12 month Long-Term Bat Monitoring Study - Data Reanalysis

For the Witberg Wind Energy Facility, near Matjiesfontein, Western Cape

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For:	Data reanalysis of a 12 Month pre-construction bat monitoring study

Independence:

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Applicable Legislation:

Legislation dealing with biodiversity applies to bats and includes the following:

NATIONAL ENVIRONMENTAL MANAGEMENT: BIODIVERSITY ACT, 2004 (ACT 10 OF 2004; Especially sections 2, 56 & 97)

The act calls for the management and conservation of all biological diversity within South Africa. Bats constitute an important component of South African biodiversity and therefore all species receive additional attention to those listed as Threatened or Protected.

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1 OBJECTIVES AND TERMS OF REFERENCE

A 12 month pre-construction bat monitoring study was undertaken over May 2011 to May 2012 by Natural Scientific Services CC. The objective of this study was to reanalyse the raw data of the study and provide further specialist input on the results.

The following aims are derived from the objective:

- Study bat species assemblage and abundance on the site.
- Study temporal distribution of bat activity across the night as well as the four seasons of the year in order to detect peaks and troughs in activity.
- Determine whether weather variables (wind speed and temperature) influence bat activity.
- Determine the weather range in which bats are mostly active.
- Identify which turbines need to have special attention with regards to bat monitoring during the operational phase and identify if any turbines occur in sensitive areas and need to be shifted into less sensitive areas or removed from the layout.
- Detail the types of mitigation measures that are possible if bat mortality rates are found to be unacceptable, including the potential times/ circumstances which may result in high mortality rates.

2 INTRODUCTION

2.1 Short Project Introduction

The Witberg wind energy facility is located near to the town of Matjiesfontein in the Western Cape Province of South Africa. A 27 turbine layout for the wind farm has received environmental authorisation (Figure 2), and an amended 22 turbine layout has been proposed (Figure 3). Both turbine layouts will be assessed in this report.

The data collection and field work aspects of this study were carried out by Natural Scientific Services CC over the time period of May 2011 to May 2012. Six bat monitoring stations were used to monitor bat activity levels (described in Section 3. Methodology). During the study time frame the South African Good Practice Guidelines for Surveying Bats in Wind Farm Developments 2nd edition (April 2011) was in use, and undergoing refinement to the 3rd edition (Sowler and Stoffberg, 2012). The study was conducted in accordance with the guidelines that were current at that time. The study design differs from the current 3rd edition guidelines (Sowler and Stoffberg, 2014) in that monitoring was carried out for only 15-25% of the likely bat activity periods over the year. This limitation is factored in to the reanalysis of the study data.

2.2 The Bats of South Africa

Bats form part of the Order Chiroptera and are the second largest group of mammals after rodents. They are the only mammals to have developed true powered flight and have undergone various skeletal changes to accommodate this (Neuweiler 2000). The forelimbs are elongated, whereas the hind limbs are compact and light, thereby reducing the total body weight. This unique wing profile allows for the manipulation of wing camber and shape, exploiting functions such as agility and manoeuvrability. This adaptation surpasses the static design of the bird wings in function and enables bats to utilize a wide variety of food sources, including, but not limited to, a large diversity of insects (Neuweiler 2000). Species based facial features may differ considerably as a result of differing life styles, particularly in relation to varying feeding and echolocation navigation strategies. Most South African bats are insectivorous and are capable of consuming vast quantities of insects on a nightly basis (Taylor 2000, Tuttle and Hensley 2001) however, they have also been found to feed on amphibians, fruit, nectar and other invertebrates. As a result, insectivorous bats are the predominant predators of nocturnal flying insects in South Africa and contribute greatly to the suppression of these numbers. Their prey also includes agricultural pests, such as moths, and vectors for diseases, such as mosquitoes (Rautenbach 1982, Taylor 2000).

Urban development and agricultural practices have contributed to the deterioration of bat populations on a global scale. Public participation and funding of bat conservation are often hindered by negative public perceptions and unawareness of the ecological importance of bats. Some species choose to roost in domestic residences, causing a disturbance and as a result are regarded as a negative pest. Other species may occur in large communities in buildings, posing as a potential health hazard to residents in addition to their nuisance value. Unfortunately, the negative association with bats obscures their importance as an essential component of ecological systems and their value as natural pest control agents, which actually serves as an advantage to humans.

Many bat species roost in large communities and congregate in small areas. Therefore, any major disturbances within and around the roosting areas may adversely impact individuals of different communities, within the same population, concurrently (Hester and Grenier 2005). Additionally, birth rates of bats are much lower than those of most other small mammals. Female bats only give birth to one or two pups per annum. O'Shea *et al*. (2003) suggests that the reason for this is that bats may live for up to 30 years, thereby limiting the amount of pups born due to an increased life expectancy. Therefore, under natural circumstances, a population's numbers may accumulate over long periods of time. This is due to the longevity and the relatively low predation of bats when compared to other small mammals. Bat populations are therefore not able to adequately recover after mass mortalities and major roost disturbances.

Three factors need to be present for most South African bats to be prevalent in an area: availability of roosting space, food (insects/arthropods or fruit), and accessible open water sources. However, the dependence of a bat on each of these factors depends on the species, its behaviour and ecology. Nevertheless, bat activity, abundance and diversity are likely to be higher in areas supporting all three above mentioned factors.

The site was evaluated by comparing the amount of surface rock (possible roosting space), topography (influencing surface rock in most cases), vegetation (possible roosting spaces and foraging sites), climate (can influence insect numbers and availability of fruit), and presence of surface water (influences insects and acts as a source of drinking water) to identify bat species that may be impacted by wind turbines. These comparisons were done chiefly by studying the geographic literature of each site, available satellite imagery and observations during site visits. Species probability of occurrence based on the above mentioned factors were estimated for the site and the surrounding larger area (see Section 4.2).

General bat diversity, abundance and activity were determined by the use of a bat detector. A bat detector is a device capable of detecting and recording the ultrasonic echolocation calls of bats which may then be analysed with the use of computer software. A real time expansion type bat detector records bat echolocation in its true ultrasonic state which is then effectively slowed down 10 times during data analysis. Thus the bat calls become audible to the human ear, but still retains all of the harmonics and characteristics of the call from which bat species with characteristic echolocation calls can be identified. Although this type of bat detection equipment is advanced technology, it is not necessarily possible to identify all bat species by just their echolocation calls. Recordings may be affected by the weather conditions (i.e. humidity) and openness of the terrain (bats may adjust call frequencies). The range of detecting a bat is also dependent on the volume of the bat call. Nevertheless it is a very accurate method of recording bat activity.

2.3 Bats and Wind Turbines

Although most bats are highly capable of advanced navigation through the use of echolocation and excellent sight, they are still at risk of physical impact with the blades of wind turbines. The corpses of bats have been found in close proximity to wind turbines and, in a case study conducted by Johnson *et al*. (2003), were found to be directly related to collisions. The incident of bat fatalities for migrating species has been found to be directly related to turbine height, increasing exponentially with altitude, as this disrupts the migratory flight paths (Howe *et al*. 2002; Barclay *et al*. 2007). Although the number of fatalities of migrating species increased with turbine height, this correlation was not found for increased rotor sweep (Howe *et al*. 2002; Barclay *et al*. 2007). In the USA it was hypothesized that migrating bats may navigate without the use of echolocation, rather using vision as their main sense for long distance orientation (Johnson *et al*. 2003, Barclay *et al*. 2007). Bat mortalities due to turbines have been attributed to be caused by direct impact with the blades and by barotrauma (Baerwald *et al*. 2008). Barotrauma is a condition where low air pressure found around the moving blades of wind turbines, causes the lungs of a bat to collapse, resulting in fatal internal haemorrhaging (Kunz *et al*. 2007). Rollins *et al.* (2012) carried out a histopathological study to assess whether direct collision or barotrauma was the major cause of mortality. They found an increased incidence of fractures, external lacerations and features of traumatic injury (diaphragmatic hernia, subcutaneous hemorrhage, and bone marrow emboli) in bats killed at wind farms. 73% of bats had lesions consistent with traumatic injury whereas there was a 20% incidence of ruptured tympana, a sensitive marker of barotrauma in humans. Thus the data of this study strongly suggests that traumatic injury from direct collision with turbine blades was the major cause of bat mortality at wind farms and barotrauma is a minor etiology.

Additionally, it has been hypothesized that barotrauma causes mortality only if the bat is within a very short distance of the turbine blade tip such that collision with the blades is a much more likely cause of death.

A study conducted by Arnett (2005) recorded a total of 398 and 262 bat fatalities in two surveys at the Mountaineer Wind Energy Centre in Tucker County, West Virginia and at the Meyersdale Wind Energy Centre in Somerset County, Pennsylvania, respectively. These surveys took place during a 6 week study period from 31 July 2004 to 13 September 2004. In some studies, such as that taken in Kewaunee County (Howe *et al.* 2002), bat fatalities were found exceed bird fatalities by up to three-fold.

Although bats are predominately found roosting and foraging in areas near trees, rocky outcrops, human dwellings and water, in conditions where valleys are foggy, warmer air is drawn to hilltops through thermal inversion which may result in increased concentrations of insects and consequently bats at hilltops, where wind turbines are often placed (Kunz *et al*. 2007). Some studies (Horn *et al*. 2008) suggest that bats may be attracted to the large turbine structure as roosting spaces or that swarms of insects may get trapped in low pressure air pockets around the turbine, also encouraging the presence of bats. The presence of lights on wind turbines have also been identified as possible causes for increased bat fatalities for non-cave roosting species. This is thought to be due to increased insect densities that are attracted to the lights and subsequently encourage foraging activity of bats (Johnson *et al*. 2003). Clearings around wind turbines, in previously forested areas, may also improve conditions for insects, thereby attracting bats to the area and the swishing sound of the turbine blades has been proposed as possible sources for disorienting bats (Kunz *et al*. 2007). Electromagnetic fields generated by the turbine may also affect bats which are sensitive to magnetic fields (Kunz *et al*. 2007). It could also be hypothesized, from personal observations that the echolocation capabilities of bats are designed to locate smaller insect prey or avoid stationary objects, and may not be primarily focused on the detection of unnatural objects moving sideways across the flight path.

