RSA) of the GW 7.8 MW turbines. Flight heights were categorised into three zones:

Below Rotor-Swept Area (BRSA): 0 to 43.5 metres
Rotor-Swept Area (RSA): 43.5 to 216.5 metres
Above Rotor-Swept Area (ARSA): Above 216.5 metres

It's important to note that birds flying in the ARSA must originate from the BRSA and pass through the RSA at some point. This interdependence meant that the categorisation was not mutually exclusive and should be interpreted as part of a continuum of flight movement rather than separate categories.

2.6 Interpretation Guidance

Density Representation: The density in the KDE maps represents the estimated concentration of eagle flight activity points, where higher densities indicate areas of more frequent use by the eagles.

Unique Keys: Each map has a unique key with a specific range tailored to the dataset it represents. This ensures that the density scales are appropriately adjusted for each map's data.

Baseline Contour Representation: The first contour, which is uncoloured, represents baseline activity or relatively insignificant areas of eagle flight. This decision is grounded in the principle of KDE data analysis, where the focus is on identifying and visualising areas of significant activity. The uncoloured contour highlights the contrast between low-activity regions and those of higher utilisation, aligning with the primary objective of the report—to pinpoint critical areas of high eagle activity across the study site. By omitting colour in the baseline contour, we ensure clarity in interpreting the most ecologically relevant data.

Accuracy Assessment

The accuracy of the data collected was generally assessed by reviewing where and how the data was collected by the team of in-field observers at different observation points with varying levels of visibility. The flight data collected was evaluated based on the observation point where it was first observed, along with the observation points where other observers participated in recording the flight. This assessment helped identify any potential discrepancies.

3 Results and Discussion

The aim of the study was met and the baseline activity of two threatened species, the Tasmanian WTE and the WBSE was recorded to assist Gold Wind Capital in impact assessment of the proposed Bashan Wind Farm. The data provided insights into eagle flight activity, utilisation areas, and behaviour, and can serve as a reference for evaluating the potential impact of wind farm development on these threatened species in the area. The results and discussion begin with a summary of the key findings, followed by an overview of eagle activity in the South Bashan and North Bashan study areas, supplemented by a detailed analysis of activity and eagle behaviour across different activity periods for each study area. Additionally, an assessment of the accuracy of flight detection is provided, along with a discussion of the study's limitations.

3.1 Key Findings

1. **Species Distribution:** The dominant eagle species observed was the WTE, with a total of 844 flights at South Bashan and 844 flights at North Bashan. The WBSE was rarely seen, accounting for only 9 flights at North Bashan and 4 flights at South Bashan.

2. **Flight Height:**

   South Bashan: Approximately 63.7% of flights were within the RSA range (43.5 to 216.5 meters), 32.4% ARSA, and 3.9% BRSA.
   North Bashan: 45.1% of eagle flights occurred within the RSA range, 53.9% ARSA, and 1.1% BRSA.

3. **Density Maps:**

   South Bashan: High-density flight areas were in the southeastern and northwestern regions, indicating the presence of at least three active WTE pairs and likely at least three active nests. Moderate activity was observed in other areas, with low-density activity scattered in the northeastern, southern, and central parts of the study area.
   North Bashan: High-density flight areas were concentrated in the central and southeastern parts of the site, particularly around observation points BN4 and BN5. The higher density of eagle flights at North Bashan indicated substantial use of the area, likely influenced by the presence of grazing and open pastures supporting an abundant prey base as well as clear observer visibility.

4. **Activity Periods**:

   South Bashan: The late breeding period showed the highest flight counts, followed by the display period, mid-breeding, fledging, and non-breeding periods. Display behaviour was observed across all periods, indicating competition among WTE pairs, multiple territories within the region, and suggested a high population of eagles.
   North Bashan: The overall trend showed a gradual decline in flight counts from the late breeding period to the non-breeding period, with higher-than-

expected flights during the mid-breeding and late-breeding periods, possibly due to favourable weather, territorial clashes, or prey abundance.

5. **Accuracy Assessment**: The accuracy of flight data was generally high around observation points with greater visibility ranges. South Bashan's observation points BE1, BE5, BE7, BE11, and BE12, and North Bashan's BN1, BN3, and BN6 were particularly effective in capturing accurate eagle flight data.

3.2 Overview of Eagle Activity

South Bashan Overview

The dominant eagle species across South Bashan was the WTE, with a total of 844 flights recorded. In contrast, the WBSE was rarely seen, accounting for only 9 flights throughout the survey period (Figure 6). The low number of WBSE flights is likely due to the wind farm's central Tasmanian location, away from the species' preferred coastal habitat. However, the site's proximity to Lake Echo may have provided suitable hunting and feeding opportunities, allowing WBSE to be occasionally observed flying over site. The WTE was the predominant species detected, likely due to the habitat suitability provided by a combination of open grasslands and woodland forests. The high frequency of WTE observations suggested the presence of multiple active WTE territories and potentially active nesting sites within the South Bashan study area.

A substantial proportion of eagle flights were observed within the rotor-swept area (RSA) range across the study area. Approximately 63.7% of flights occurred within the RSA range (43.5 to 216.5 metres), 32.4% above the RSA (ARSA, above 216.5 metres), and 3.9% below the RSA (BRSA, 0 to 43.5 metres) (Figure 4). This distribution suggested that the RSA range likely captured the optimal flight height of resident eagles. This aligned with expectations given the extensive swept area range of the turbines (43.5 to 216.5 metres above ground).

As eagles flew higher into the ARSA and beyond, they became more difficult to see, potentially leading to an underrepresentation of flights in these higher zones. Similarly, flights within the BRSA range were more likely to be interrupted by vegetation, causing potential underrepresentation in these lower zones. However, the substantial proportion of flights observed within the RSA range indicated that eagles spent a considerable amount of time at this height. Despite the study's visibility limitations above and below the RSA, the RSA range effectively captured the height at which eagles were most likely to be active within the South Bashan study area.

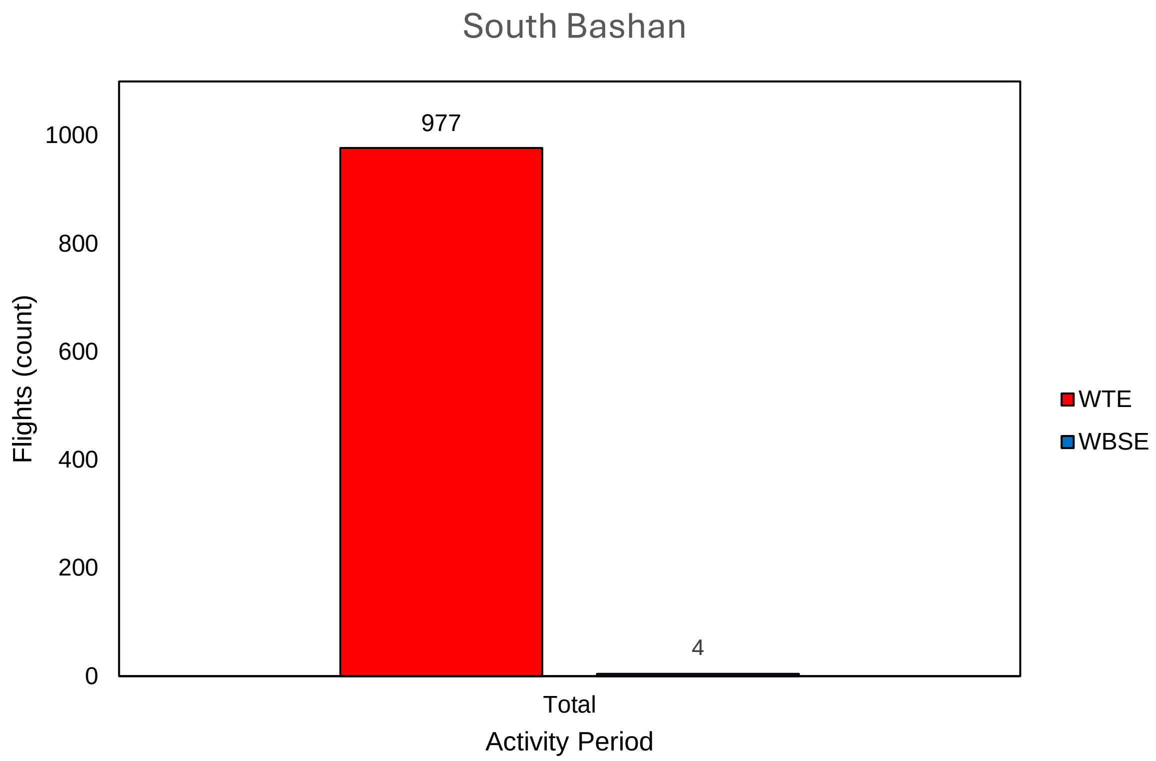

Figure 6. Count of Wedge-tailed Eagle (WTE, red) and White-bellied Sea Eagle (WBSE, blue) flights observed during *all surveys at South* Bashan

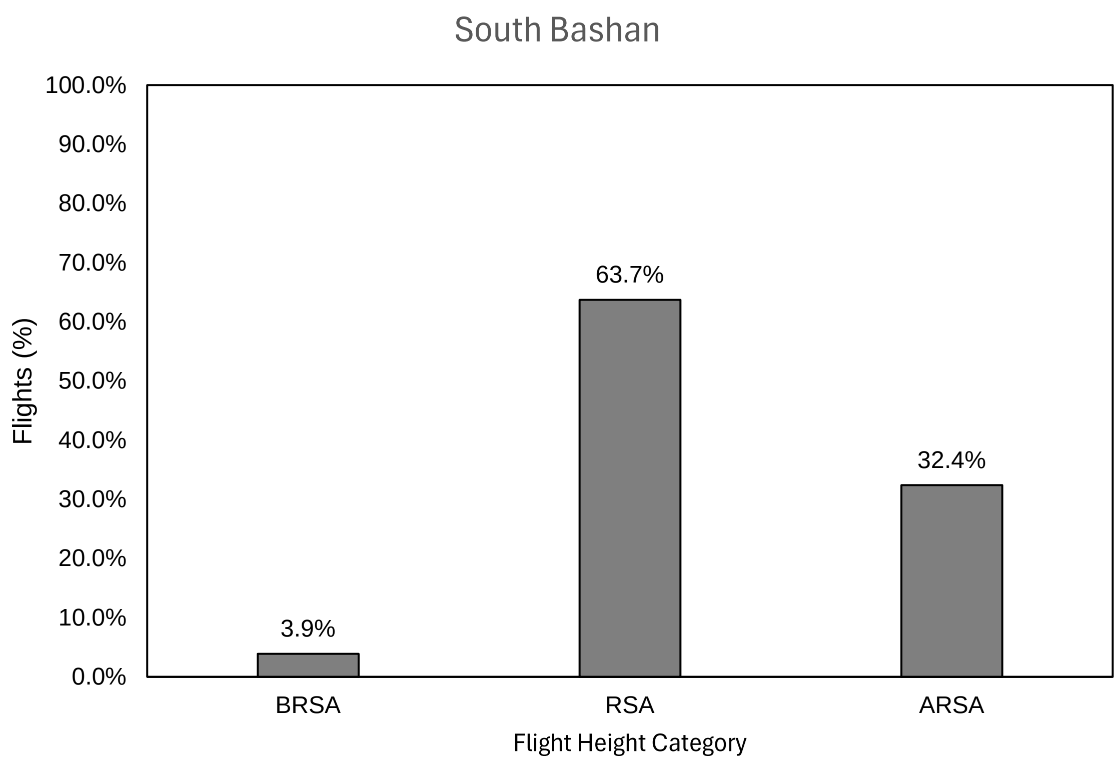

Figure 7. Proportion of eagle flights (%) observed in relation to the rotor-swept area range (RSA) at South Bashan. Flight height categories: below the RSA (BRSA), within the RSA range, and above the RSA (ARSA).

The density map of all eagle flights recorded at South Bashan revealed several critical patterns of eagle activity (Figure 8). High-density flight areas were prominently located in the southeastern region of the site near observation points BE1 and BE7 (Figure 8). This region indicated the most intense eagle flight activity, likely corresponding to an active nesting site and optimal conditions for dynamic soaring with wind blowing over hills, ridges, and dense vegetation. The spatial distribution of flight density, with two high-density areas separated by a moderate density zone, suggested the presence of at least one active nesting site inhabited by a single pair of WTEs which exhibited a substantial amount of observable activity. The presence of native eucalyptus forest with mature tree stands within the high activity further supported this suggestion given there are appropriate trees to accommodate a nest. The high activity in this area aligned with expectations, given the proximity of two observation points with a high visibility range near probable nesting sites, suitable vegetation, and optimal ridgelines for dynamic soaring.

Moderate flight activity was observed in the northwestern region of the site around points BE5 and BE12, indicated by yellow and light green areas (Figure 8). The central tendency of this moderate activity suggested another potential active nest site within native eucalyptus forest. A similar pattern was noted in the southwestern part of the site near points BE2 and BE8 (Figure 8). The considerable distance between all three clearly appearing hotspots implied the likely presence of at least three active nests of three distinct WTE pairs within the South Bashan study area.

Low-density areas, depicted in darker green shades, were scattered predominantly in the northeastern, southern, and the central parts of the study area around points BE3, BE6, and BE9 (Figure 8). This distribution may have indicated the presence of one or two additional actively of additional eagle pairs. However, the observed activity was insufficient to confirm additional resident pairs, and it was more likely that this activity belonged to one or more of the previously mentioned pairs ranging within their territory. Additionally, the visibility limitations of these observation points being in the low to medium range contributed to the uncertainty (Table 3).

In summary, the three identified hotspots likely represented at least three active nesting sites detected within the South Bashan study area during the survey period. The density map, created using kernel density estimation, provided valuable insights into the spatial distribution of eagle flights. These findings highlight key areas for further investigation and consideration in the planning of the Bashan Wind Farm to mitigate potential impacts on predominately WTEs, the dominant threatened eagle species in the area.

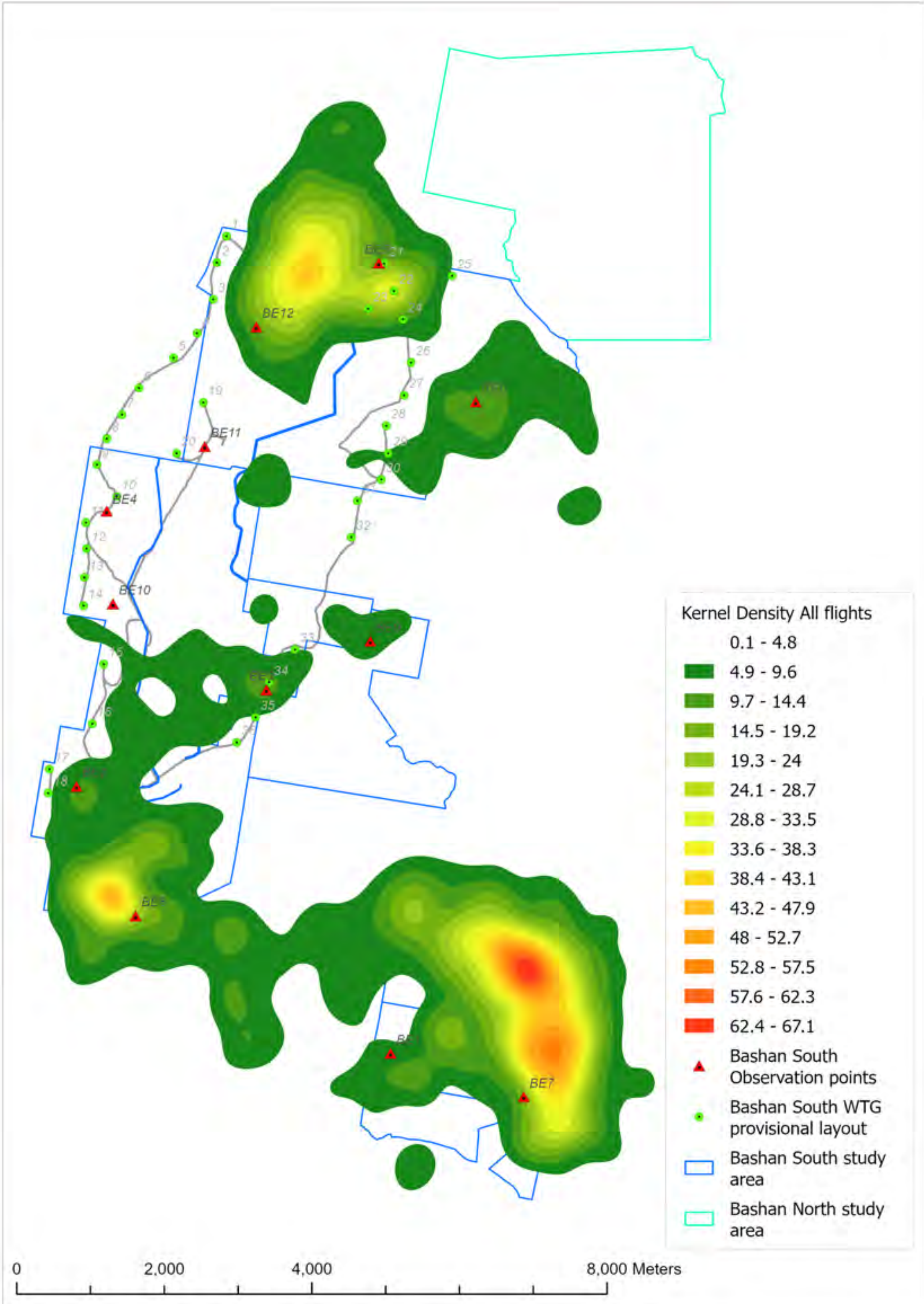

Figure 8. Density map of all eagle flights recorded at South Bashan (981 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

North Bashan Overview

The dominant eagle species at North Bashan was the WTE, with a total of 844 flights recorded, while the WBSE was rarely observed, accounting for only 9 flights (Figure 9). This observation mirrored the findings at South Bashan, where the WTE was also the predominant species and the WBSE was rarely observed. The higher number of WBSE flights observed at North Bashan may be attributed to the site's closer proximity to Lake Echo. The presence of open grasslands and woodland forests at both sites likely contributed to the clear dominance of WTEs and indicated that the habitat suitability for WTEs was consistent across the entire proposed development site.

At North Bashan, 45.1% of eagle flights occurred within the RSA range, 53.9% were above the RSA (ARSA), and 1.1% were below the RSA (BRSA, 0 to 43.5 meters) (Figure 10). In comparison, at South Bashan, 63.7% of flights were within the RSA, 32.4% were above the RSA, and 3.9% were below the RSA. The higher proportion of flights above the RSA at North Bashan (53.9% compared to 32.4% at South Bashan) suggested that eagles at North Bashan flew at greater heights more frequently, likely utilising the area predominantly for hunting and soaring at greater heights in search of food and to survey and defend established territories (Figure 7, Figure 10). This difference may be influenced by varying landscape features, prey abundance in the more open grasslands, weather conditions during the survey, and the visibility ranges of the observation points (Table 3). Notably, the observation points at North Bashan had a greater visibility range, which could contribute to the higher detection of flights at greater heights.

Conversely, the lower proportion of flights within the RSA range at North Bashan (45.1% compared to 63.7% at South Bashan) indicated that eagles spent less time at rotor-swept heights in North Bashan (Figure 7, Figure 10). This could also be attributed to the same factors affecting ARSA flights. Both sites had a low proportion of flights below the RSA, with North Bashan at 1.1% and South Bashan at 3.9% (Figure 7, Figure 10). This low proportion suggested that eagles flew less frequently within this range, and vegetation obstruction and visibility limitations had an impact, making it difficult to observe flights at these lower heights.

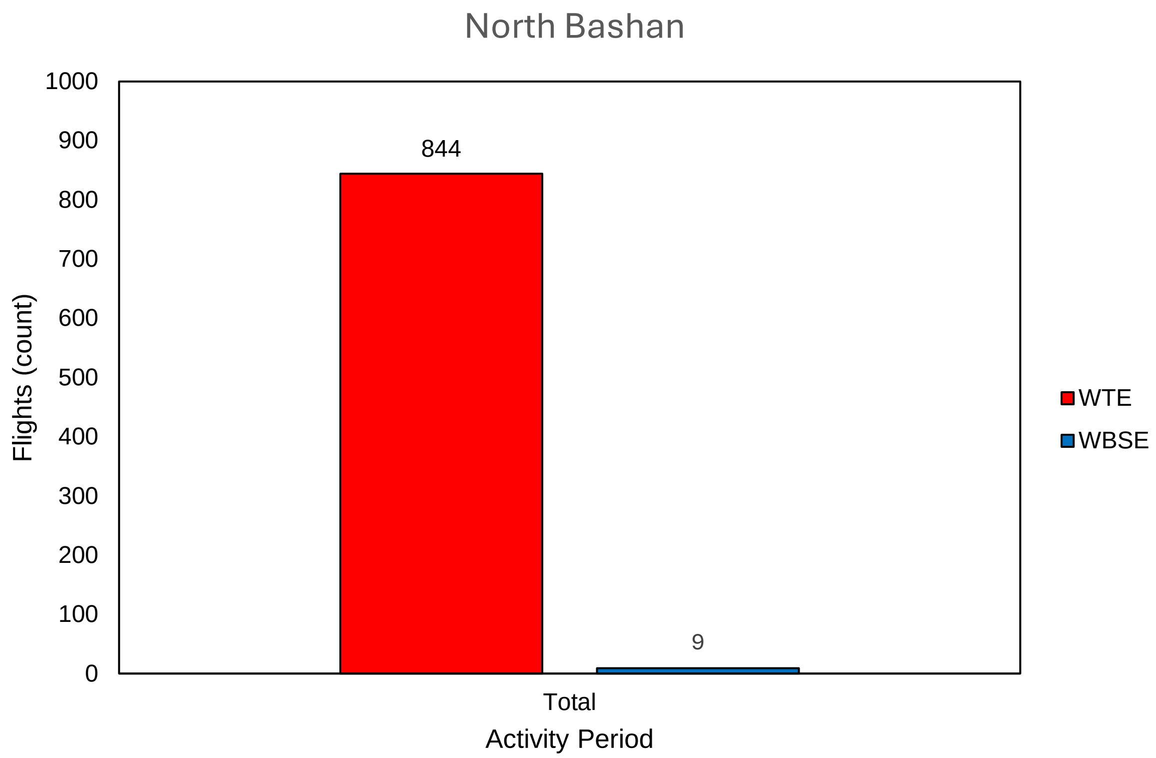

Figure 9. Count of Wedge-tailed Eagle (WTE, red) and White-bellied Sea Eagle (WBSE, blue) flights observed during all surveys at North Bashan.

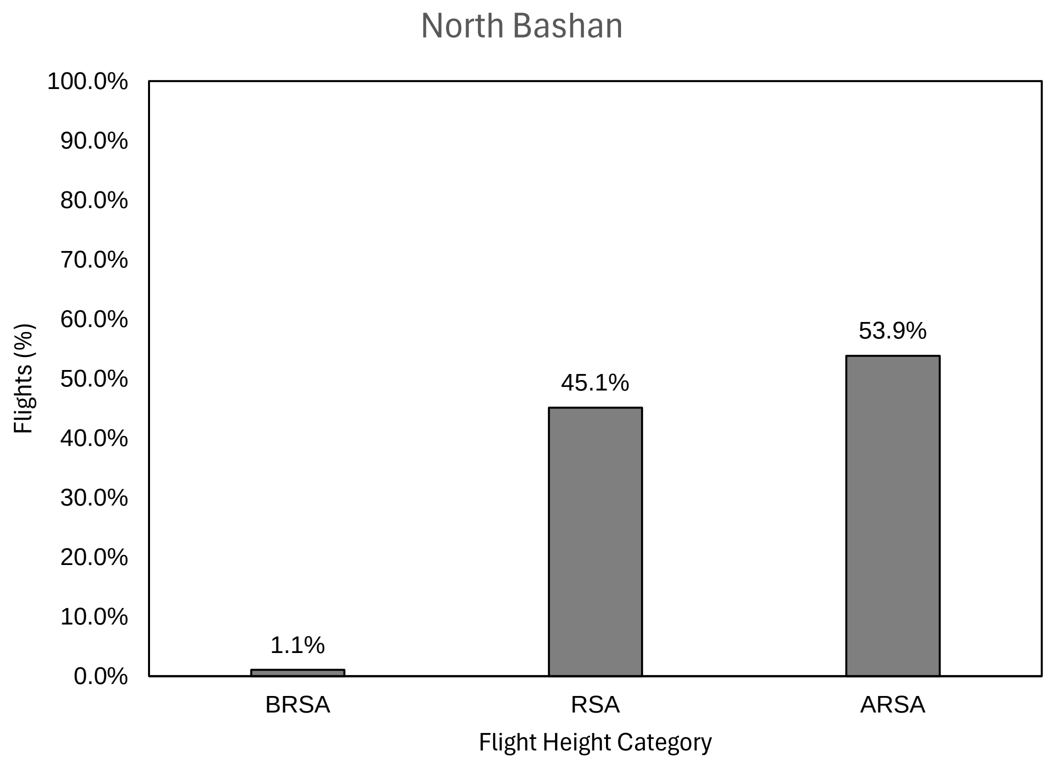

Figure 10. Proportion of eagle flights (%) observed in relation to the rotor-swept area range (RSA) at North Bashan. Flight height categories: below the RSA (BRSA), within the RSA range, and above the RSA (ARSA).

The density map of eagle flights at North Bashan revealed several key findings (Figure 11). High-density flight areas were prominently located in the central and southeastern parts of North Bashan, particularly around observation points BN4 and BN5. Moderate flight activity was distributed throughout the study area, especially in the southwestern and northwestern regions around observation points BN3 and BN6 (Figure 11). These areas, marked by yellow and light green gradients, indicated consistent but less intense eagle activity compared to the high-density hotspots. Low-density flight activity was primarily observed in the northern and northeastern parts of the study area, with observation points BN1 and BN6 situated within these zones, marked by darker green shades (Figure 11).

Comparing North Bashan with South Bashan, it was evident that North Bashan exhibited a higher overall density of eagle flights. This higher activity density at North Bashan could be attributed to the presence of more grazing and open pasture vegetation, which supported an abundant prey base, including Bennett's wallabies, pademelons, European hares, and rabbits. Although the number of surveys conducted was the same in both North and South Bashan, the condensed survey timeline at North Bashan, which was completed over a single seasonal cycle, may have also contributed to the consistently high activity levels observed. This shortened timeline likely resulted in less variation between surveys, as it did not capture the seasonal fluctuations that might occur over two cycles. If surveys at North Bashan had been conducted over at least two seasonal cycles, similar to South Bashan, a greater variation in eagle activity patterns might have been observed, potentially revealing more detailed patterns of high-use areas and movement corridors.

The high-density areas were distributed across the study area, with hotspots occurring in close proximity to each other (Figure 11). This widespread distribution suggested that eagle activity was not confined to a single area but spanned multiple regions of substantial use within North Bashan. Notably, these high-density areas are located close to an active nest site in South Bashan, approximately 3 km to the southwest (Figure 8). This proximity suggested that the same eagles from the South Bashan nest area may also be utilising North Bashan. These areas corresponded with regions containing native eucalyptus forests, where WTEs frequently used mature eucalyptus trees within plantation forests as regular roosting sites. Eagles were often observed beginning and ending their flights in these trees, especially those in the central portion of the North Bashan area. In conclusion, the distribution of high-density flight areas across North Bashan underscores its importance as a key habitat for WTEs.