Whatever the reason for bat fatalities in relation to wind turbines, it is clear that this is a grave ecological problem which requires attention. During a study by Arnett *et al*. (2009), 10 turbines monitored over a period of 3 months showed 124 bat fatalities in South-central Pennsylvania (America), which can cumulatively have a catastrophic long term effect on bat populations if this rate of fatality continues. Most bat species only reproduce once a year, bearing one young per female, therefore their numbers are slow to recover from mass mortalities. It is very difficult to assess the true number of bat deaths in relation to wind turbines, due to carcasses being removed from sites through predation, the rate of which differs from site to site as a result of habitat type, species of predator and their numbers (Howe *et al*. 2002; Johnson *et al*. 2003). Mitigation measures are being researched and experimented with globally, but are still only effective on a small scale. An exception is the implementation of curtailment processes, where the turbine cut-in speed is raised to a higher wind speed. This relies on the principle that the prey of bats will not be found in areas of strong winds and more energy is required for the bats to fly under these conditions. It is thought, that by the implementation of such a measure, that bats in the area are not likely to experience as great an impact as when the turbine blades move slowly in low wind speeds. However, this measure is currently not effective enough to translate the impact of wind turbines on bats to a category of low concern.

3 METHODOLOGY

Natural Scientific Services CC conducted all field work aspects of this study, thus the below description of methodology and bat monitoring equipment was taken directly from their report, Pre-construction Bat Monitoring for the Witberg Wind Energy Facility: Baseline Only (2013).

The bat monitoring at Witberg has covered more than the minimum required 15 – 25% of the total bat activity season, as was required by Sowler & Stoffberg (2011). The following main monitoring periods were applicable:

- May – June 2011
- September – October 2011
- December 2011 – May 2012

The following monitoring techniques, in line with the requirements of the Best Practise Guidelines, were employed during the monitoring:

3.1 Activity Surveys - Static monitoring at ground level and height

Six static monitoring sites were set up in early May 2011, as per the Bat Monitoring Station localities W1– W6 (Figure 1). The bat sound recording equipment used for the static monitoring was the Wildlife Acoustics Song Meter SM2BAT Ultrasonic Recorder. This system was selected due to its effective recording, lower costs and weatherproof casings. Two different heights were monitored for bat activity. Monitoring at 10m above ground took place on temporary masts at stations W1, W3 and W5 and meteorological (MET) masts W2, W4 and W6. MET masts (W2, W4 and W6) also allowed microphones to be deployed at 60m above ground. The detectors at these masts were equipped with a stereo recording option, with a two channel sample rate card. The two channels allowed for monitoring to take place at two different heights on the masts. The right channel ultrasonic microphone was erected at 60m and the left channel at 10m. The detectors were powered by a 12V 7 Amp/hour battery and solar panel.

At sites W1, W3 and W5, the mono 384 kHz SM2BAT option, including a one-channel 384 kHz 16 bit sample rate card was used. These detectors only had a left channel for a single ultrasonic microphone, but could record bats at higher frequencies. The left channel ultrasonic microphone connected to these detectors was erected at 10m on temporary steel masts. The 384 kHz detectors were powered by the same combination of a 12 Volt 7Amp/hour battery and solar panel. Strips of bristle brush and/ or Perspex spikes were inserted on the microphone connector to reduce the risk of birds perching and damaging the microphones.

Recording times for all detectors were based on the SD card and battery capacity. Unfortunately, the recharging of the battery fully for every night was a limited factor. Hence, the following time programme was applied: At sunset record for two hours, rest for 15 minutes, record for 45 minutes, rest for 15 min, record for 45min, etc. until two hours before sunrise, record for two hours, then sleep until sunset.

Table 1: GPS co-ordinates of the Witberg bat monitoring stations

Monitoring station	**GPS co-ordinate**
W1	33°16'55.30"S 20°29'50.15"E
W2	33°17'5.00"S 20°28'10.80"E
W3	33°17'24.65"S 20°27'0.70"E
W4	33°17'8.70"S 20°25'47.14"E
W5	33°17'24.63"S 20°23'59.24"E
W6	33°17'45.92"S 20°22'34.92"E

3.2 Activity Surveys - Manual surveys & Mist-netting

Mist-netting and driven transects were performed by Natural Scientific Services CC over the course of the study. However the raw data results of this methodology aspect was not provided for reanalysis and thus will not be presented and considered in this report.

3.3 Assumptions and Limitations to General Bat Monitoring Studies

- Distribution maps of South African bat species still require further refinement such that the bat species proposed to occur on the site (that were not detected) are assumed accurate. If a species has a distribution marginal to the site it was assumed to occur in the area. The literature based table of species probability of occurrence may include a higher number of bat species than actually present.
- The migratory paths of bats are largely unknown, thus limiting the ability to determine if the wind farm will have a large scale effect on migratory species.
- The satellite imagery partly used to develop the sensitivity map may be slightly imprecise due to land changes occurring since the imagery was taken.
- Species identification with the use of bat detection and echolocation is less accurate when compared to morphological identification, nevertheless it is a very certain and accurate indication of bat activity and their presence with no harmful effects on bats being surveyed.
- It is not possible to determine actual individual bat numbers from acoustic bat activity data, whether gathered with transects or the passive monitoring systems. However, bat passes per night are internationally used and recognized as a comparative unit for indicating levels of bat activity in an area.

3.3.1 Sampling Limitations Encountered by NSS during Field Work

- High winds buffeted the microphones of the monitoring stations causing memory cards to fill up more quickly than expected, restricting the amount of bat data that was recorded. Also, bat calls were most likely not recorded during very high wind periods. It was reasoned that this was the cause for the lack of any bat data for W4 during a large portion of the summer and W6 during February 2012.
- Two SD memory cards were corrupted, resulting in a loss of data. Further detail as to which systems suffered data loss and the relevant time frames was not provided.
- Birds were pecking at microphones of the monitoring stations and thus destroying the microphones. Further detail as to which systems suffered data loss and the relevant time frames was not provided.

- During the September – October 2011 monitoring period the weatherproof casing of W4 was compromised. Hence, unfortunately, the detector was damaged by rain and had to be replaced. Accordingly, no data was recorded at this station during this time.
- A problem with the microphone at W3 caused all data at this station to be over-ridden with noise, hence, no data for this station for September – October 2011.
- Natural Scientific Services was experimenting with the correct setting to be applied to the SM2BATs for optimal bat sampling as they acquired a lot of noise interference when sampling.

4 RESULTS AND DISCUSSION

4.1 Land Use, Vegetation, Climate and Topography

Seven vegetation units are in close proximity to the Witberg site boundary (Figures 4 and 5) namely, Koedoesberge-Moordenaars Karoo, Matjiesfontein Quartzite Fynbos, Matjiesfontein Shale Fynbos, Matjiesfontein Shale Renosterveld, Tanqua Karoo, Tanqua Wash Riviere and Western Little Karoo. Turbines (of both 27 and 22 turbine layouts) fall only within the Matjiesfontein Shlae Fynbos and Matjiesfontein Quartzite Fynbos vegetation units.

The Koedoesberge-Moordenaars Karoo vegetation unit consists of a slightly undulating to hilly terrain covered by low succulent scrub and dotted by scattered tall shrubs and patches of 'white' grass on the plains. Geology is mostly mudstone with shale and sandstone of the Adelaide Subgroup, Permian Waterford Formation and other Ecca Group Formations. This type of geology results in the presence of shallow, skeletal soil. Rainfall is bimodal, with one peak occurring in July/August and a further peak over March and April. Mean annual precipitation is 200mm and mean annual temperature being 16°C.

Koedoesberge-Moordenaars Karoo is of the least threatened conservation category with a small portion transformed and no serious alien vegetation invasions recorded (Mucina and Rutherford, 2006).

The Matjiesfontein Quartzite Fynbos vegetation unit consists of ridges and low mountains in the Western Little Karoo. The landscape consists of low flat mountains and parallel ridges running in east-west direction. The vegetation is a medium dense, medium tall shrubland, which is structurally classified as asteraceous and proteoid fynbos. The geology is sandy and skeletal soils derived from Witteberg Group quartzites. The unit experiences a mean annual precipitation of 320mm with peaks over May to August. The vegetation unit conservation status is Least Threatened, with about 15% of the unit that has been transformed (Mucina and Rutherford, 2006).

The Matjiesfontein Shale Fynbos vegetation unit is a very fragmented unit that falls on higher peaks of mountain ranges in the extreme Western Little Karoo. It is confined to summits and slopes. The unit consists of moderately tall and dense proteoid shrubland. The soil is acidic and moist clay-loam, red-yellow apedal or skeletal soils. The unit gets a mean annual precipitation amount of 320mm peaking over May – August. The unit has a conservation status of Least Threatened with 30% of the unit under statutory conservation. 3% of the unit has been transformed for cultivation purposes (Mucina and Rutherford, 2006).

The Matjiesfontein Shale Renosterveld vegetation unit surrounds the higher elevation ridges of Matjiesfontein Quartzite Fynbos and Matjiesfontein Shale Fynbos. The landscape features low mountains, parallel hills and mid-altitude plateaus. The vegetation is a low, open to medium dense, leptophyllous shrubland with a medium dense matrix of short shrubs. Soil is clays and loams derived from the Witteberg and Bokkeveld Group shales. The unit acquires a mean annual precipitation of 300mm. It is of the Least Threatened conservation status with 7% conserved and 9% transformed (Mucina and Rutherford, 2006).

The Tanqua Karoo vegetation unit features slightly undulating intramountain basin sheltered by steep slopes of mountain ranges. The plain is interrupted by solitary dolerite butts and elevated ridges. The plains are sparsely vegetated and barren over dry years. The slopes of the koppies and adjacent mountain piedmonts have well-developed medium-tall succulents. The unit has a winter rainfall regime with peaks between May and August. The mean annual precipitation varies from 72mm to 112mm. It is of Least Threatened conservation category with 10% statutorily conserved and 4% privately conserved (Mucina and Rutherford, 2006).