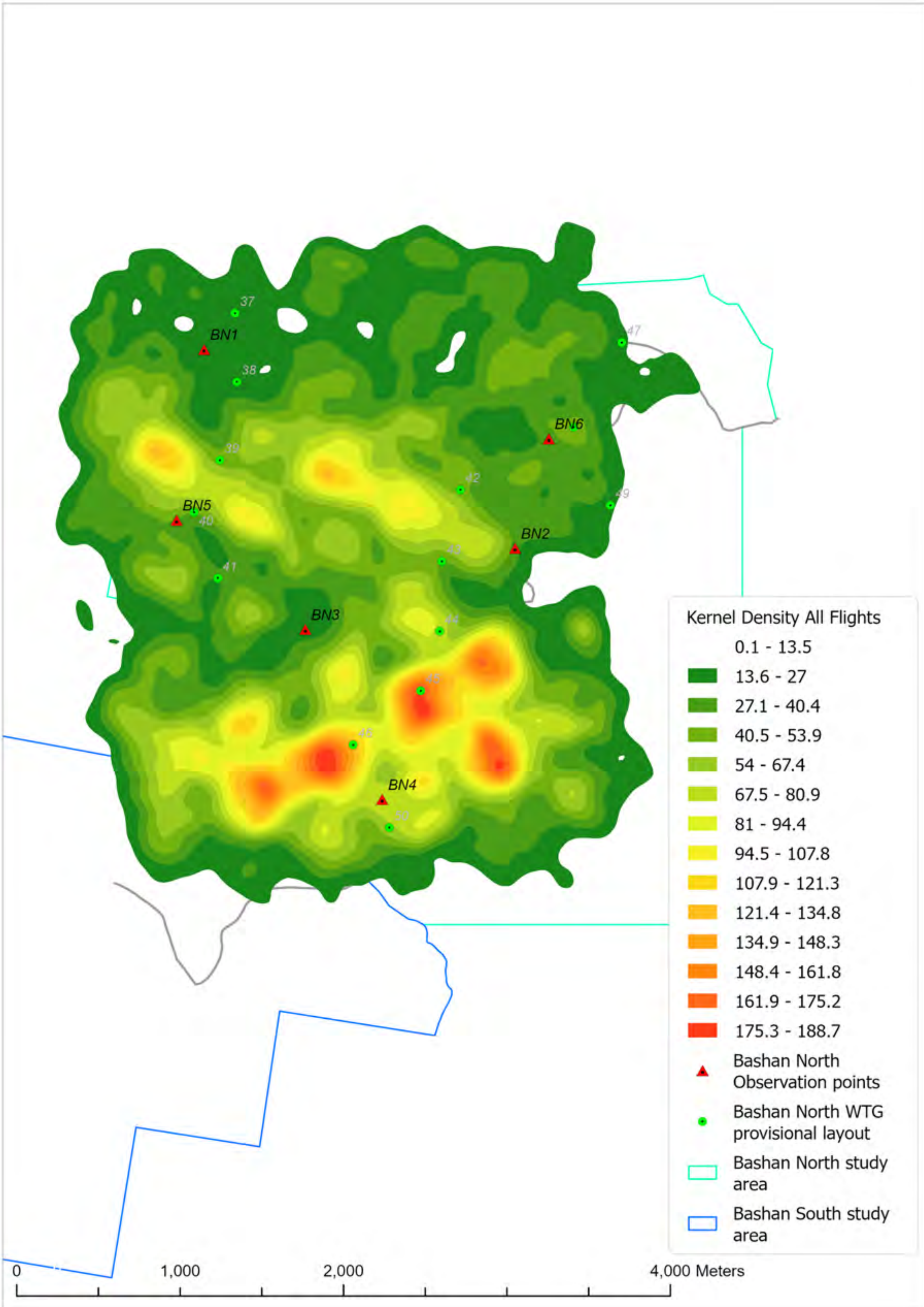

Figure 11. Density map of all eagle flights recorded at North Bashan (853 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

3.3 Activity Period and Behaviour Analysis

South Bashan

The analysis of eagle activity at South Bashan across different activity periods revealed key patterns in both flight counts and behaviours. Categorising flight activity into established periods, the late breeding period had the highest WTE flight count, followed by the display period, mid-breeding, fledging, and the non-breeding period (Figure 12). WBSE flights were rare, with only a few randomly recorded throughout the survey period during the display, fledging, and non-breeding activity periods.

The overall trend showed a gradual decline in flight counts from the display period to the non-breeding period, aligning with the expectation that territorial activity peaks during the breeding season and decreases towards the non-breeding season (Figure 12). The late-breeding period was the exception to this trend and showed an unexpectedly high number of flights more typical of the display period (Figure 12). The display period is regarded as the height of the breeding season with a lot of aerial activity expected whereas the late-breeding period is when eagles are primarily focused on chick rearing and nest defence.

Ideal weather conditions during the late breeding period likely contributed to this high activity level and adverse weather conditions may have contributed to the lower-than-expected flight during the display period (see Appendix, Figure A1). Behaviours varied across activity periods, with soaring being the most common, followed by flying and displaying (Figure 13). Display activity was comparatively low (13%) during the Display activity period but unexpectedly high during the fledging and late breeding periods (Figure 13). However, the presence of display behaviour across all periods suggested competition among WTE pairs, indicating a potentially high population of WTE in the area, reconfirming there may be at least three active pairs across the study site. The substantial amount of display behaviour observed, typical between competing pairs with neighbouring territories, suggested a considerable population of WTEs within or surrounding the South Bashan study site.

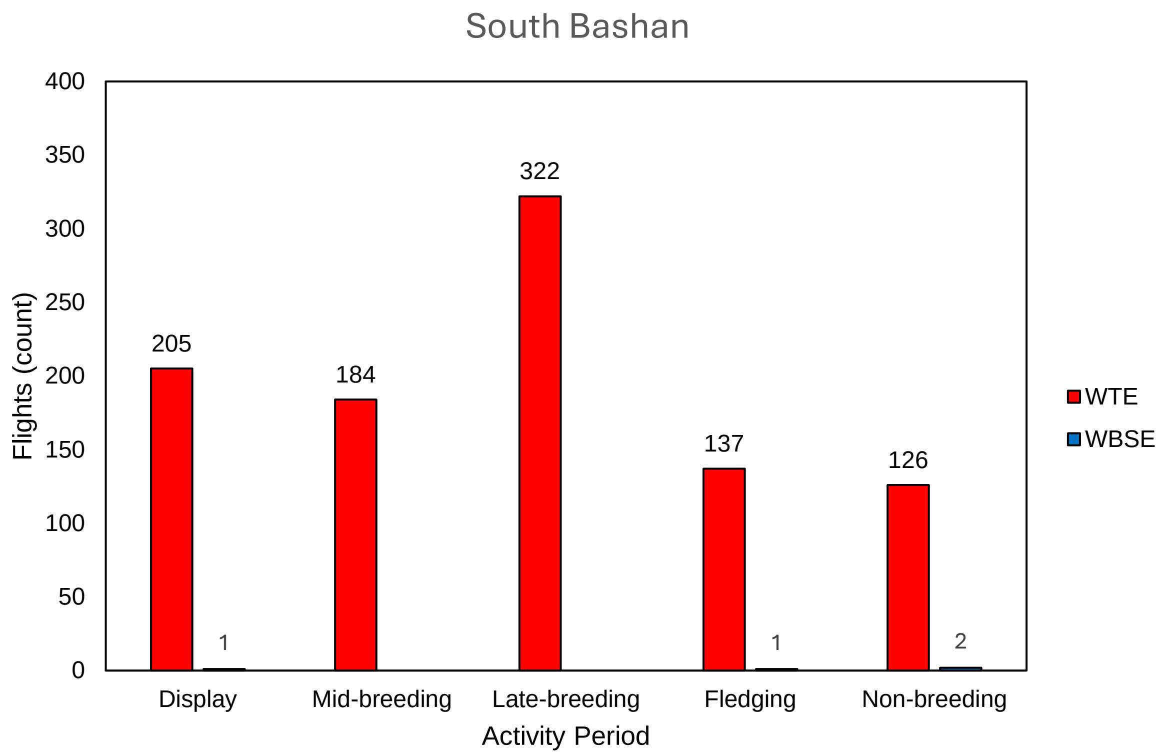

Figure 12. Count of Wedge-tailed Eagle (WTE, red) and White-bellied Sea Eagle (WBSE, blue) flights observed during each activity period at South Bashan.

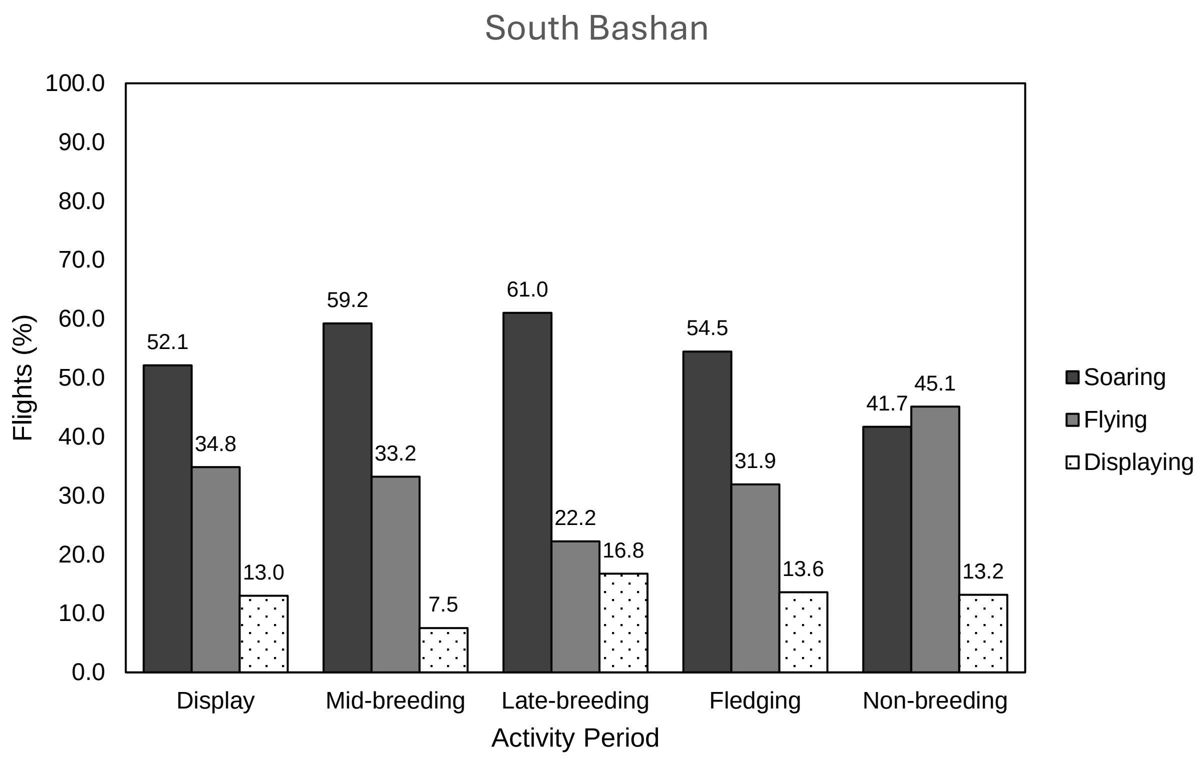

Figure 13. Proportion of eagle flight behaviours (%) at South Bashan *within* activity periods. Soaring (black), flying (grey), and displaying (dotted white). Activity periods include, Display, Mid-breeding, Late-breeding, Fledging, and Non-breeding.

The contour maps for each activity period provided insight into the spatial distribution of eagle flights at South Bashan, helping to identify where activity occurred and its magnitude. These maps reinforced the understanding of overall activity patterns and highlighted key areas of utilisation during specific time periods.

Display Activity Period

During the display period, high-density flight areas were concentrated in the northwestern region near observation points BE5 and BE12, and in the southeastern region near BE1 and BE7 (Figure 14). This pattern suggested active nest sites in these areas, of distinct pairs where eagles were defending and re-establishing their territories in preparation for egg-laying, incubation, and chick rearing. The absence of significant activity in the southwestern region during this period indicated that nesting activity in this area might not have been prominent during the display period (Figure 14).

Mid-breeding Activity Period

In the mid-breeding period, flight activity remained consistent with the display period's hotspots, though with slightly expanded areas of moderate activity (Figure 15). The northwestern and southeastern hotspots continued to show high activity, reaffirming the presence of active nests (Figure 15). The southwestern region near BE2 and BE8 began to show increased activity, which indicated that activity in this area was either increasing during the mid-breeding period or may have gone unobserved or was during earlier surveys (Figure 15).

Late-breeding Activity Period

The late-breeding period exhibited the highest overall flight activity, with prominent hotspots in the northwestern and entire south regions (Figure 16). The southwestern region near BE2 and BE8 showed a peak in activity, providing further evidence that this was an active nest of a distinct eagle pair (Figure 16). This period had the least amount of adverse weather, which could explain the high number of flights observed. The consistent presence of high-density areas across these periods supported the conclusion of at least three active WTE pairs within the South Bashan study area.

Fledging Activity Period

During the fledging period, flight activity became more dispersed across the site (Figure 17). High-density areas were still present in the northern and southern regions, but activity also spread into the central parts of the study area (Figure 17). This suggested that territorial boundaries may have been more relaxed during this period, and more fledglings might have been utilising the landscape.

Non-breeding Activity Period

In the non-breeding period, flight activity was generally lower and more spread out (Figure 18). High-density areas were less pronounced, indicating a reduction in activity around specific points on the map (Figure 18). This period showed a broader distribution of eagle flights, which could suggest that eagles were ranging more widely across the site, potentially due to the absence of nest-related territorial behaviours.

Summary

The contour maps across all activity periods at South Bashan consistently highlighted three substantial hot-spots of high-use areas, one in the north and two in the south, with varying levels of activity in other parts of the site. The presence of display behaviour across all periods suggested competition among WTE pairs and indicated a high density of eagles of at least three distinct pairs utilising the site. The observed activity patterns provided critical insights into the spatial and temporal distribution of eagle activity. These findings underscored the importance of considering both temporal and spatial dimensions when assessing the potential impact on eagle populations.

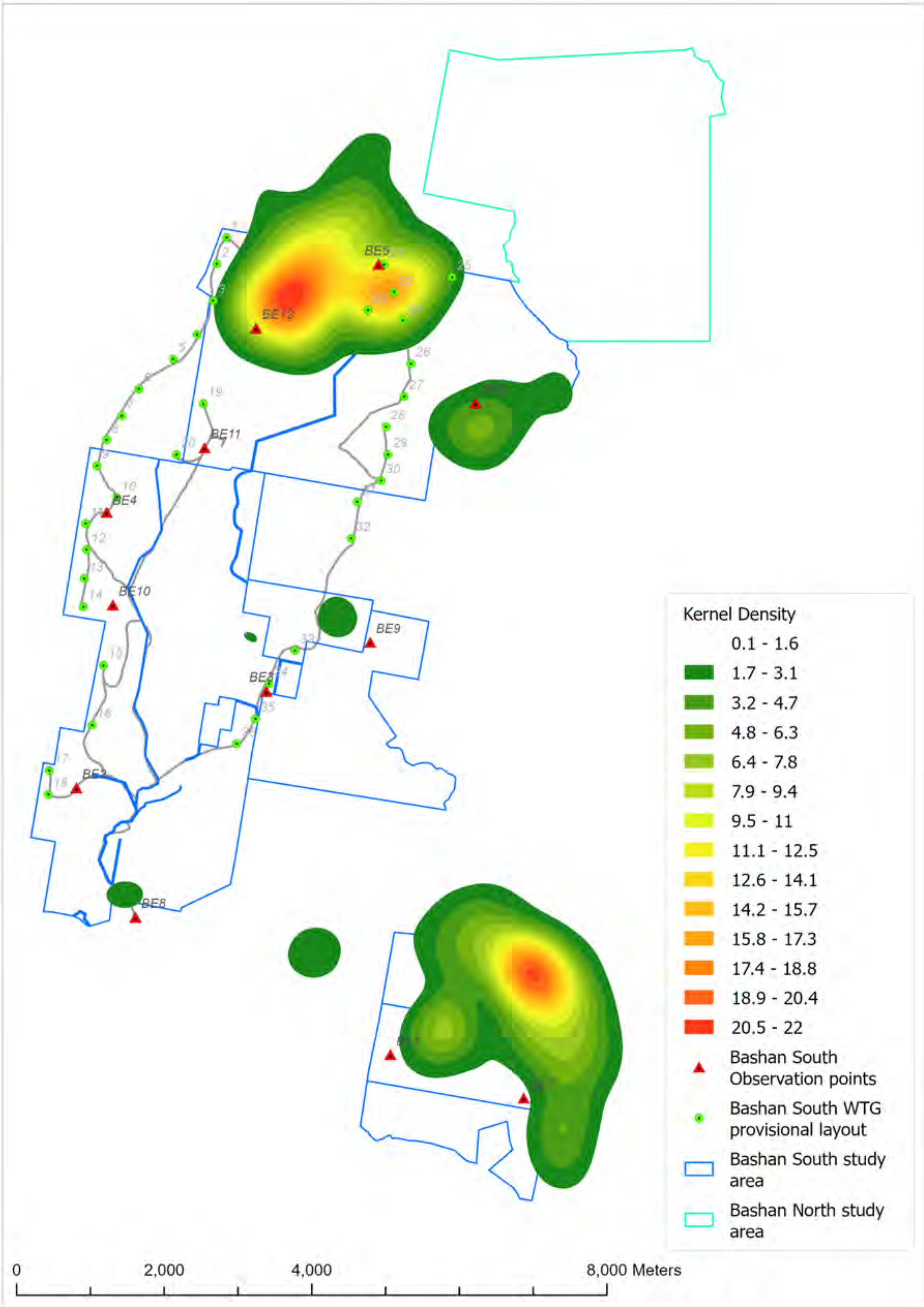

Figure 14. Density map of eagle flights recorded during Display Activity Period at South Bashan (206 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

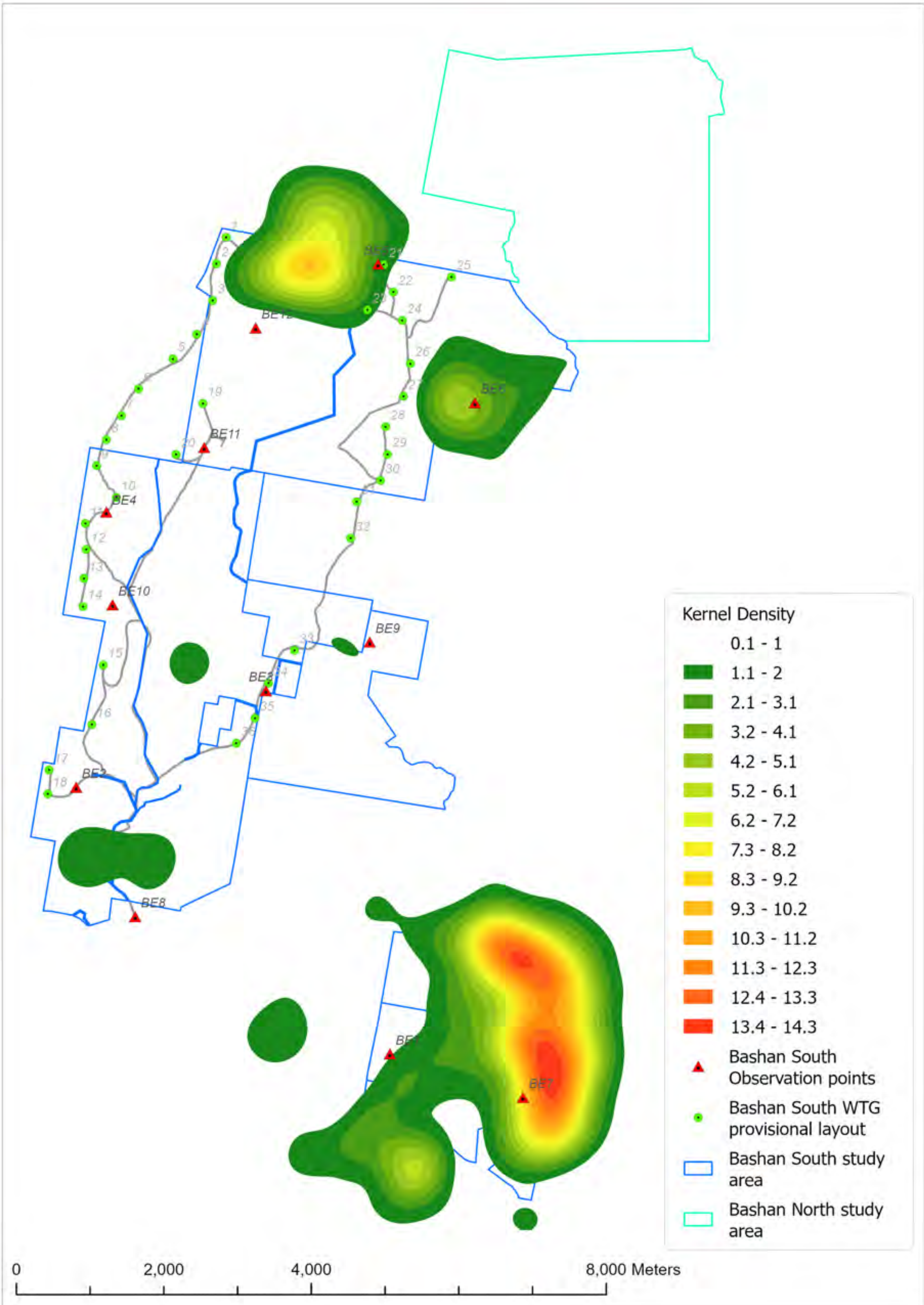

Figure 15. Density map of eagle flights recorded during Mid-breeding Activity Period at South Bashan (184 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

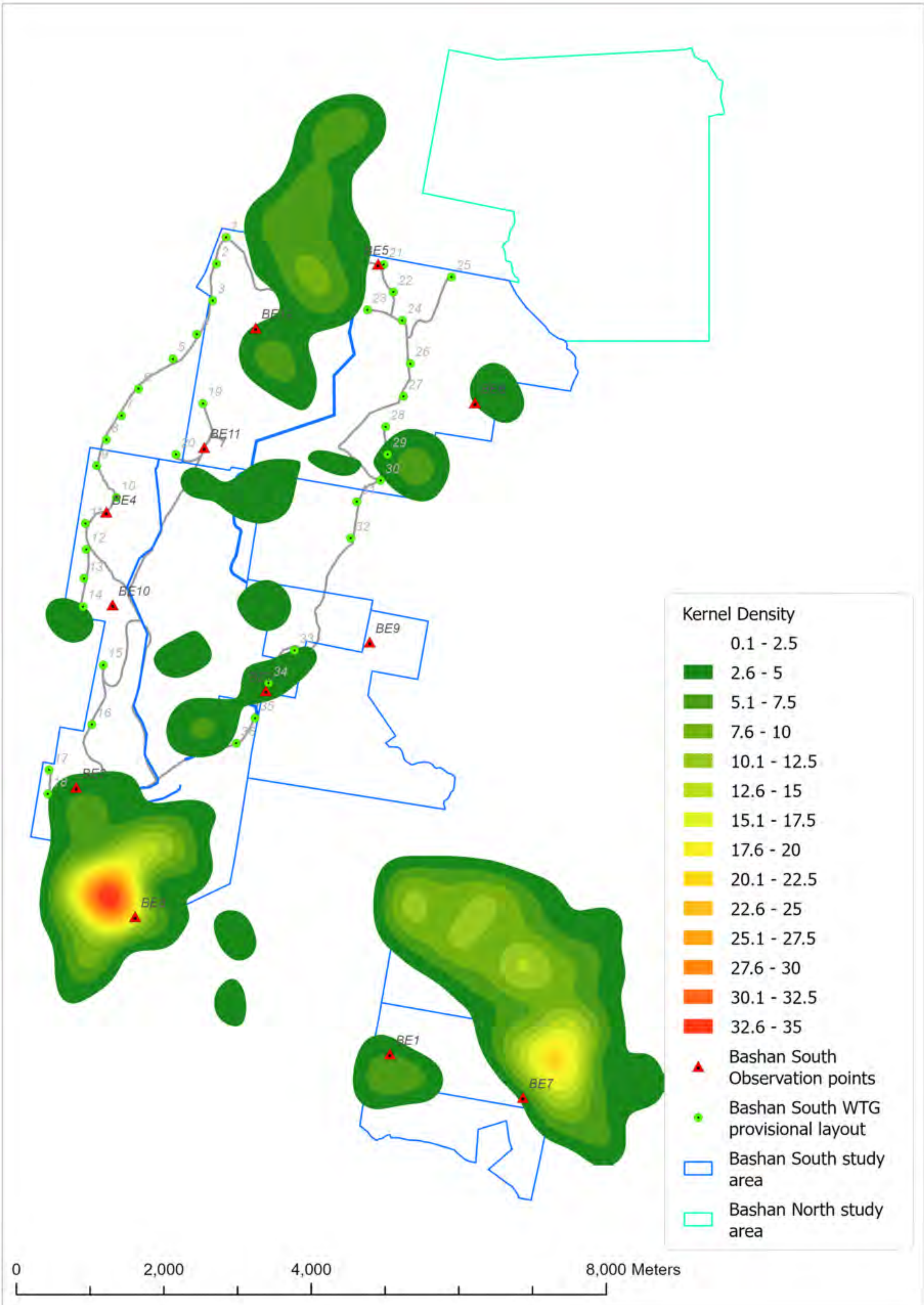

Figure 16. Density map of eagle flights recorded during Late-breeding Activity Period at South Bashan (322 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

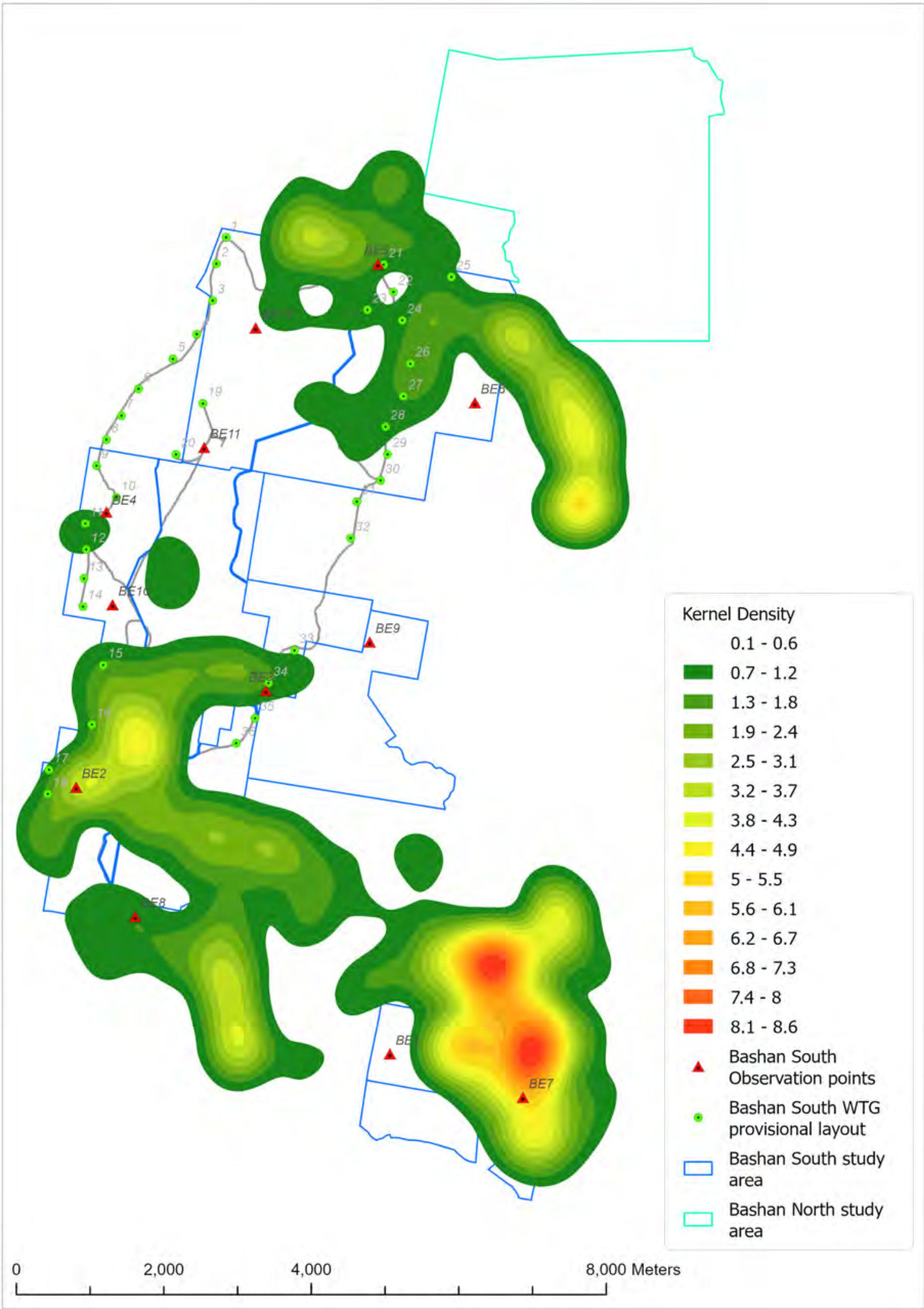

Figure 17. Density map of eagle flights recorded during Fledging Activity Period at South Bashan (138 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

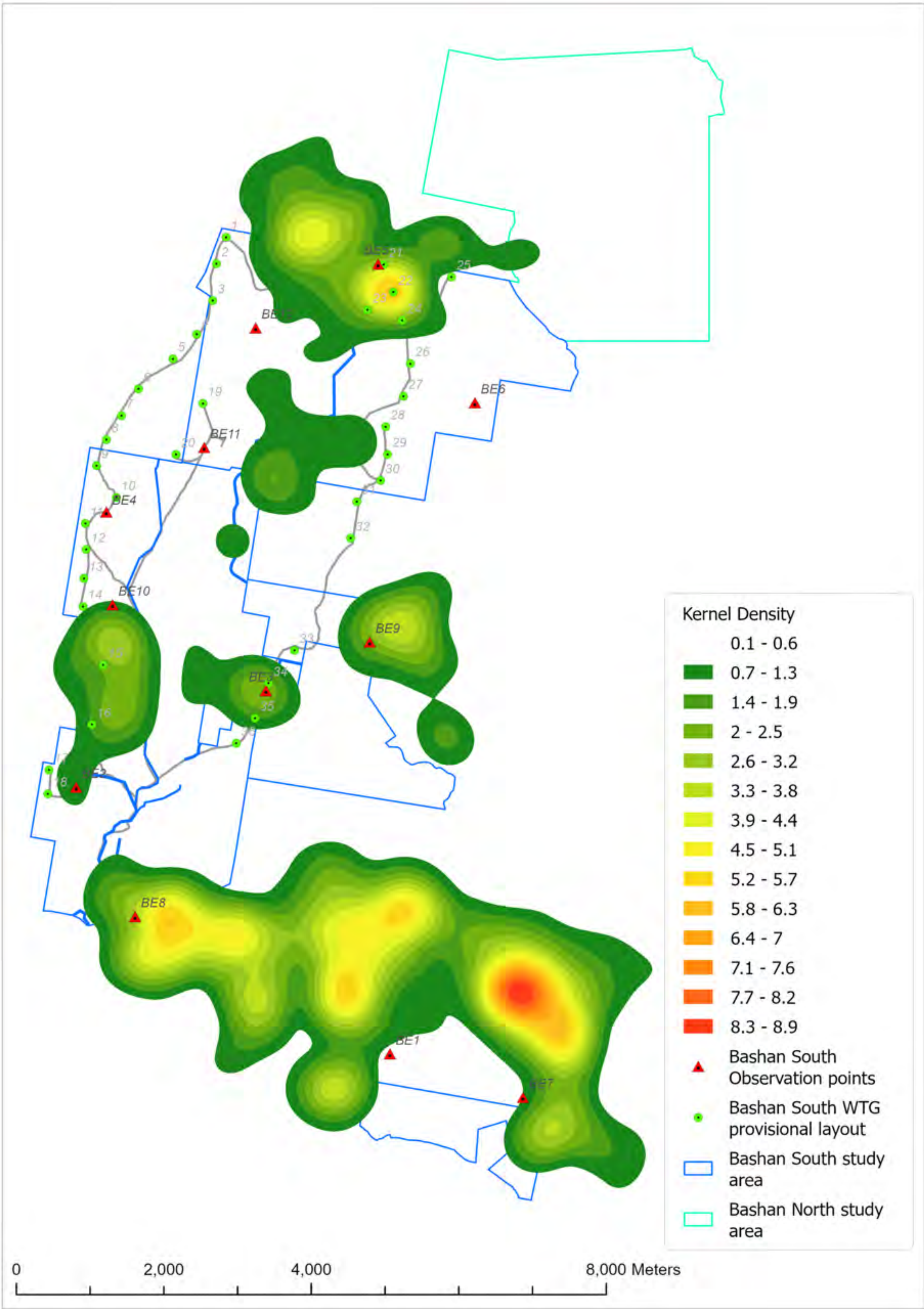

Figure 18. Density map of eagle flights recorded during Non-breeding Activity Period at South Bashan (128 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