Tanqua Wash Riviere vegetation occurs in the Western and, to a lesser extent, Northern Capes and consists of Alluvia of the Tankwa and Doring rivers. The deeply incised valleys of intermittent rivers support various succulent shrubs alternating with *Acacia* gallery thickets. This vegetation unit occurs upon broad quaternary alluvial floors and drainage lines made up of sediments eroded from the Karoo Supergroup. The area receives a low overall MAP of 162mm which falls mainly in autumn-winter and overall mean annual temperature is >17^{o}C. The unit's conservation status is least threatened with about 3% already transformed for cultivation and dam-building. About 13% is statutorily conserved in the Tankwa National Park and some private reserves (Mucina and Rutherford, 2006).

The Western Little Karoo vegetation unit has flat or slightly undulating landscapes dominated by a mosaic of Karoo shrublands of low and medium height with both succulent and non-succulent shrubs. The geology consists of sandstone and shale, and supports deep, loamy-sandy soils. The precipitation follows a primary peak over May and August and secondary peaks in March and November. Mean annual precipitation is approximately 230mm. It is Least threatened conservation status with 3% transformed for cultivation and 4% statutorily conserved (Mucina and Rutherford, 2006).

Vegetation units and geology are of great importance as these may serve as suitable sites for the roosting of bats and support of their foraging habits (Monadjem *et al.* 2010). Houses and buildings may also serve as suitable roosting spaces (Taylor 2000; Monadjem *et al.* 2010). The importance of the vegetation units and associated geomorphology serving as potential roosting and foraging sites have been described in Table 2.

Table 2: Potential of the vegetation to serve as suitable roosting and foraging spaces for bats

Vegetation Unit	Foraging Potential	Roosting Potential	Comments
Koedoesberge-Moordenaars Karoo	Moderate	Moderate	Hilly terrain provides useful roosting crevices. Vegetation present may be used for foraging purposes by both open air foragers and clutter/clutter-edge foragers.
Matjiesfontein Quartzite Fynbos	Moderate	Moderate	Ridges and mountainous area provides roosting space, while the medium-tall shrubland provides foraging areas for open air and clutter foragers.
Matjiesfontein Shale Fynbos	Low	Moderate	The unit is confined to summits and slopes and thus should experience more extreme weather conditions and less optimal foraging and roosting opportunities.
Matjiesfontein Shale Renosterveld	Moderate-High	Moderate-High	The variety in landscape features and vegetation types available in this vegetation unit opens it up to use by several bat species.
Tanqua Wash Riviere	Moderate-High	Low-Moderate	The *Acacia* thickets may provide roosting space for crevice-roosters. The deep valleys and associated vegetation is likely useful foraging habitat for clutter/clutter-edge foragers.
Western Little Karoo	Moderate	Low	The flat landscape limits roosting potential of the unit, while the vegetation type in combination with landscape provides foraging habitat for open and clutter-edge foraging bats.

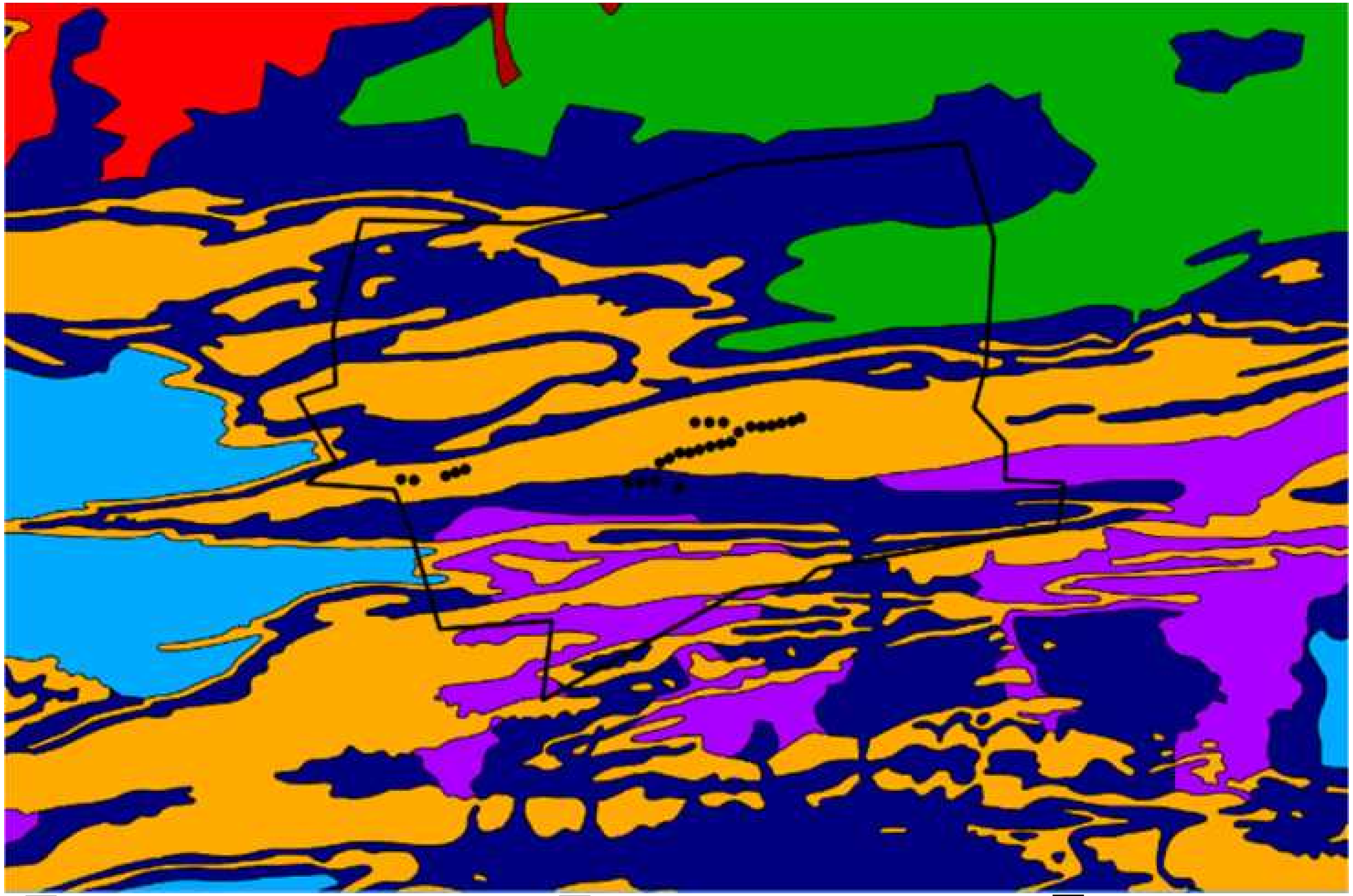
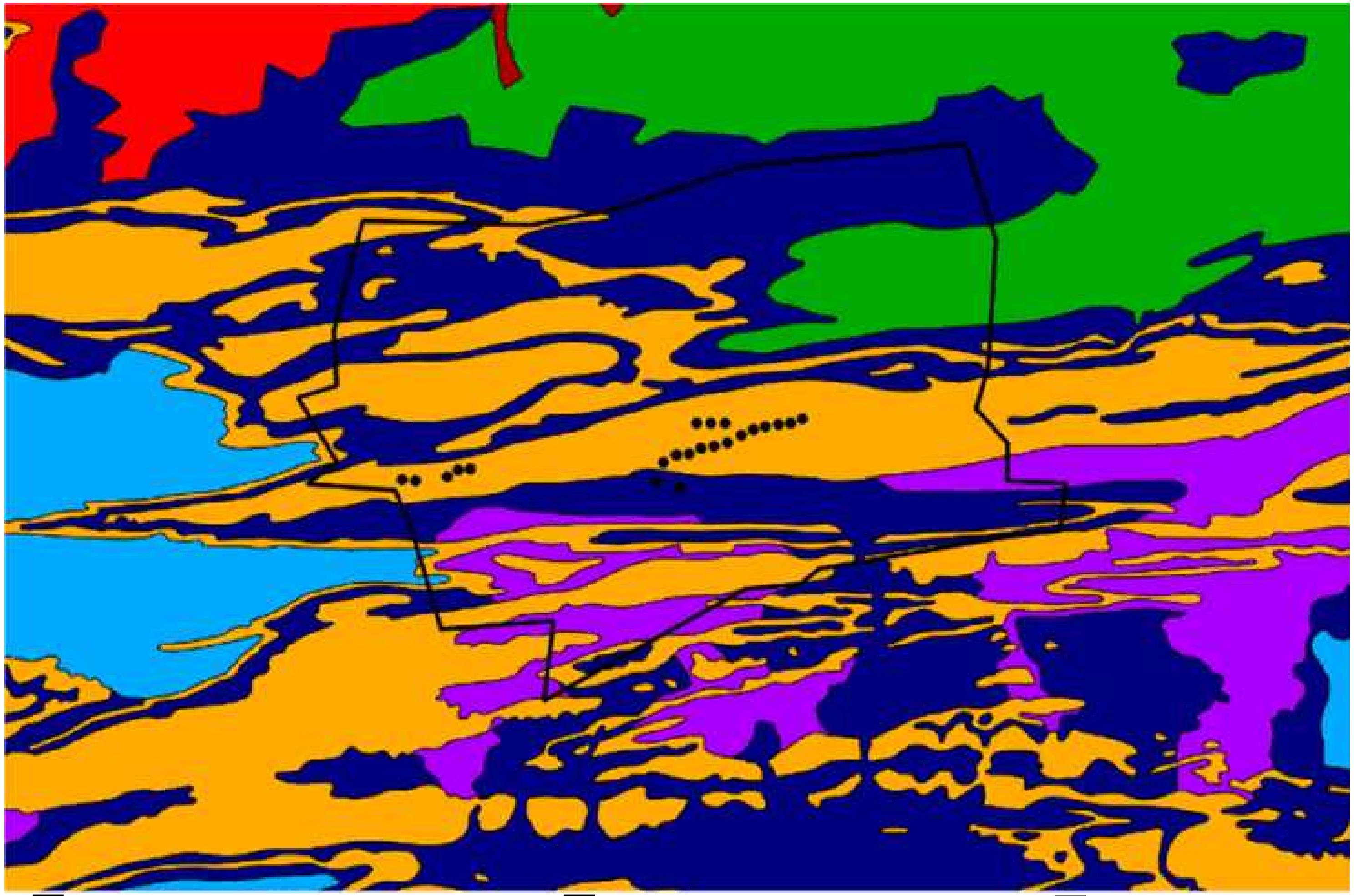


Figure 4: Vegetation units present on the site (Mucina and Rutherford 2006), with the 27 turbine layout.