North Bashan

North Bashan, which is approximately one fifth of the size of South Bashan, exhibited similar flight counts, indicating a highly active area. North Bashan likely captured a lot of activity from the established eagle pair from South Bashan, particularly those nesting in the northwestern region. The overall trend showed a gradual decline in flight counts from the late breeding period to the non-breeding period, but there were higher-than-expected flights during the mid-breeding and late-breeding activity periods (Figure 19). This trend was similar to the data from South Bashan, excluding the higher-than-expected count of flights during the mid-breeding period (Figure 19). The higher-than-expected flight counts during the mid-breeding and late-breeding periods could be attributed to favourable weather conditions, territorial clashes, or prey abundance during the survey timing, all of which may have facilitated increased aerial activity (see Appendix, Figure 2A). Conversely, the display period, typically regarded as the height of the breeding season, did not exhibit the expected peak in flight activity, which could be due to adverse weather conditions suppressing flight counts during that period (Figure 19, Figure 2A).

Behaviours varied across activity periods, with soaring being the most common, followed by flying and displaying (Figure 20). Display activity was low during the display period but increased during the fledging and late breeding periods (Figure 20). The presence of display behaviour across all periods suggested competition among WTE pairs, which suggested that the study site is populated by a substantial number of birds and reconfirming the presence of at least three active territories across the study site. Notably, the mid-breeding period exhibited the highest proportion of soaring behaviour (63.6%), which may reflect the eagles' search for food and territory surveillance during this crucial breeding stage (Figure 20).

The substantial amount of display behaviour observed, typical between competing pairs with neighbouring territories, suggested a considerable population of WTEs within or surrounding the North Bashan study site. The high activity levels recorded in the smaller North Bashan area suggested that this activity is primarily from the South Bashan eagles extending their range. In summary, the activity periods at North Bashan demonstrated substantial eagle flight and behaviour patterns, reflecting both the influence of seasonal activities and weather conditions on eagle behaviour.

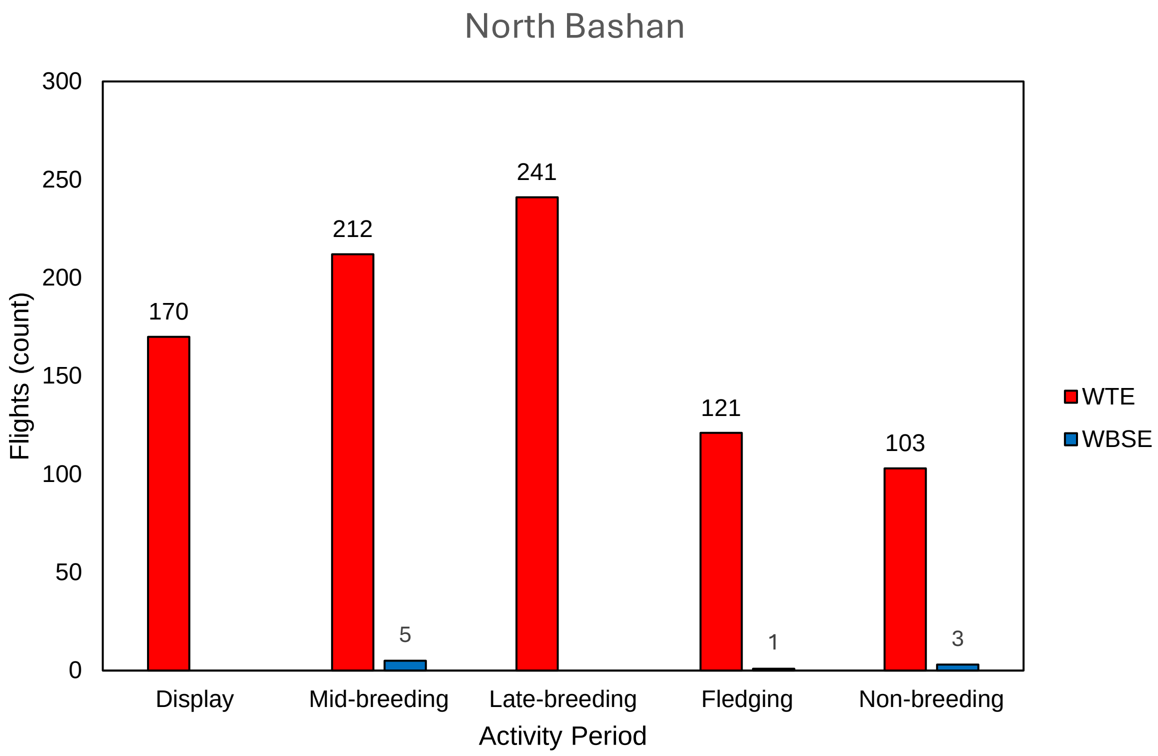

Figure 19. Count of Wedge-tailed Eagle (WTE, red) and White-bellied Sea Eagle (WBSE, blue) flights observed during each activity period at North Bashan.

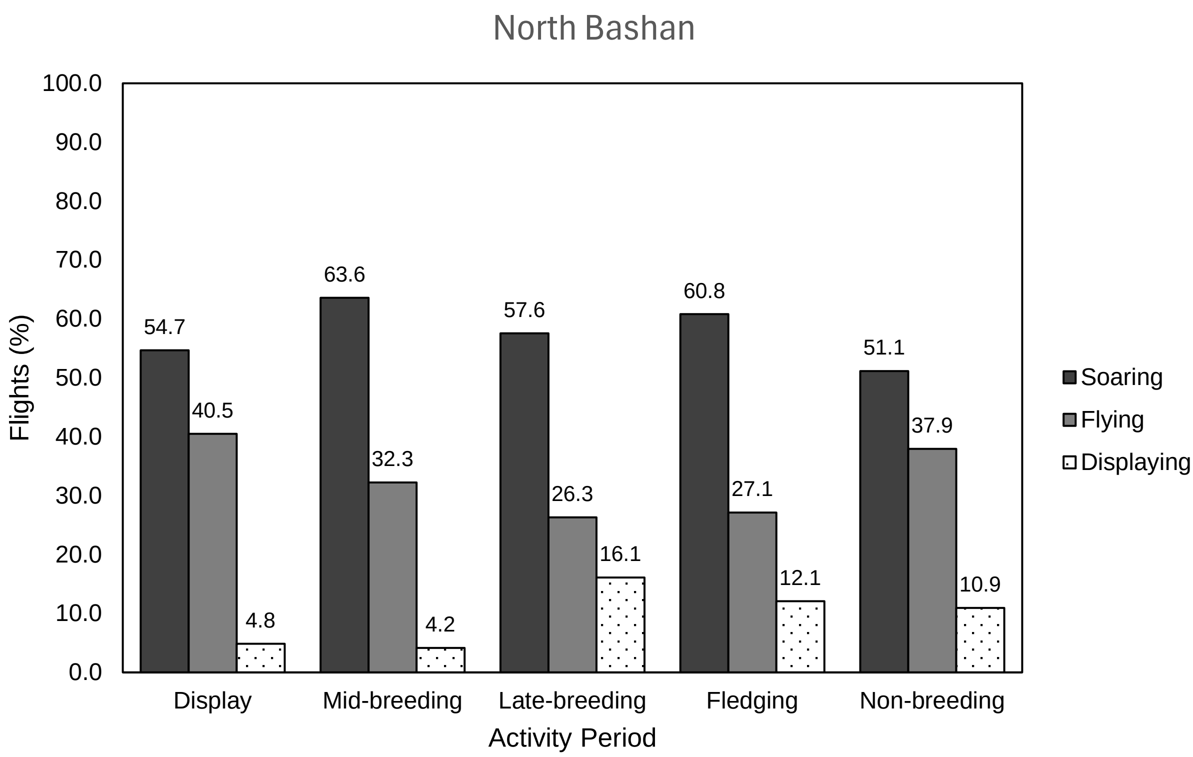

Figure 20. Proportion of eagle flight behaviours (%) at North Bashan across activity periods. Soaring (black), flying (grey), and displaying (dotted white).

The activity density across North Bashan differed substantially from South Bashan, with more concentrated activity within a smaller region. The hotspots were inconsistently spread throughout the landscape and varied highly across each activity period. However, overall North Bashan was a heavily utilised area by WTEs.

Display Period

In the display period, most activity was focused around the central to the central eastern portion of the region, particularly close to BN2 (Figure 21). There were a few scattered hotspots to the west and northwest of the region (Figure 21). The dominant vegetation type across the landscape was grazing and modified pastures, plantation forest, and sparse native eucalyptus forest. WTE were often observed using remaining mature eucalyptus trees as homing trees, and many of these homing trees were in proximity to the density hotspots. These trees were clearly visible to on-ground observers, and no obvious nests were located.

Mid-breeding Period

During the mid-breeding season, the highest density of activity shifted from the central region during the display period to the northwestern region (Figure 22). The distribution of the densest activity was relatively spread out and close to observation point BN5 (Figure 22). Many of the moderate activity hotspots were in the central to the central south region of the map, notably over areas of remaining native eucalyptus forest (Figure 22).

Late-breeding Period

In the late breeding period, eagle activity became less spread out and more condensed in the south and southwestern region of North Bashan, edging onto South Bashan (Figure 22). This period showed the highest overall flight activity, likely due to ideal weather conditions and reduced adverse weather impacts (see Appendix, Figure 2A). Furthermore, during this survey period infield observers reported seeing evidence discarded wallaby carcasses at North Bashan south of observation point BN2. This mass of food for scavenging may explain the large amount of concentrated activity in this area.

Fledging Period

During the fledging period, the activity was more dispersed compared to the late-breeding period, with hotspots around stands of remaining eucalyptus trees across the site (Figure 23). This spread indicated more dispersed eagle movements likely due to the eagles ranging more extensively within their greater territories and the presence of more young birds in the population.

Non-breeding Period

In the non-breeding period, activity patterns were similar to the fledging period, with scattered hotspots throughout North Bashan (Figure 24). This period likely reflected an increase in ranging activity as eagles moved throughout their territories without the constraints of breeding responsibilities.

Summary

Overall, North Bashan exhibited high levels of eagle activity, with substantial use of the area across all activity periods. This intense utilisation, despite the smaller size compared to South Bashan, underscores the importance of North Bashan as a critical habitat for WTE.

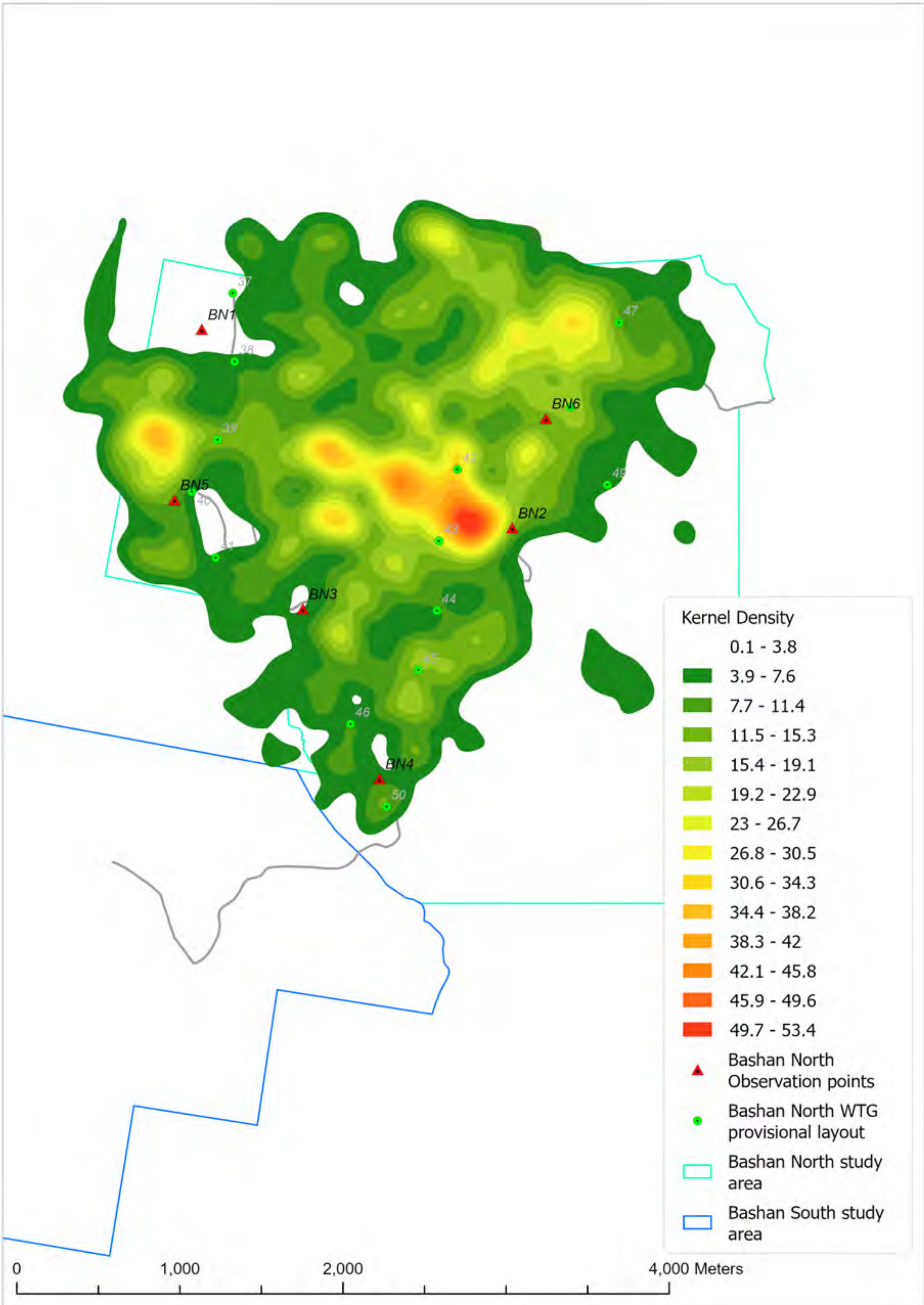

Figure 21. Density map of eagle flights recorded during Display Activity Period at North Bashan (170 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