■	Koedoesberge-Moordenaars Karoo	■	Matjiesfontein Quartzite Fynbos	■	Matjiesfontein Shale Fynbos		
■	Matjiesfontein Shale Renosterveld	■	Tanqua karoo	■	Tanqua Wash Riviere	■	Western Little Karoo
●	22 Turbine Layout						

Figure 5: Vegetation units present on the site (Mucina and Rutherford 2006), with the 22 turbine layout.

4.2 Literature Based Species Probability of Occurrence

"Probability of Occurrence" is assigned based on consideration of the presence of roosting sites and foraging habitats on the site, compared to literature described preferences. The probability of occurrence is described by a percentage indicative of the expected numbers of individuals present on site and the frequency at which the site will be visited by the species (in other words the likelihood of encountering the bat species).

The column of "Likely risk of impact" describes the likelihood of risk of fatality from direct collision or barotrauma with wind turbine blades for each bat species. The risk was assigned by Sowler and Stoffberg (2014) based on species distributions, altitudes at which they fly and distances they traverse; and assumes a 100% probability of occurrence. The ecology of most applicable bat species recorded in the vicinity of the site is discussed below.

Table 3: Table of species that may be roosting or foraging on the study area, the possible site specific roosts, and their probability of occurrence based on literature (Monadjem *et al.* 2010).

Species	Common name	Probability of occurrence (%)	Conservation status	Possible roosting habitat on site	Possible foraging habitat utilised on site	Likelihood of risk of fatality (Sowler & Stoffberg 2014)
Eptesicus hottentotus	Long-tailed serotine	80 - 90	Least Concern	It is a crevice dweller roosting in rock crevices, expansion joints in bridges and road culverts	It seems to prefer woodland habitats, and has been caught in granitic hills and near rocky outcrops	Medium
Miniopterus natalensis	Natal long-fingered bat	Confirmed	Near Threatened	It is cave or hollow dependent and hence the availability of suitable roosting sites is a critical factor in determining its presence	Forages around the edge of clutters of vegetation	Medium - High
Myotis tricolor	Temmink's myotis	50 - 60	Least Concern	Roosts gregariously in caves	It is restricted to areas with suitable caves, which may explain its absence from flat and featureless terrain; it has been found in a culvert in the Eastern Cape.	Medium - High
Neoromicia capensis	Cape serotine	Confirmed	Least Concern	Roosts under the bark of trees, at the base of aloe leaves, and under the roofs of houses	It appears to tolerate a wide range of environmental conditions from arid semi-desert areas to montane grasslands, forests, and savannas	Medium - High
Nycteris thebaica	Egyptian slit-faced bat	20 - 30	Least Concern	Roosts in caves, aardvark burrows, culverts under roads and the trunks of large trees	It appears to occur throughout the savanna and karoo biomes, but avoids open grasslands. May occur in the thickets.	Low
Rhinolophus capensis	Cape horseshoe bat	40 - 50	Near Threatened	Roosts in caves and mine adits	Forages predominantly in the canopy of trees	Low
Rhinolophus clivosus	Geoffroy's horseshoe bat	Confirmed	Least Concern	Roosts in caves and mine adits	It is associated with a variety of habitats including arid savanna, woodland and riparian forest. Thickets.	Low
Tadarida aegyptiaca	Egyptian free-tailed bat	Confirmed	Least Concern	Roost during the day in caves, rock crevices, under exfoliating rocks, in hollow trees, and behind the bark of dead trees. The species has also taken to roosting in buildings, in particular roofs of houses	It forages over a wide range of habitats; its preferences of foraging habitat seem independent of vegetation. It seems to forage in all types of natural and urbanised habitats	High
Taphozous mauritianus	Mauritian tomb bat	20 - 30	Least Concern	Roosts on rock faces, tree trunks, and walls, where it rests its belly on the surface of the roost with its head facing down	It is associated with savanna woodlands, preferring open habitats and avoiding closed forest interior	High

Rousettus aegyptiacus	Egyptian rousette bat	0 - 10	Least concern	Roosts gregariously in caves where distribution is dependent on the availability of caves in the area. Often found in moist well watered eastern parts of the country. This is thought to be due to the presence of fruiting trees.	Feed mostly on *ficus* spp. and fruiting trees. Orchards in valleys, highly unlikely on mountain top.	Medium - High
Cistugo leseuri	Lesueur's wing-gland bat	30 - 40	Vulnerable	Roosts in rock crevices, usually near water. It appears to be associated with broken terrain in high-altitude montane grasslands (> 1,500 m above sea level) with suitable rock crevices and water in the form of dams, rivers or marshes.	Forages around the edge of clutters of vegetation	Low
Cistugo seabrae	Angolan wing-gland bat	0 - 10	Near Threatened	It is restricted to the arid western parts of southern Africa, typically in desert and semi-desert conditions (< 100 mm rainfall per annum), where it has been netted in riverine vegetation along dry river beds.	Forages around the edge of clutters of vegetation	Low
Sauromys petrophilus	Roberts's flat-headed bat	Confirmed	Least Threatened	It roosts communally in small groups of up to 10 individuals. Their natural roost sites are in narrow cracks and under slabs of exfoliating rock. This species is closely associated with rocky habitats, usually in dry woodland, mountain fynbos or arid scrub.	It is an open-air forager. Its diet consists mainly of Diptera, Hemiptera and Coleoptera	Medium - High

4.3 Ecology of Bat Species That May be Largely Impacted by the Witberg WEF

There are three dominant bat species recorded on the site. These species are of importance based on their likelihood of being impacted by the proposed WEF, which is a combination of abundance and behaviour. The relevant species are discussed below.

Miniopterus natalensis

Miniopterus natalensis, also commonly referred to as the Natal long-fingered bat, occurs widely across the country but mostly within the southern and eastern regions and is listed as Near Threatened (Monadjem *et al*. 2010).

This bat is a cave-dependent species and identification of suitable roosting sites may be more important in determining its presence in an area than the presence of surrounding vegetation. It occurs in large numbers when roosting in caves with approximately 260 000 bats observed making seasonal use of the De Hoop Guano Cave in the Western Cape, South Africa. Culverts and mines have also been observed as roosting sites for either single bats or small colonies. Separate roosting sites are used for winter hibernation activities and summer maternity behaviour, with the winter hibernacula generally occurring at higher altitudes in more temperate areas and the summer hibernacula occurring at lower altitudes in warmer areas of the country (Monadjem *et al*. 2010).

Mating and fertilisation usually occur during March and April and is followed by a period of delayed implantation until July/August. Birth of a single pup usually occurs between October and December as the females congregate at maternity roosts (Monadjem *et al.* 2010 & Van Der Merwe 1979).

The Natal long-fingered bat undertakes short migratory journeys between hibernaculum and maternity roosts. Due to this migratory behaviour, they are considered to be at high risk of fatality from wind turbines if a wind farm is placed within a migratory path (Sowler and Stoffberg 2014). The mass movement of bats during migratory periods could result in mass casualties if wind turbines are positioned over a mass migratory route and such turbines are not effectively mitigated. Very little is known about the migratory behaviour and paths of *M. natalensis* in South Africa with migration distances exceeding 150 kilometres. If the site is located within a migratory path the bat detection systems will detect if there are high numbers of this species and whether it is a migratory event or high activity period. This will be examined over the course of the 12 month monitoring survey.

A study by Vincent *et al.* (2011) on the activity and foraging habitats of Miniopteridae found that the individual home ranges of lactating females were significantly larger than that of pregnant females. It was also found that the bats predominately made use of urban areas (54%) followed by open areas (19.8%), woodlands (15.5%) orchards and parks (9.1%) and water bodies (1.5%) when selecting habitats. Foraging areas were also investigated with the majority again occurring in urban areas (46%). However a lot of foraging also occurred in woodland areas (22%), crop and vineyard areas (8%), pastures, meadows and scrubland (4%) and water bodies (4%).

Sowler and Stoffberg (2014) advise that *M. natalensis* faces a medium to high risk of fatality due to wind turbines. This evaluation was based on broad ecological features and excluded migratory information.

Neoromicia capensis

Neoromicia capensis is commonly called the Cape serotine and has a conservation status of Least Concern as it is found in high numbers and is widespread over much of Sub-Saharan Africa.

High mortality rates of this species due to wind turbines would be a cause of concern as *N. capensis* is abundant and widespread and as such has a more significant role to play within the local ecosystem than the rarer bat species. They do not undertake migrations and thus are considered residents of the site.

This species roosts individually or in small groups of two to three bats in a variety of shelters, such as under the bark of trees, at the base of aloe leaves, and under the roofs of houses. They will use most man-made structures as day roosts which can be found throughout the site and surrounding areas (Monadjem *et al*. 2010).

They are tolerant of a wide range of environmental conditions as they survive and prosper within arid semi-desert areas to montane grasslands, forests, and savannas; indicating that they may occupy several habitat types across the site, and are amenable towards habitat changes. They are however clutter-edge foragers, meaning they prefer to hunt on the edge of vegetation clutter mostly, but can occasionally forage in open spaces. They are thought to have a Medium-High likelihood of risk of fatality due to wind turbines (Sowler and Stoffberg 2014).

Mating takes place from the end of March until the beginning of April. Spermatozoa are stored in the uterine horns of the female from April until August, when ovulation and fertilisation occurs. They give birth to twins during late October and November but single pups, triplets and quadruplets have also been recorded (van der Merwe 1994 & Lynch 1989).

Tadarida aegyptiaca

The Egyptian Free-tailed bat, *Tadarida aegyptiaca*, is a Least Concern species as it has a wide distribution and high abundance throughout South Africa. It occurs from the Western Cape of South Africa, north through to Namibia and southern Angola; and through Zimbabwe to central and northern Mozambique (Monadjem *et al*. 2010). This species is protected by national legislation in South Africa (ACR 2010).

They roost communally in small (dozens) to medium-sized (hundreds) groups in rock crevices, under exfoliating rocks, caves, hollow trees and behind the bark of dead trees. *T. aegyptiaca* has also adapted to roosting in buildings, in particular roofs of houses (Monadjem *et al*. 2010).

The Egyptian Free-tailed bat forages over a wide range of habitats, flying above the vegetation canopy. It appears that the vegetation has little influence on foraging behaviour as the species forages over desert, semi-arid scrub, savannah, grassland and agricultural lands. Its presence is strongly associated with permanent water bodies due to concentrated densities of insect prey (Monadjem *et al*. 2010).

The Egyptian Free-tailed bat is considered to have a High likelihood of risk of fatality by wind turbines (Sowler and Stoffberg 2014). Due to the high abundance and widespread distribution of this species, high mortality rates by wind turbines would be a cause of concern as these species have more significant ecological roles than the rarer bat species. The sensitivity maps are strongly informed by the areas that may be used by this species.

After a gestation of four months, a single pup is born, usually in November or December, when females give birth once a year. In males, spermatogenesis occurs from February to July and mating occurs in August (Bernard and Tsita 1995). Maternity colonies are apparently established by females in November (Herselman 1980).

Several North American studies indicate the impact of wind turbines to be highest on migratory bats, however there is evidence to the impact on resident species. Fatalities from turbines increase during natural changes in the behaviour of bats leading to increased activity in the vicinity of turbines. Increases in non-migrating bat mortalities around wind turbines in North America corresponded with when bats engage in mating activity (Cryan and Barclay 2009). This long term assessment will also be able to indicate seasonal peaks in species activity and bat presence.

4.4 Sensitivity Map

Figure 6 – 8 depict the sensitive areas of the site, based on features identified to be important for foraging and roosting of the species that are most probable to occur on site. Thus the sensitivity map is based on species ecology and habitat preferences. This map can be used as a pre-construction mitigation in terms of improving turbine placement with regards to bat preferred habitats on site.

Table 4: Description of parameters used in the construction of a sensitivity map

Last iteration	June 2015
High sensitivity buffer	200m radial buffer
Moderate sensitivity buffer	100m radial buffer
Features used to develop the sensitivity map	Manmade structures, such as houses, barns, sheds and road culverts, these structures provide easily accessible roosting sites.
	The presence of probable hollows/overhangs, rock faces and clumps of larger woody plants. These features provide natural roosting spaces and tend to attract insect prey.
	The different vegetation types and presence of riparian/water drainage habitat is used as indicators of probable foraging areas.
	Open water sources, be it man-made farm dams or natural streams and wetlands, are important sources of drinking water and provide habitat that host insect prey.
	Areas frequented by cattle and livestock often (e.g. congregation areas and kraal areas) were assigned a moderate sensitivity since large groups of animals tend to attract insects, but will only be in the area intermittently.

There are no South African guidelines for the consideration of specific buffer zone distances for bats in relation to wind farms. Guidance can be taken from other guidelines:

- Gauteng Department of Agriculture and Rural Development recommend a 500m buffer for natural bat caves and a 200m buffer on conservation important vegetation.
- The Eurobats Guidance (Rodrigues *et al.,* 2008) proposes a minimum buffer distance of 200m from forest edges.

Table 5: Description of sensitivity categories utilized in the sensitivity map

Sensitivity	Description
Moderate Sensitivity	Areas of foraging habitat or roosting sites considered to have significant roles for bat ecology. Turbines within or close to these areas must acquire priority (not excluding all other turbines) during pre/post-construction studies and mitigation measures, if any is needed.
High Sensitivity	Areas that are deemed critical for resident bat populations, capable of elevated levels of bat activity and support greater bat diversity than the rest of the site. These areas are 'no-go' areas and turbines must not be placed in these areas.

Areas not depicted as having a Moderate or High Bat Sensitivity are considered of a Low Bat Sensitivity category. Table 6 below lists the turbines located within sensitive areas according to the 27 and 22 turbine layouts. Turbines in high sensitivity areas and buffers are be removed or relocated. Turbines in moderate sensitivity areas and buffers must receive mitigation.

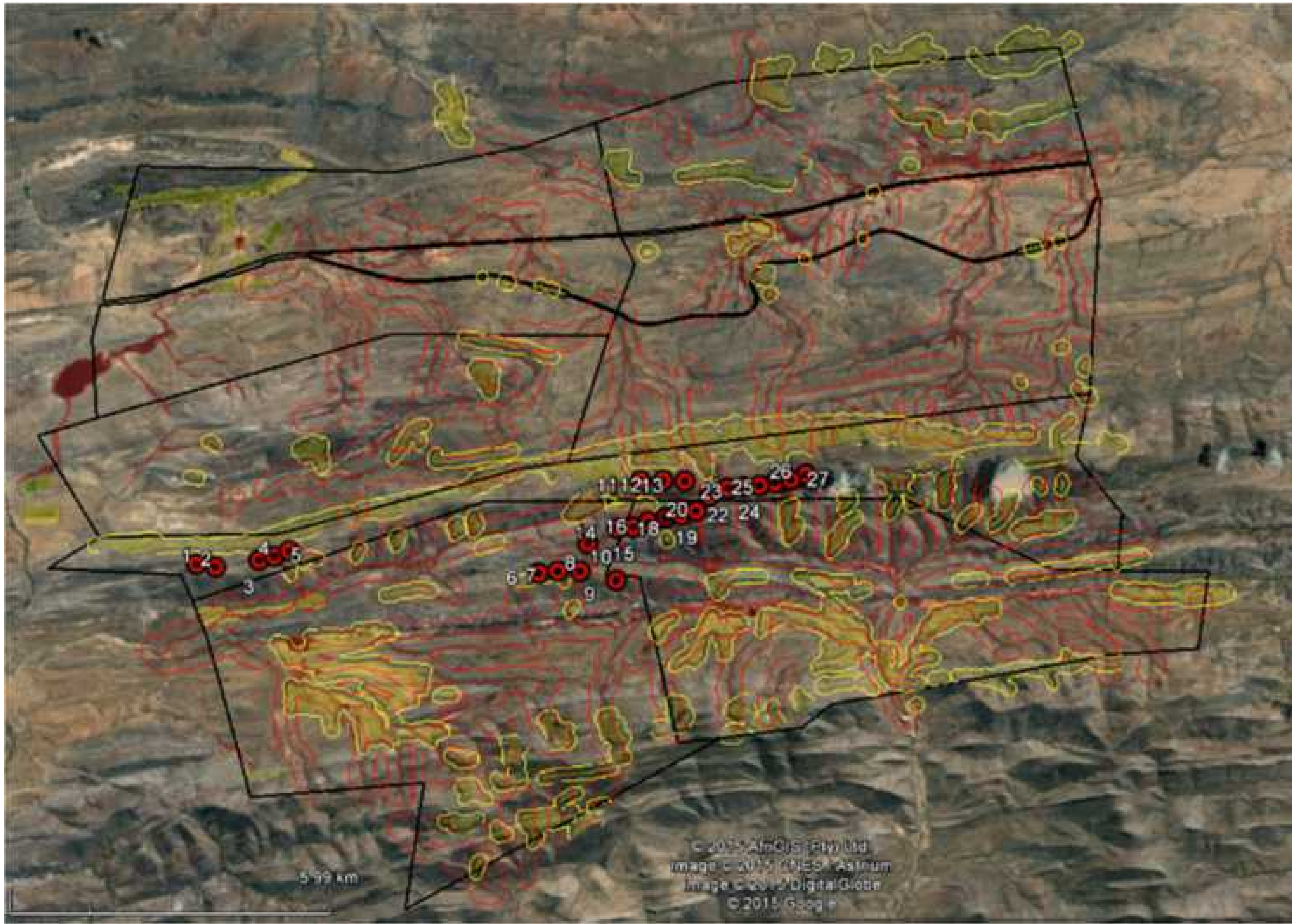
Table 6: Turbines located within bat sensitive areas

Bat sensitive area	**27 Turbine layout**	**22 Turbine layout**
High	None	None
High buffer/high buffer border	WTG10 **(border)** and 25 **(border)**	WTG10 **(border)**
Moderate	None	None
Moderate buffer	WTG06, 7 and 8	WTG08

A number of turbines are located very near to the border of the high sensitivity buffers. Due to their location, it is advised that they be mitigated (Section 5 and 6) and not necessarily removed or relocated. **This applies to turbines WTG10 and 25** (27 turbine layout) and **WTG10** (22 turbine layout). All turbines located within moderate sensitivity buffers must also receive the outlined mitigation (Section 5 and 6).

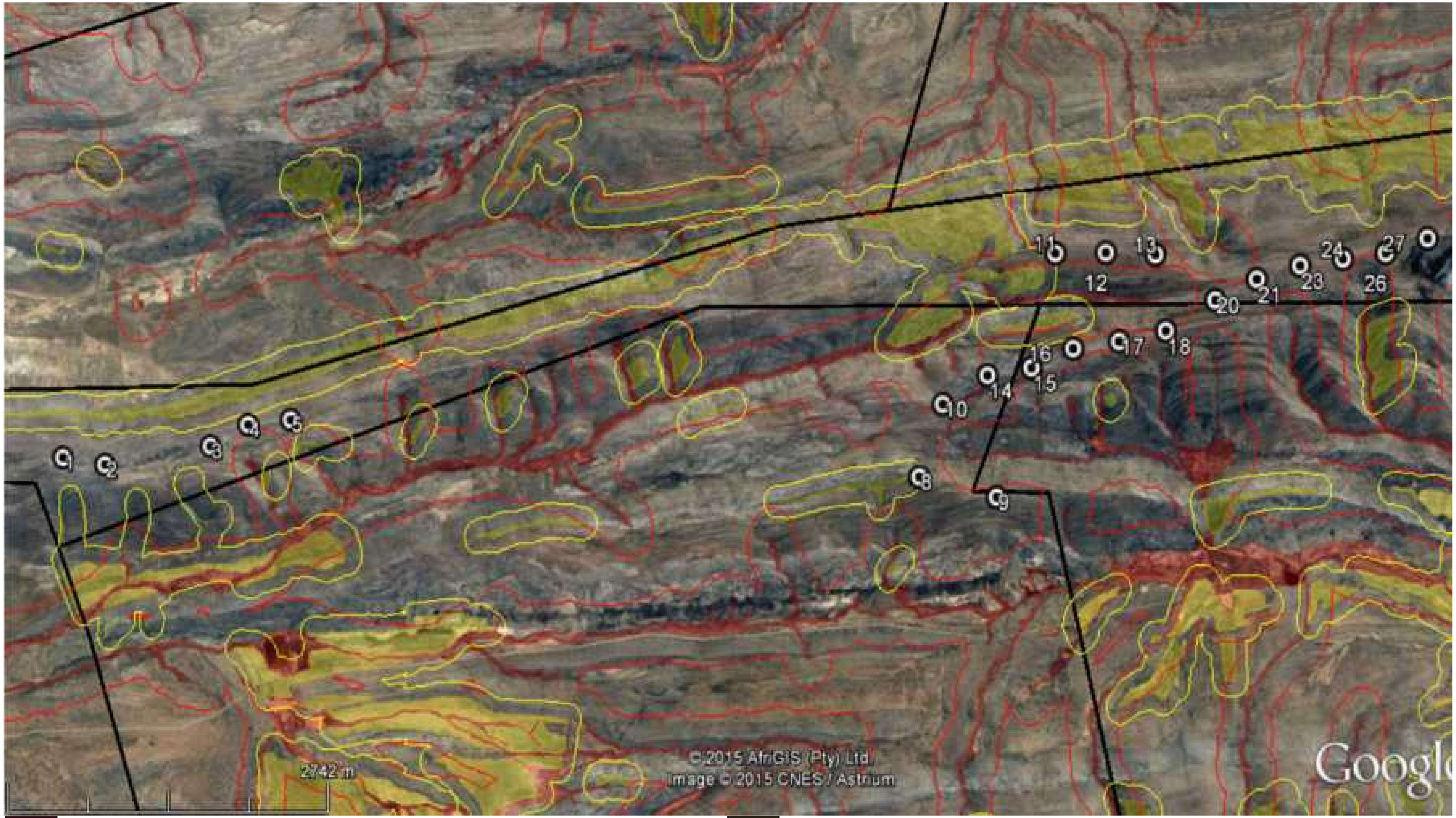
High bat sensitivity area — High bat sensitivity buffer — Moderate bat sensitivity area — Moderate bat sensitivity buffer