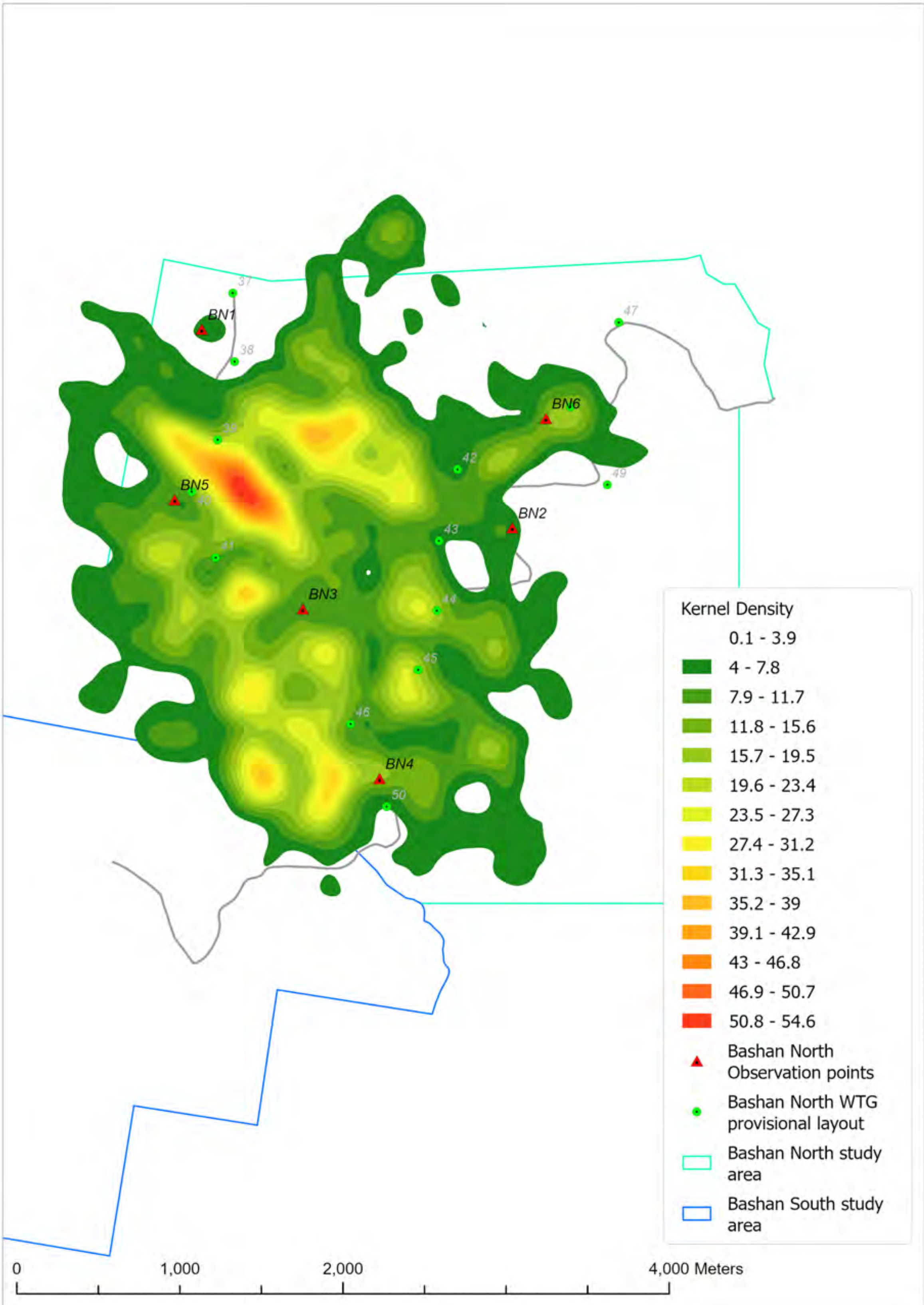

Figure 22. Density map of eagle flights recorded during Mid-breeding Activity Period at North Bashan (217 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

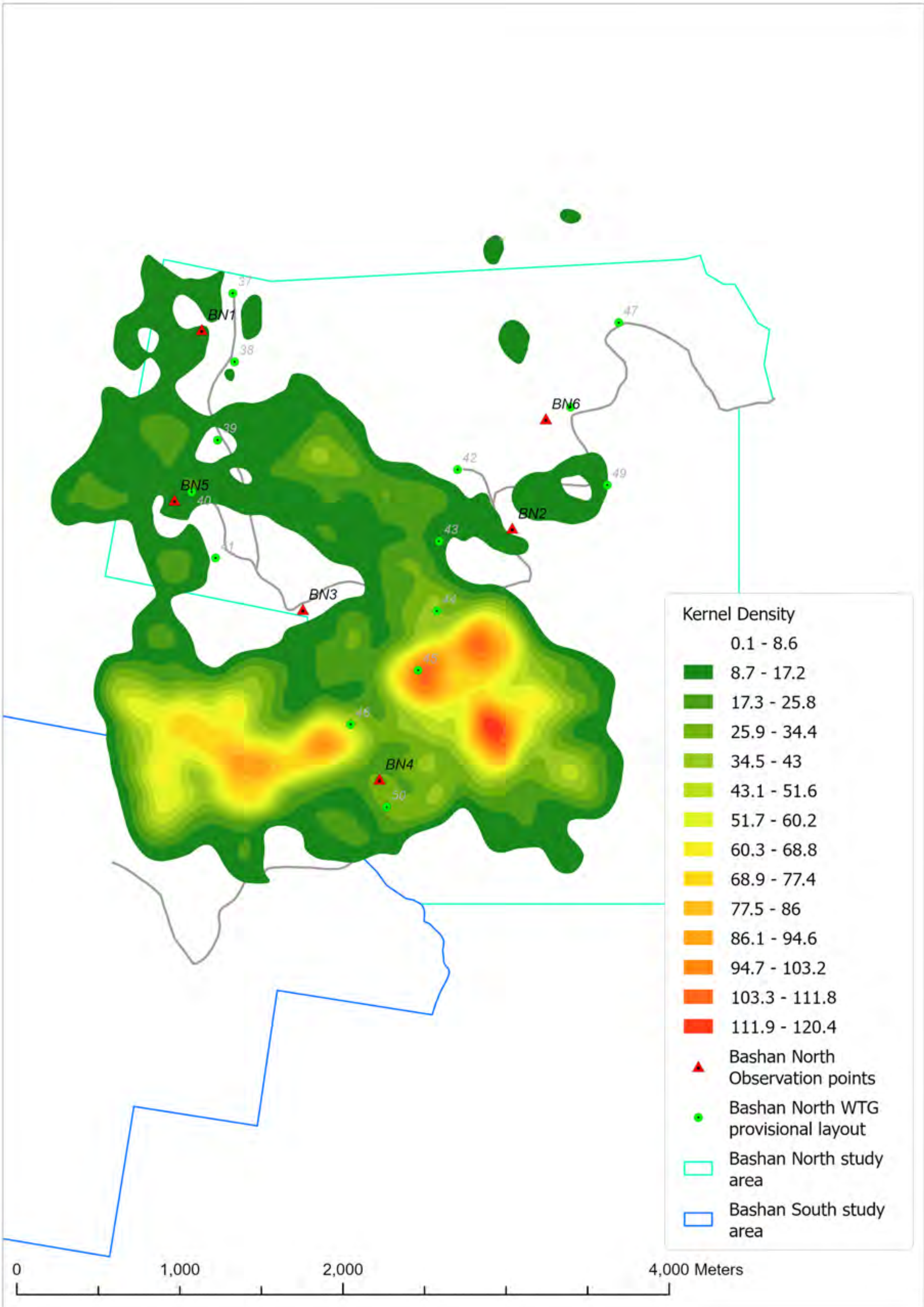

Figure 23. Density map of eagle flights recorded during Late-breeding Activity Period at North Bashan (241 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

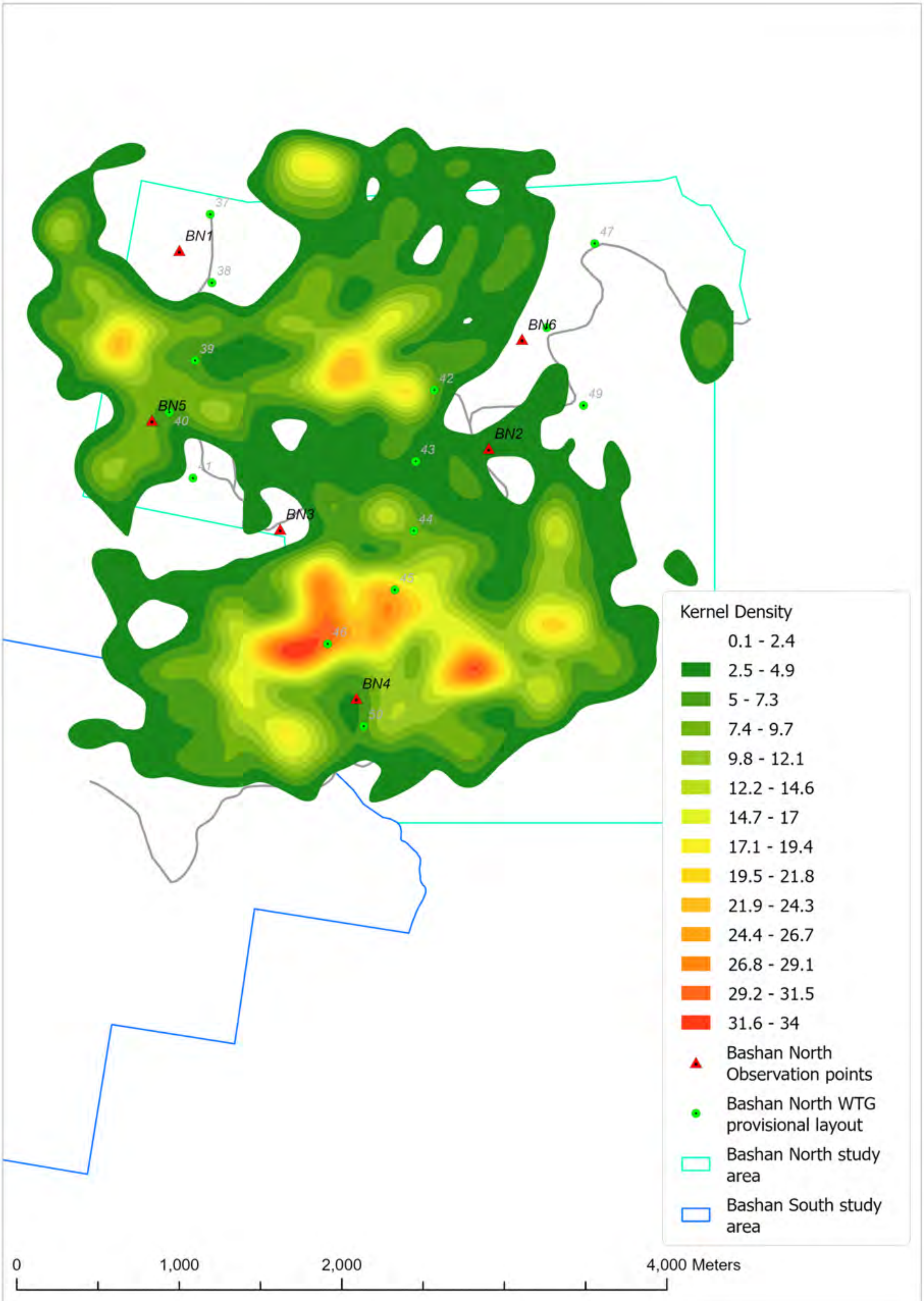

Figure 24. Density map of eagle flights recorded during Fledging Activity Period at North Bashan (122 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue.

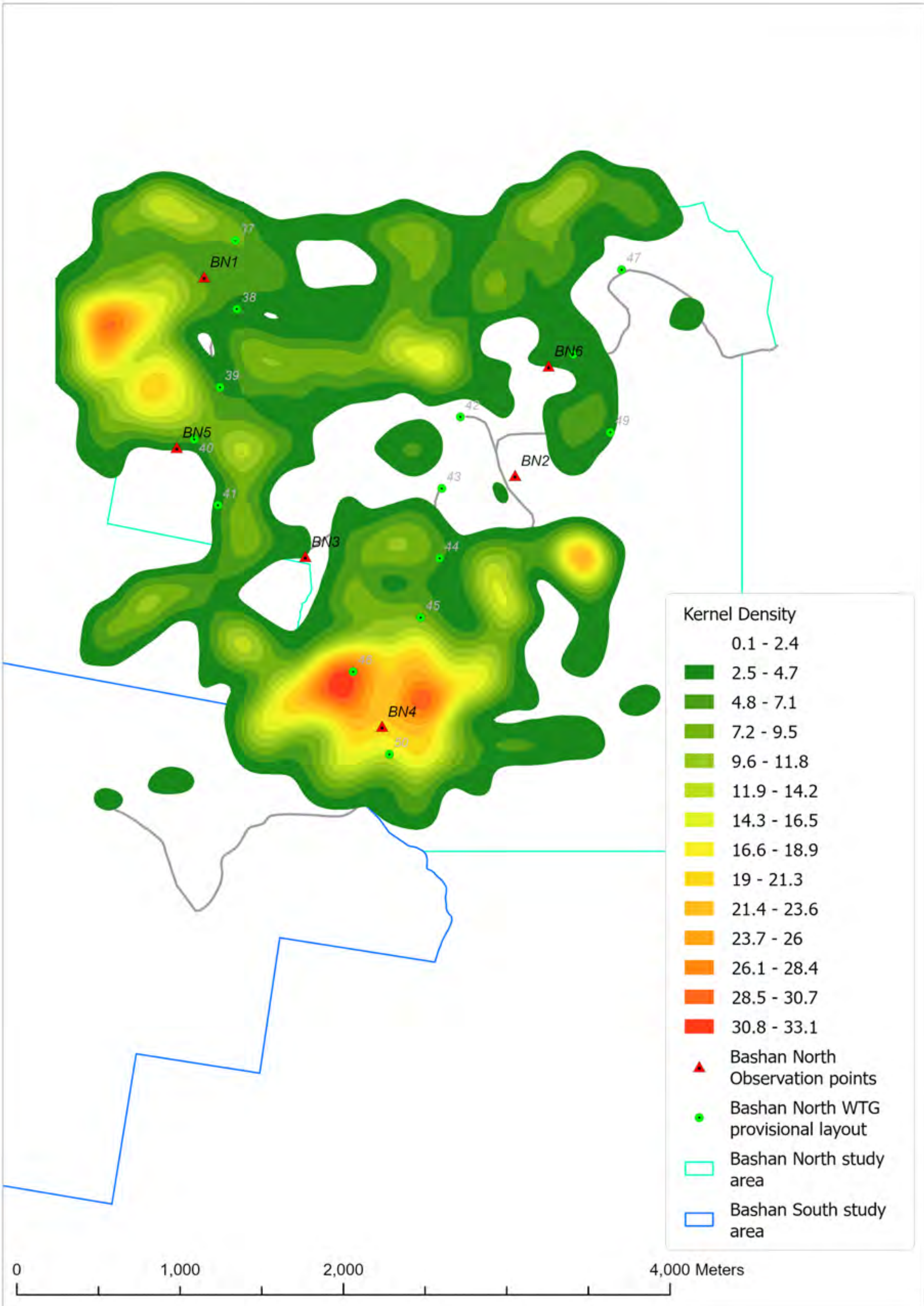

Figure 25. Density map of eagle flights recorded during Non-breeding Activity Period at North Bashan (106 flights), generated using kernel density estimation (KDE). Colour gradients from green to red indicate increasing flight density. Red triangles mark observation points, and green circles show the provisional layout for wind turbines. South Bashan study area boundaries are in blue

3.4 Accuracy Assessment

This section presents an example assessment of accuracy using selected observation points from South Bashan (Figure 26) to provide context to preceding figures (Figure 27, Figure 28).