Figure 6: Bat sensitivity map of the Witberg site.



High bat sensitivity area — High bat sensitivity buffer — Moderate bat sensitivity area — Moderate bat sensitivity buffer

Figure 2: Bat sensitivity map of the Witberg site with the 27 turbine layout



High bat sensitivity area — High bat sensitivity buffer — Moderate bat sensitivity area — Moderate bat sensitivity buffer

Figure 8: Bat sensitivity map of the Witberg site with the 22 turbine layout

4.5 Passive Data

The raw data from the bat monitoring stations was analysed to identify peak periods of bat activity (across the year and night). These peaks were then used to identify if there is a need for mitigation and its schedule.

The table below outlines the time periods over which the systems were monitoring for and recording bat activity for each season. Monitoring was not continuous throughout the year and only covered specific portions of the seasons. Simultaneously, the monitoring stations suffered damage and/or malfunctioned resulting in some data loss. These periods of data loss were not clearly outlined in Natural Scientific Services CC final report for the study.

Table 7: Time periods over which monitoring stations were active

	Winter 2011	**Spring 2011**	**Summer 2011 - 2012**	**Autumn 2012**
W1	14 - 27 May 2011 6 - 7 June 2011	7 Sep - 12 Oct 2011	22 Dec 2011 - 27 Jan 2012 2 - 8 February 2012 12 - 20 February 2012	29 March 2012 21 Apr - 7 May 2012
W2	14 May - 6 June 2011	8 Sep - 12 Oct 2011	22 Dec 2011 - 28 Feb 2012	1 - 20 Mar, 30 Mar 2012 4 - 5 May 2012
W3	13 May - 7 June 2011	8 Sep - 12 Oct 2011	2 - 28 Feb 2012	1 Mar - 15 May 2012
W4	14 May - 7 June 2011	None	22 Nov 2011 - 29 Jan 2012 1 - 28 Feb 2012	1 - 14 Mar 2012 31 Mar - 14 Apr 2012
W5	14 May - 6 June 2011	8 Sep - 12 Oct 2011	22 Dec 2011 - 26 Jan 2012 1 - 28 Feb 2012	31 Mar - 15 May 2012
W6	14 - 26 May 2011	22 Sep - 8 Oct 2011	21 Dec 2011 - 28 Feb 2012	1 - 31 Mar 2012

4.5.1 Abundances and Composition of Bat Assemblages

Figure 9 depicts the sum of bat passes per species detected by each monitoring station over the full monitoring period. A total of five different species were detected across the site namely, *Miniopterus natalensis, Neoromicia capensis, Tadarida aegyptiaca, Sauromys petrophilus* and *Rhinolophus clivosus*. Of the five detected species, *Miniopterus natalensis* has a Near Threatened conservation status.

W3 (10m) monitoring station detected the highest number of total bat passes over the year. This is most likely due to its location near the slope of the mountain ridge and its close proximity too exfoliating rock. Fewer bat passes were detected by the microphones at 60m of the met mast monitoring stations than at 10m height. This shows a vertical gradient in bat activity however, the monitoring station W2 is an exception to this as a higher number of bat passes were detected at 60m height. This may have been due to a microphone fault that was not clearly specified. The monitoring station W6 detected significantly low numbers across the entire monitoring period, the reason for this is unknown. It may have been a system failure (Figure 9).

An activity index of the average number of bat passes detected per night was used in Figure 10. This graph displays the seasonal trends in bat activity per monitoring station. The autumn season shows a generally higher activity index compared to the other seasons, with lowest activity over winter. Considerable levels of activity were detected over spring and summer months. This graphical representation will be influenced by the intermittent monitoring regime and system failures experienced over the year, and thus should only be taken as a guideline representation of seasonal bat activity.

The common and abundant species detected on site, *Neoromicia capensis* and *Tadarida aegyptiaca*, are of a larger value to the local ecosystems as they provide a greater contribution to most ecological services than the more rare species due to their higher numbers. Thus the activity of these species will be used to infer mitigation measures.

The Horseshoe bat, *Rhinolophus clivosus*, was detected in low numbers by only two monitoring stations, W2 and W5. This species is at lower risk of impact by the wind farm due its ecology and behaviour.

The migratory species, *Miniopterus natalensis*, was detected by all six monitoring stations and is rather prevalent on site. This species is at high risk of mortality if a wind farm is located within its migratory path. The monitoring on this site was not continuous across the year, so it cannot be concluded with full confidence that the wind farm is not located within a migratory pathway. However, no migratory event was detected over the monitoring time frames of this study.

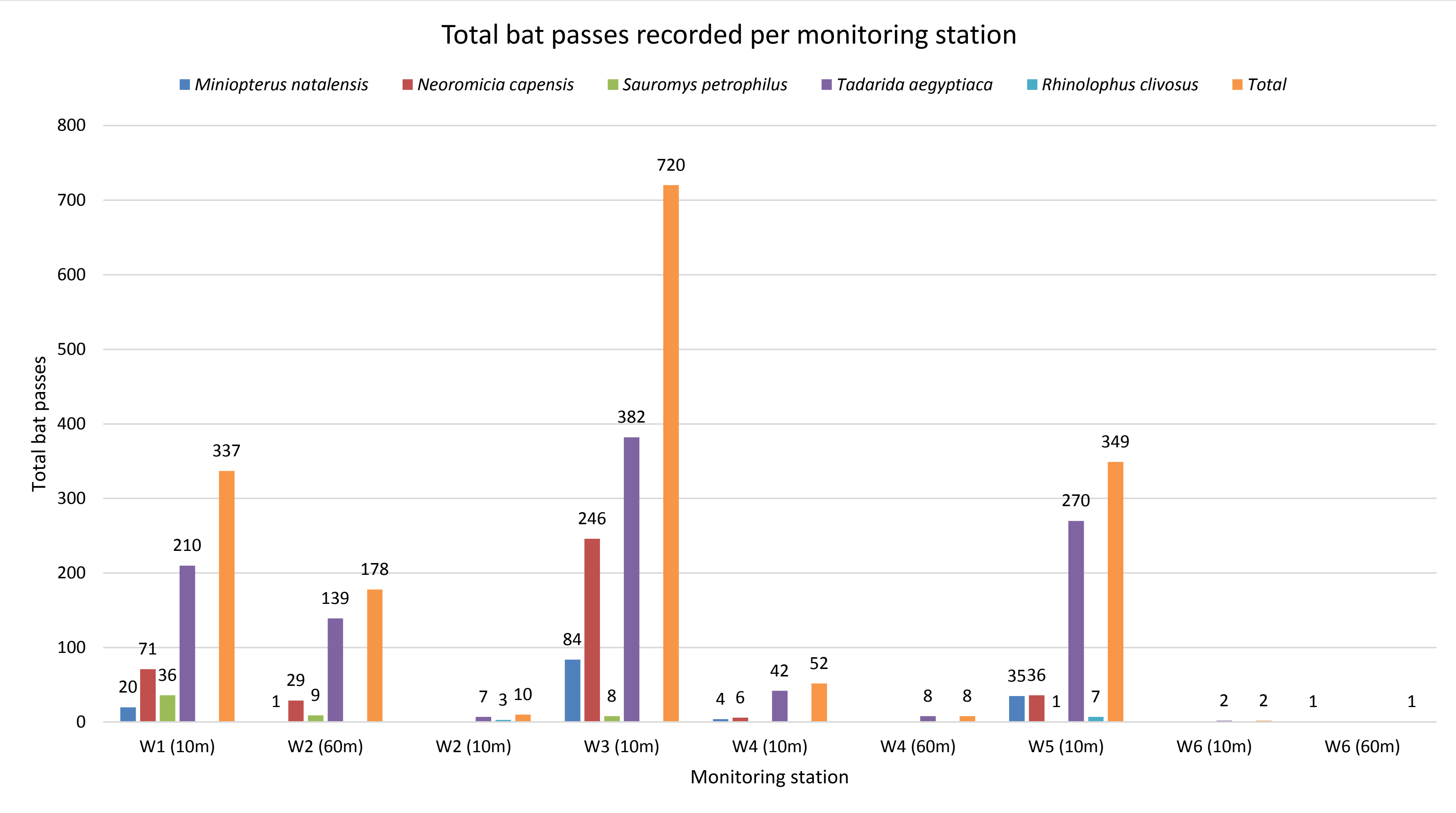


Figure 9: Total bat passes recorded by each monitoring station over the entire monitoring period

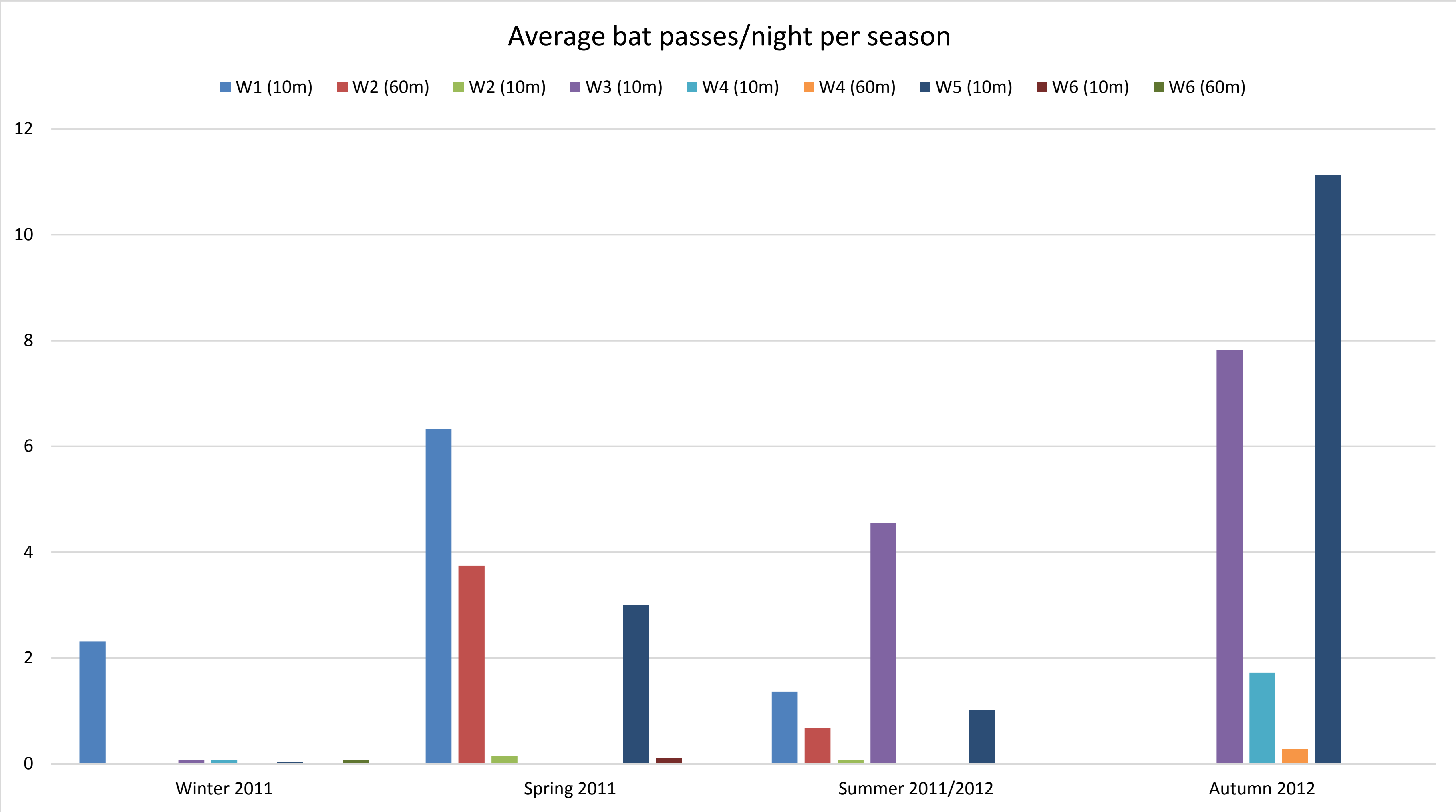


Figure 10: Average bat passes per night for each season per monitoring station

4.5.2 Temporal Distribution

The distribution of detected bat passes across the seasons and the night are important mitigation parameters that will reduce the mortality risk of bats from turbines. Figures 11 – 22 display these temporal trends for each monitoring station. The number of bat passes detected per species is displayed for each date. The time frames over which the monitoring stations were not actively recording have been displayed. The bat passes for all detected species were summed for each season to display the general trend of activity across the night.

The peak activity periods detected are displayed in Table 8 below.

Table 8: peak bat activity dates and times per monitoring station

Monitoring station	Season	Dates	Time
W1	Spring	Early September – mid October	Sunset - midnight
W2	Spring	Mid September – mid October	Sunset – midnight and 05:00 – 06:00
W3	Autumn	Early February – mid May	Sunset – midnight and 05:00 – 06:30
W4	Autumn	Early – mid April	18:00 – 19:30
W5	Spring	Late September – mid October	Sunset – 20:00
	Autumn	Mid April – mid May	Sunset – 20:00 and 01:00 – 03:00
W6	None	None	None