The map in (Figure 26) shows eagle flight first detection points (purple dots) overlaid with the estimated observation accuracy gradient (yellow) and observation points (red triangles) at South Bashan. The estimated observation accuracy gradient represents the likelihood that multiple observers participated in detecting a particular flight. The more observers involved in detecting a flight, the higher the accuracy of the data. The yellow gradient on the map varies in darkness, with darker shades indicating a higher number of observers participating in the flight, and lighter shades representing fewer observers. For example, if an eagle is observed to the east of BE5 (Figure 26), the north-to-south positioning is likely to be accurate. However, without bidirectional interpretation from another observer involved in the flight, the accuracy of the east-to-west positioning is limited. This limitation arises because the human capacity to estimate a bird’s distance without multiple perspectives is generally poor, highlighting the importance of multiple observer participation in flight detection.

The placement of observation points was strategic, ensuring broad coverage across the study area. However, the limited number of observation points in the western extremity likely reduced the accuracy of flight detections in that region. This portion of the site was less accessible, contributing to the challenge of placing more observation points in that section of the study area. This reduction in accuracy arises primarily due to the challenge of achieving consistent bidirectional interpretation of eagle flight paths without multiple observers. Additionally, the ability to achieve triangulation-based observations was further compromised by visibility constraints caused by intervening vegetation and terrain features.

The high concentration of detection points around certain observation points not only suggested these areas were key activity hotspots for eagles but also underscored the reliability of the data in those regions. The accuracy gradient provided critical insights into the data's reliability, with higher confidence in areas where more observers contributed to the detection. This enhanced understanding of observation accuracy allows for a more nuanced interpretation of the spatial distribution of eagle activity within the South Bashan study area, thereby providing valuable context for the overall findings presented in this report.

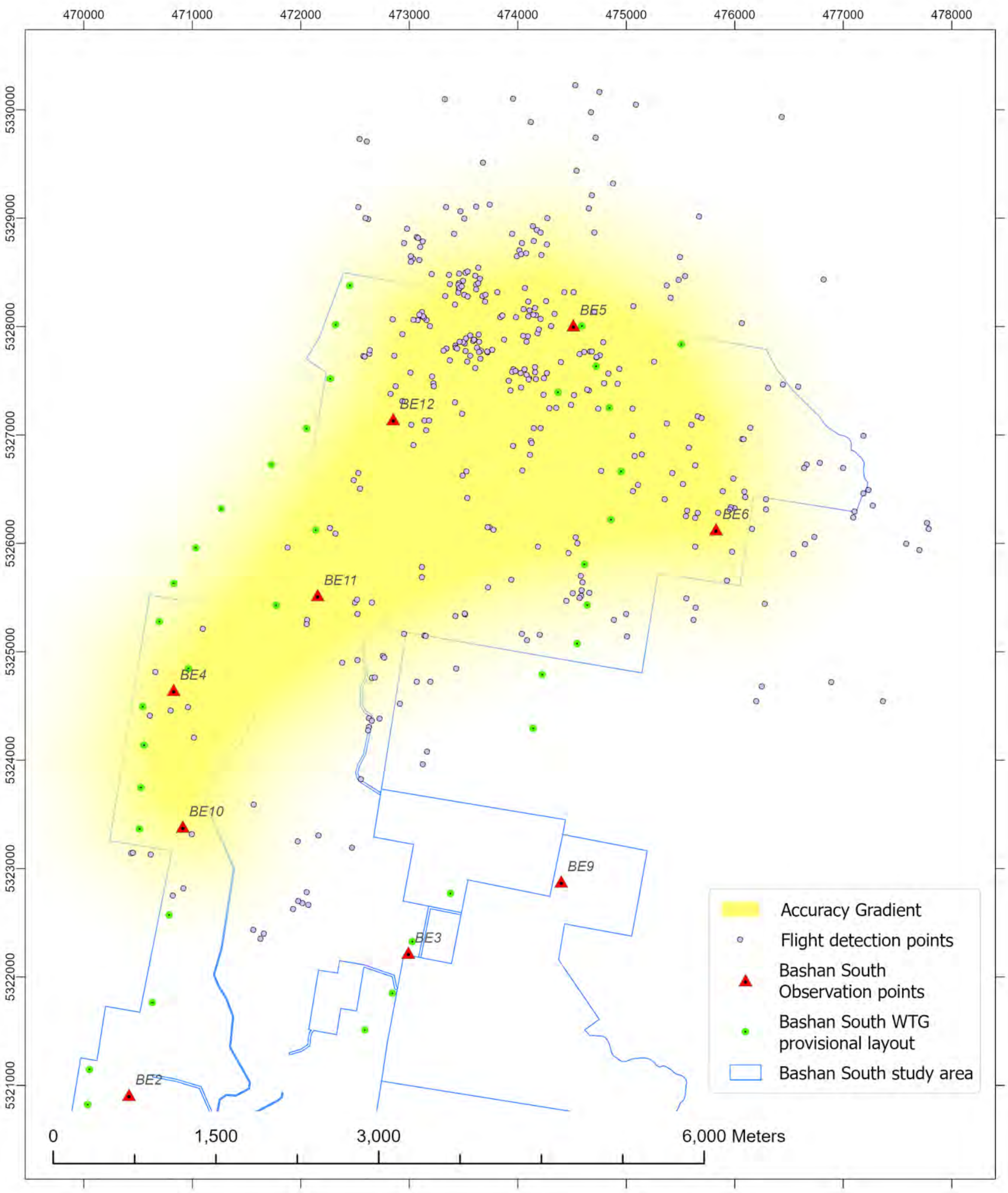

Figure 26. Map showing eagle flight first detection points (purple dots) overlaid with the estimated observation accuracy gradient (yellow) and observation points (red triangles) at South Bashan.

The analysis of South Bashan observation points (Figure 27) revealed that BE1 had the highest number of first detections (227) and total flight participations (391). This suggested BE1 was a highly effective detection point for eagle flights due to its high visibility range and strategic placement in an area close to a known nest site. Observation points BE2, BE3, and BE4 had significantly lower detection counts, indicating potential gaps in data accuracy. BE3, with moderate counts, had a medium visibility range, while BE2 and BE4's low counts were due to their location within dense forests and plantation areas, limiting detection capabilities and the ability to participate consistently in bidirectional interpretation and triangulation of eagle flights.

Observation point BE5 stood out with high detection and participation counts (180 and 305, respectively), attributable to its high visibility range and its proximity to a known nest. Observation points BE6 and BE7 showed varying success, with BE6 having moderate detections (67) and BE7 having high detections (191). BE7's high visibility range contributed to its effectiveness, whereas BE6's medium visibility range somewhat limited its detection capability. BE8 and BE9 had low to moderate detections, reflecting the medium to low visibility ranges of these points. This suggested potential inaccuracies in these areas due to the observer's limited capacity to consistently participate in bidirectional interpretation and triangulation. BE10, BE11, and BE12 had higher detections, with BE11 and BE12 particularly effective due to their medium visibility ranges, which facilitated reliable data collection.

In North Bashan (Figure 28), BN1 had high detections (175) and total flight participations (388), indicating its high effectiveness due to a high visibility range and strategic location. BN2 and BN3 showed varying results, with BN3 having higher detections due to its high visibility range, indicating better positioning for accurate data collection. BN4 had the lowest detections (92) due to its low visibility range, which likely limited the observer's ability to engage in bidirectional interpretation and triangulation, whereas BN5, with moderate detections, provided a moderate level of detection capability due to its medium visibility range. BN6 had high detections (153) and total flight participations (277), reflecting its high visibility range and strategic position, making it highly effective in data collection.

The comparison highlighted that observation points with higher visibility ranges and strategic placements consistently had higher detection and participation counts, indicating their effectiveness in capturing accurate eagle flight data. Points with high detection and participation rates were in areas with significant eagle activity and optimal visibility conditions, reinforcing the reliability of the data collected. Conversely, points with lower visibility ranges and detection counts suggested potential gaps in data accuracy due to their limited effectiveness in capturing eagle activity and the observer's reduced ability to consistently participate in bidirectional interpretation and triangulation of flights.

The spatial distribution of detection points showed a high concentration around certain observation points, indicating key activity hotspots for eagles. The accuracy gradient provided insights into the reliability of the data, with higher confidence in areas of higher accuracy. This assessment underscored the importance of visibility and strategic placement in ensuring data accuracy, highlighting that while some points provided highly reliable data, others may have potential gaps due to visibility constraints.

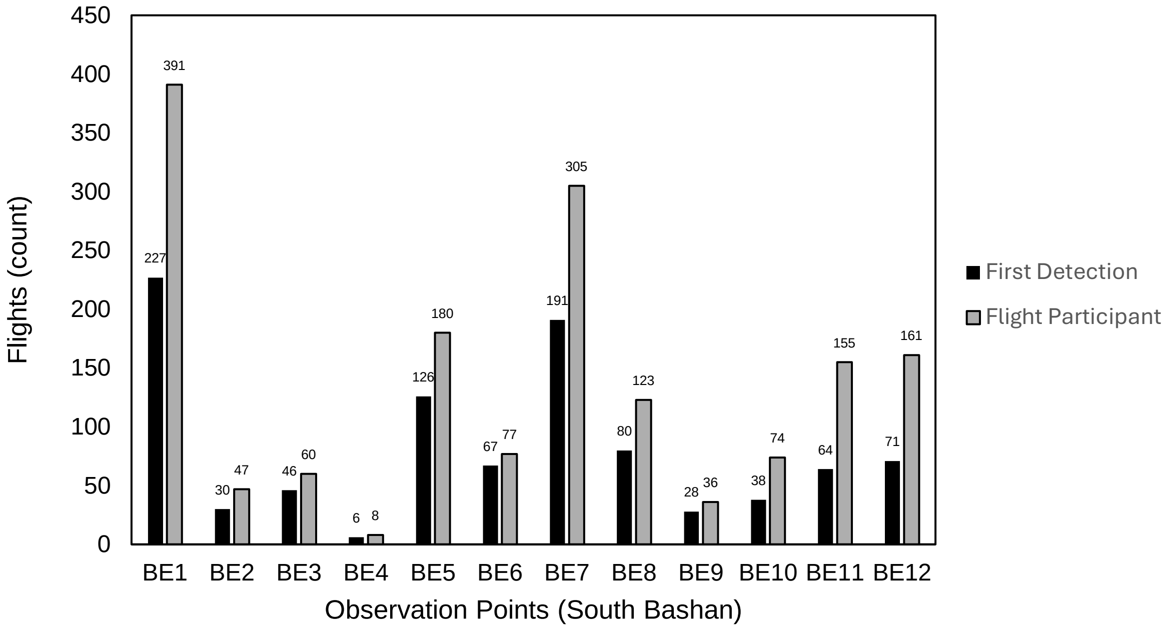

Figure 27. Count of eagle flights first detected by infield observers (black) and flights participated in as part of the observation team (grey) at each observation point in South Bashan.

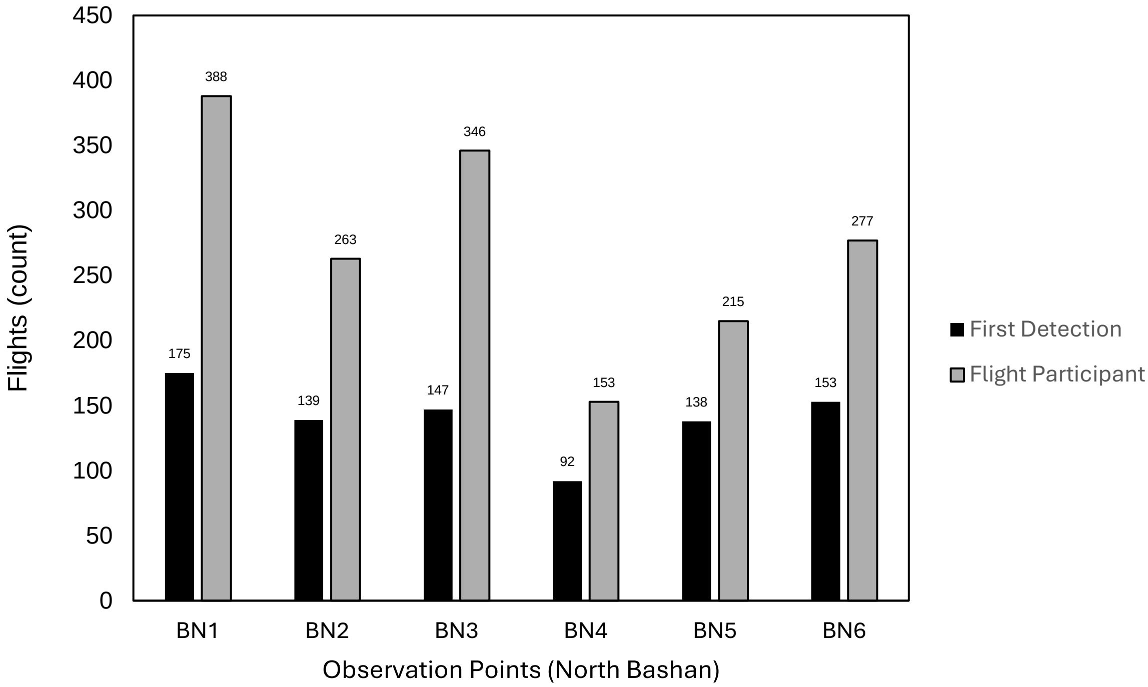

Figure 28. Count of eagle flights first detected by infield observers (black) and flights participated in as part of the observation team (grey) at each observation point in North Bashan.

3.5 Study Limitations

1. **Survey Timing:** The survey timing differed between South Bashan and North Bashan; however, the same survey effort was applied to both areas. At least two surveys were conducted over two summers, two autumns, two winters, and two springs for South Bashan, while the same survey effort was concentrated within one summer, one autumn, one winter, and one spring for North Bashan. This difference in timing may have led to less variation being captured at North Bashan due to the condensed survey period, which impacts the comparability of data within the study and complicates future post-construction surveys. Despite the shorter survey timeline at North Bashan, substantial evidence of eagle activity and behaviour was collected, ensuring consistent data collection across both areas.

2. **Observer Bias**: The varying visibility ranges and vegetation density at observation points introduced observer bias, affecting the accuracy and consistency of flight path recordings.

3. **Weather Conditions**: Adverse weather conditions, particularly during the display period, may have suppressed eagle flight activity, leading to potential underrepresentation in the data.

4. **Visibility Limitations**: Flights at higher altitudes (ARSA) and lower altitudes (BRSA) were more challenging to observe, possibly leading to underrepresentation in these flight zones.

5. **Human Disturbance**: Evidence of human hunting activity, particularly at North Bashan, could have influenced eagle behaviour and flight patterns during the survey period.

These limitations were acknowledged and addressed where possible to ensure the accuracy and reliability of the results, but they highlight areas for improvement in future studies and considerations for interpreting the data.

4 Conclusion

This report detailed the Eagle Utilisation Surveys conducted at the proposed Bashan Wind Farm site in Tasmania's Central Highlands, focusing on the Tasmanian WTE, while the WBSE was rarely observed. The data provided essential baseline insights into the flight activity, habitat use, and behaviour of the WTE, a species of conservation concern due to its endangered status. The surveys identified the WTE as the dominant species in the area, with a substantial number of flights recorded across both South and North Bashan study areas. In contrast, the WBSE was scarcely observed.

High-density flight areas were found primarily in the southeastern and northwestern regions of South Bashan, indicating the presence of at least three active WTE pairs and associated nests. If each pair successfully fledged a chick, this could account for a minimum of nine birds across the study site. Additionally, it is likely that the suitable landscape would also support immature non-territorial birds, underscoring the area's importance as a crucial habitat. Similarly, North Bashan showed high-density flight areas in the central and southeastern regions, suggesting optimum habitat with high prey availability.

A substantial proportion of eagle flights occurred within the RSA range of the proposed turbines, indicating a potential risk of mortality. The prominence of WTE activity underscored the ecological importance of the Bashan Wind Farm site for this species. The overlap between the RSA range and eagle flight heights raised concerns about potential turbine-related mortalities, which could have serious implications for the local WTE population without appropriate mitigation strategies.

The inherent limitations of the study such as observer bias, weather conditions, and visibility constraints may have influenced data accuracy. Furthermore, the limited observations of the WBSE restricted the generalisability of these findings to this species. These factors should be considered when interpreting the results and planning future studies.

Ongoing monitoring of the WTE population, particularly in high-density flight areas and potential nesting sites, was recommended. Long-term studies would be valuable for assessing the impact of wind farm operations on eagle mortality and population dynamics. These efforts would ensure that the aim of this study—to provide essential insights into eagle flight activity, utilisation areas, and behaviour—is fully realised, serving as a critical reference for evaluating any potential impact of wind energy development on these threatened species.

5 References

Alerstam, T. and Hedenström, A., 1998. The development of bird migration theory. Journal of Avian Biology, pp.343-369.

Bekessy, S.A., Fox, J.C., Brown, B., Regan, T. and Mooney, N., 2004. Tasmanian wedge-tailed eagle (Aquila audax fleayi). Linking landscape ecology and management to population viability analysis, p.215.

Bekessy, S.A., Wintle, B.A., Gordon, A., Fox, J.C., Chisholm, R., Brown, B., Regan, T., Mooney, N., Read, S. and Burgman, M.A., 2009. Modelling human impacts on the Tasmanian wedge-tailed eagle (Aquila audax fleayi). Biological Conservation, 142(11), pp.2438-2448.

Bembrick, J., 2021. Cattle Hill Wind Farm EPBC 2009/4839, 13 August 2021. Goldwind Australia. Available at: https://cattlehillwindfarm.com/wp-content/uploads/2021/11/CHWF-EPBC-Compliance-Report-2021-FINAL-10Nov2021-incl-Appendices.pdf (Accessed: 30 January 2023).

Brown, B. et al., 2006. Threatened Tasmanian Eagles Recovery Plan: 2006-2010. Report by the Threatened Species Section. Available at: https://www.dcceew.gov.au/sites/default/files/documents/tasmanian-wedge-tailed.pdf (Accessed: 2023).

Debus, S., 2019. Birds of prey of Australia: a field guide. CSIRO publishing.

Debus, S.J., Hatfield, T.S., Ley, A.J. and Rose, A.B., 2007. Breeding biology and diet of the Wedge-tailed Eagle Aquila audax in the New England region of New South Wales. Australian Field Ornithology, 24(3), pp.93-120.

Dennis, T.E., McIntosh, R.R. and Shaughnessy, P.D., 2011. Effects of human disturbance on productivity of White-bellied Sea-Eagles (Haliaeetus leucogaster). Emu, 111(2), pp.179–185. doi:10.1071/MU10044.

Kozakiewicz, C.P., Carver, S., Austin, J.J., Shephard, J.M. and Burridge, C.P., 2017. Intrinsic factors drive spatial genetic variation in a highly vagile species, the wedge-tailed eagle Aquila audax, in Tasmania. Journal of Avian Biology, 48, pp.1025-1034.

McClure, C.J., Rolek, B.W., Braham, M.A., Miller, T.A., Duerr, A.E., Mccabe, J.D., Dunn, L. and Katzner, T.E., 2021. Eagles enter rotor swept zones of wind turbines at rates that vary per turbine. Ecology and Evolution, 11, pp.1-14.

Mooney, N.J. and Taylor, R.J., 1996. Value of nest site protection in ameliorating the effects of forestry operations on Wedge-tailed Eagles in Tasmania. In: Bird, D.M., Varland, D.E. and Negro, J.J. (eds.) Raptors in human landscapes: adaptations to built and cultivated environments. London: Academic Press, pp.275–282.

Olsen, J., 2014. Australian high country raptors. CSIRO Publishing.

Olsen, P., 2005. Wedge-tailed eagle. Molecular Phylogenetics and Evolution, 37, pp.327-346.

Pay, J.M., Patterson, T.A., Proft, K.M., Cameron, E.Z., Hawkins, C.E., Koch, A.J., Wiersma, J.M. and Katzner, T.E., 2022. Considering behavioral state when predicting habitat use: Behavior-specific spatial models for the endangered Tasmanian wedge-tailed eagle. Biological Conservation, 274, p.109743. doi:10.1016/j.biocon.2022.109743.

Settele, J. (ed) 1996. Species survival in fragmented landscapes, 1st ed. 1996. Kluwer Academic Publishers, Dordrecht, Netherlands. doi:10.1007/978-94-009-0343-2.

Smales, I. and Muir, S., 2005. Modelled cumulative impacts on the Tasmanian Wedge-tailed Eagle of wind farms across the species' range. Report by Biosis Research Pty. Ltd. For Australian Department of Environment and Heritage. Project, (4857).

Thaxter, C.B., Buchanan, G.M., Carr, J., Butchart, S.H.M., Newbold, T., Green, R.E., Tobias, J.A., Foden, W.B., O'Brien, S. and Pearce-Higgins, J.W., 2017. Bird and bat species' global vulnerability to collision mortality at wind farms revealed through a trait-based assessment. Proceedings of the Royal Society B: Biological Sciences, 284(1862), p.20170829. doi:10.1098/rspb.2017.0829.

Thurstans, S., 2009. Modelling the nesting habitat of the White-bellied Sea-Eagle Haliaeetus leucogaster in Tasmania. Corella, 33(3), pp.51-65.

Warrick, D.R., Bundle, M.W. and Dial, K.P., 2002. Bird manoeuvring flight: blurred bodies, clear heads. Integrative and Comparative Biology, 42(1), pp.141-148.

Appendix A

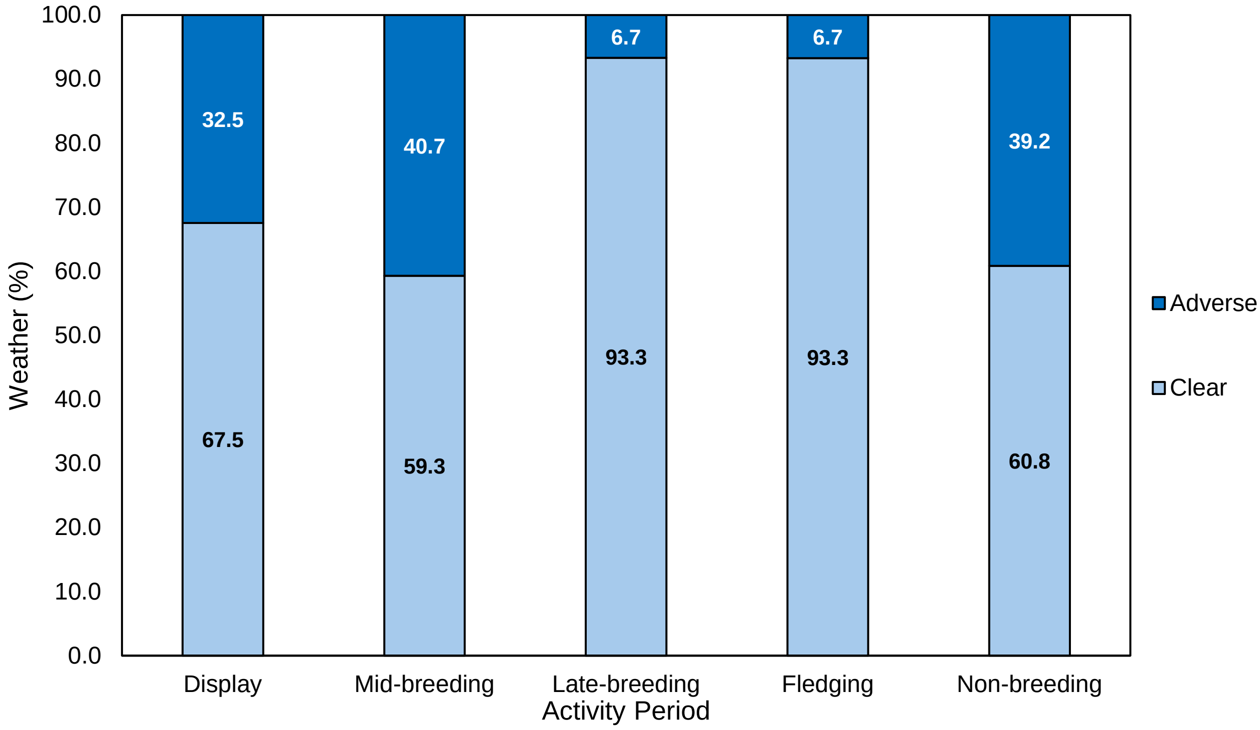

Figure A1. The proportion (%) of clear versus adverse weather within each activity period at South Bashan.

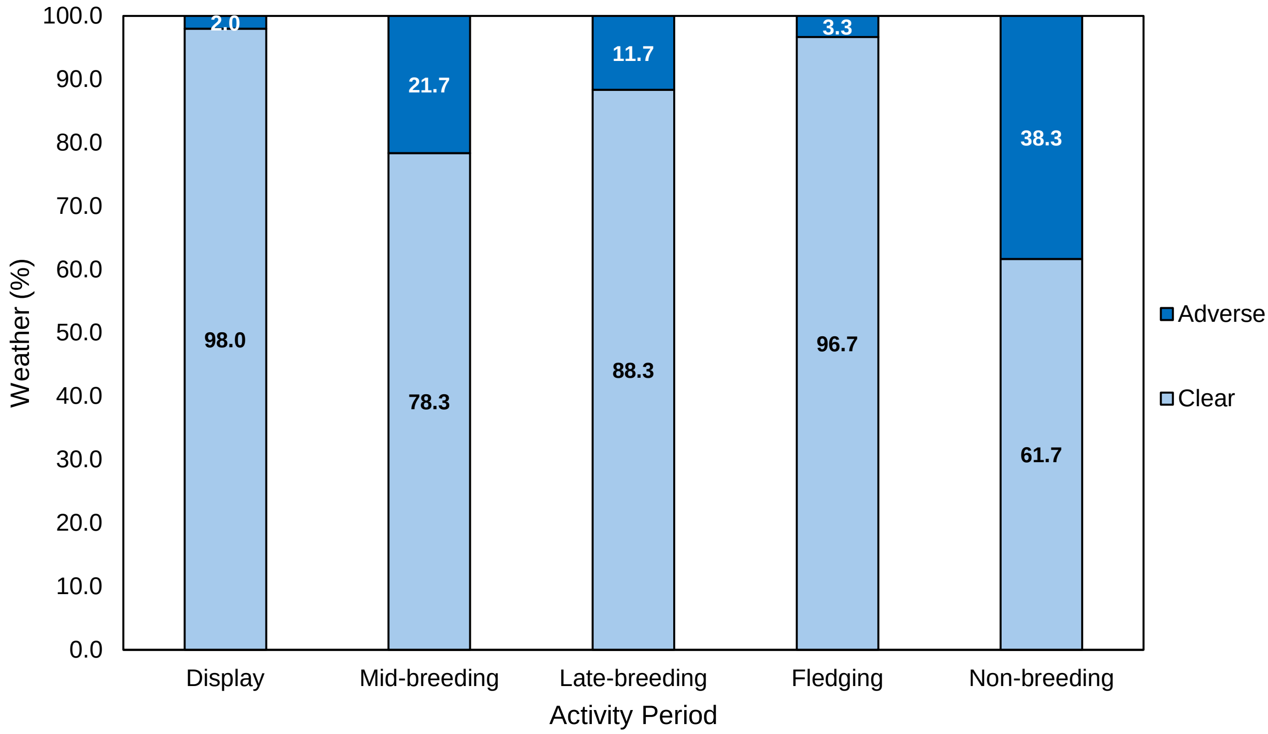

Figure A2. The proportion (%) of clear versus adverse weather within each activity period at North Bashan.