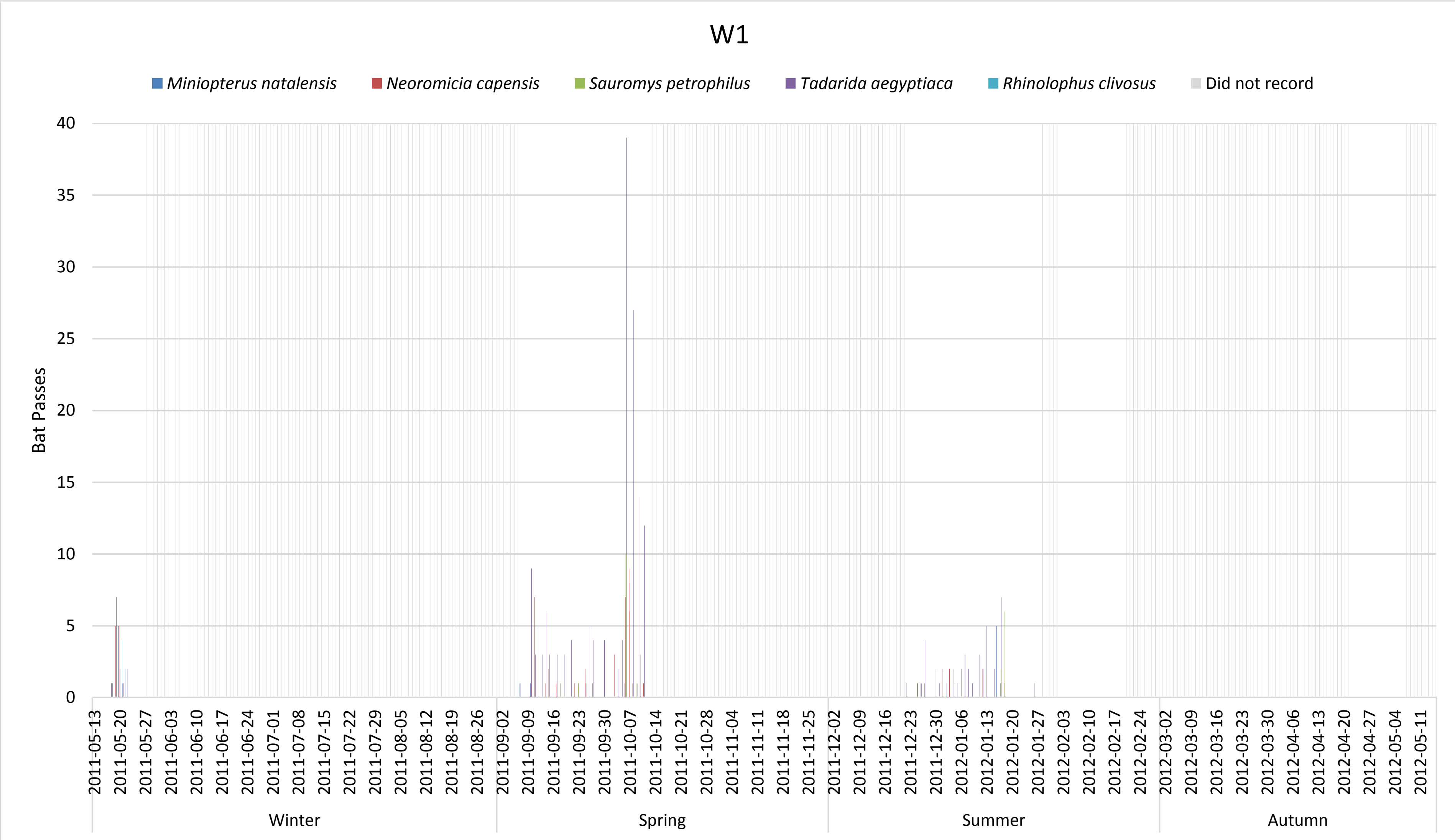


Figure 11: Temporal distribution of bat passes detected by W1 monitoring station

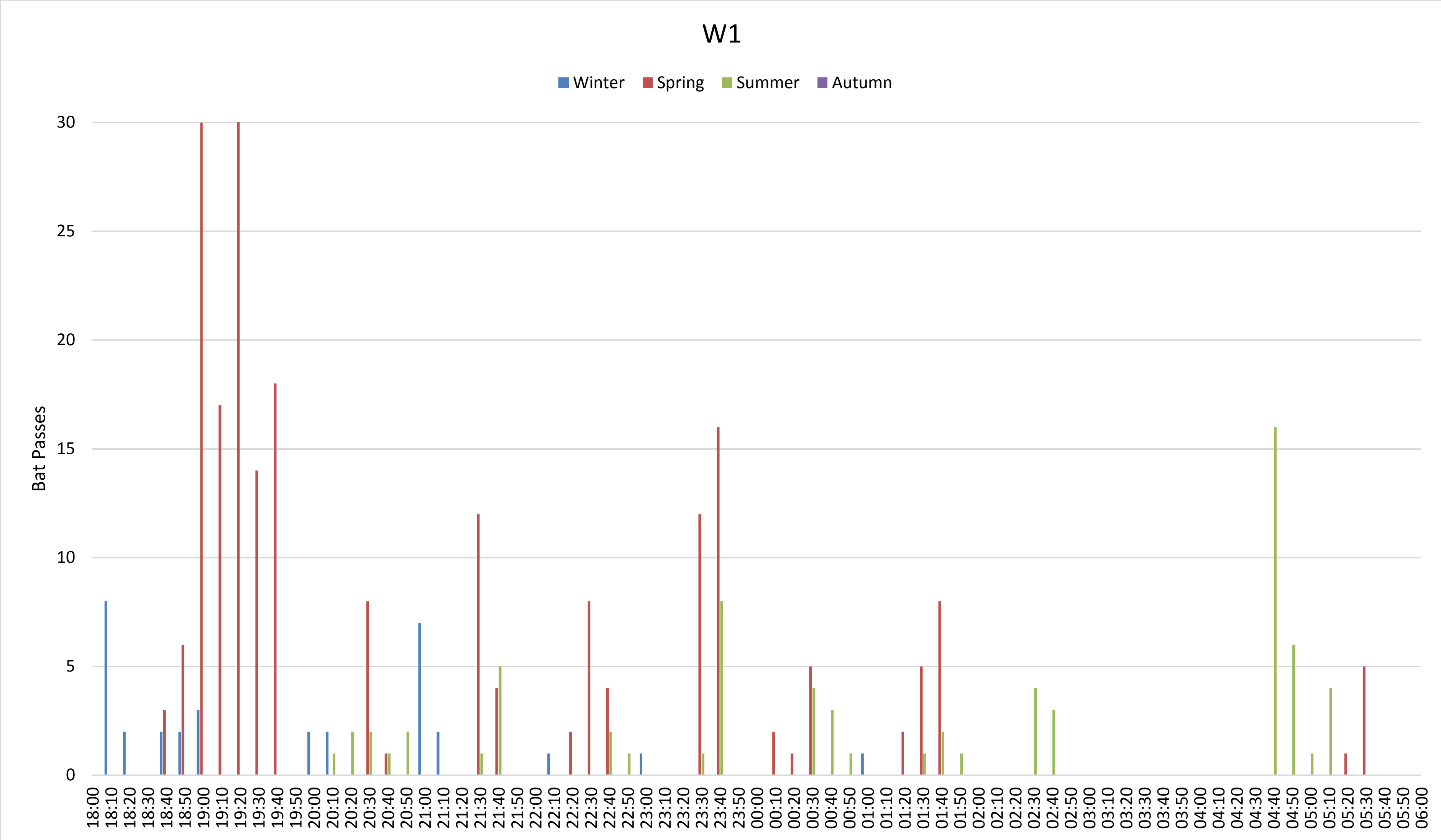


Figure 12: Bat passes detected over the night for each season from monitoring station W1.

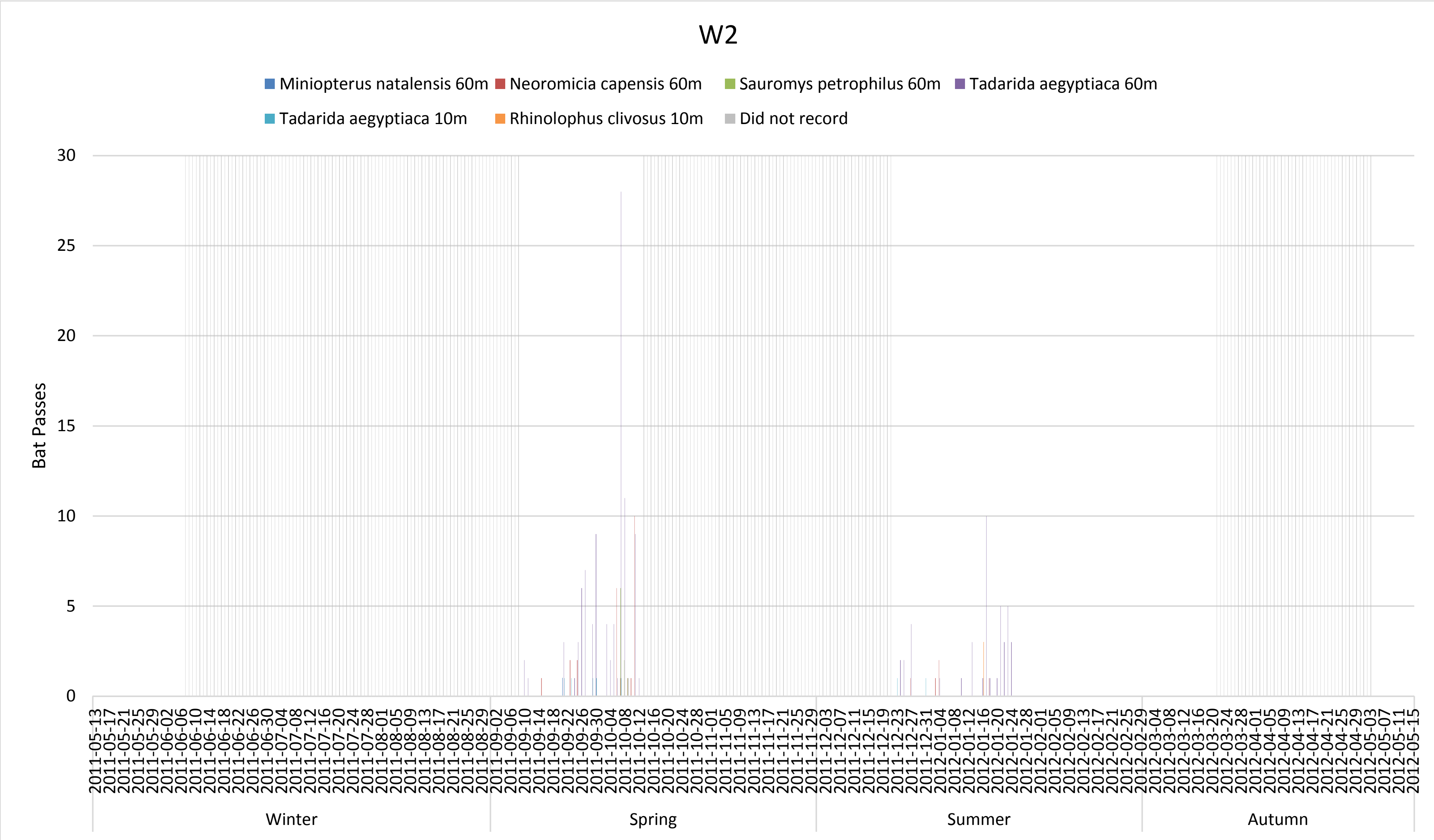


Figure 13: Temporal distribution of bat passes detected by W2 monitoring station

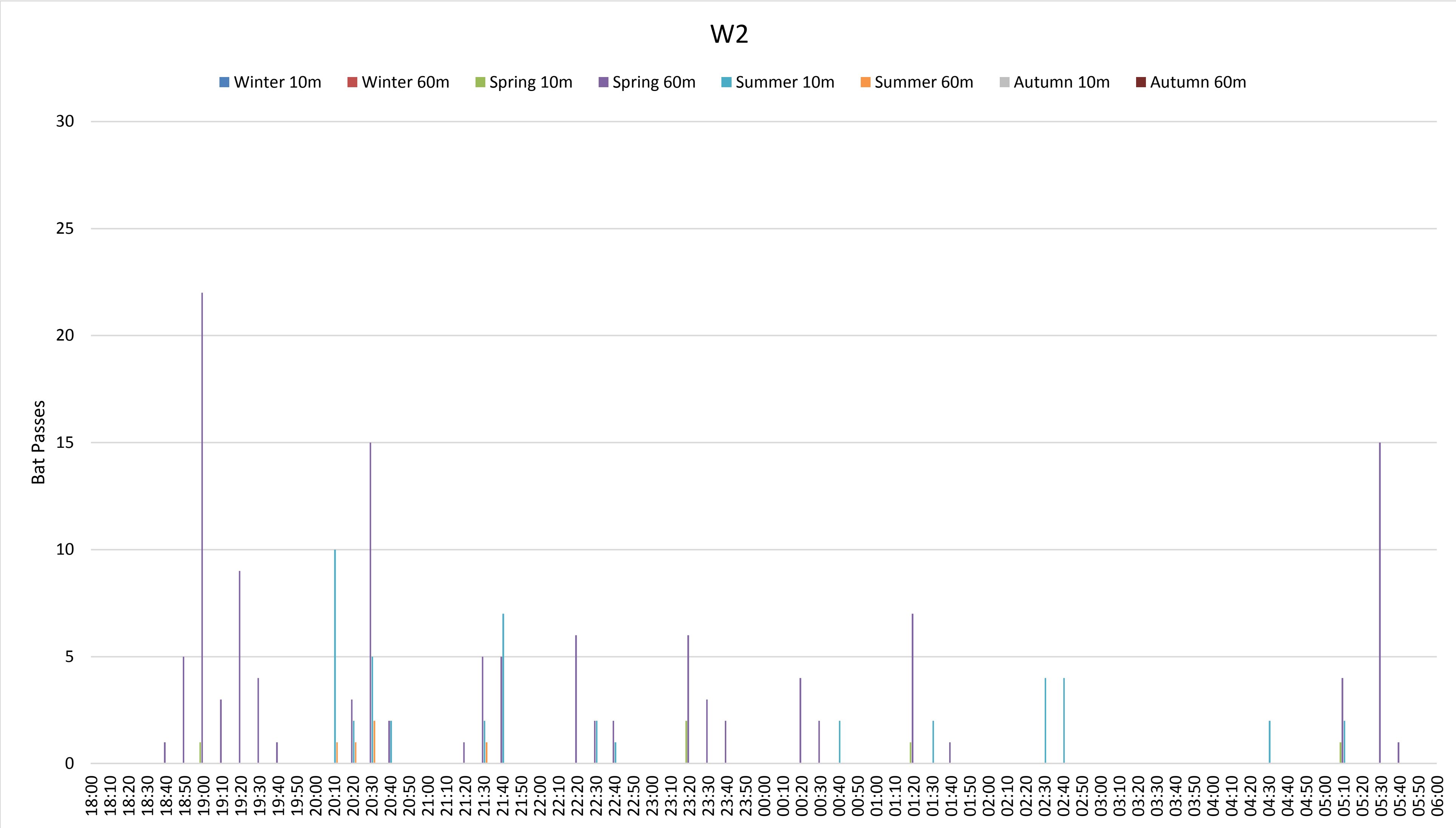


Figure 14: Bat passes detected over the night for each season from monitoring station W2.

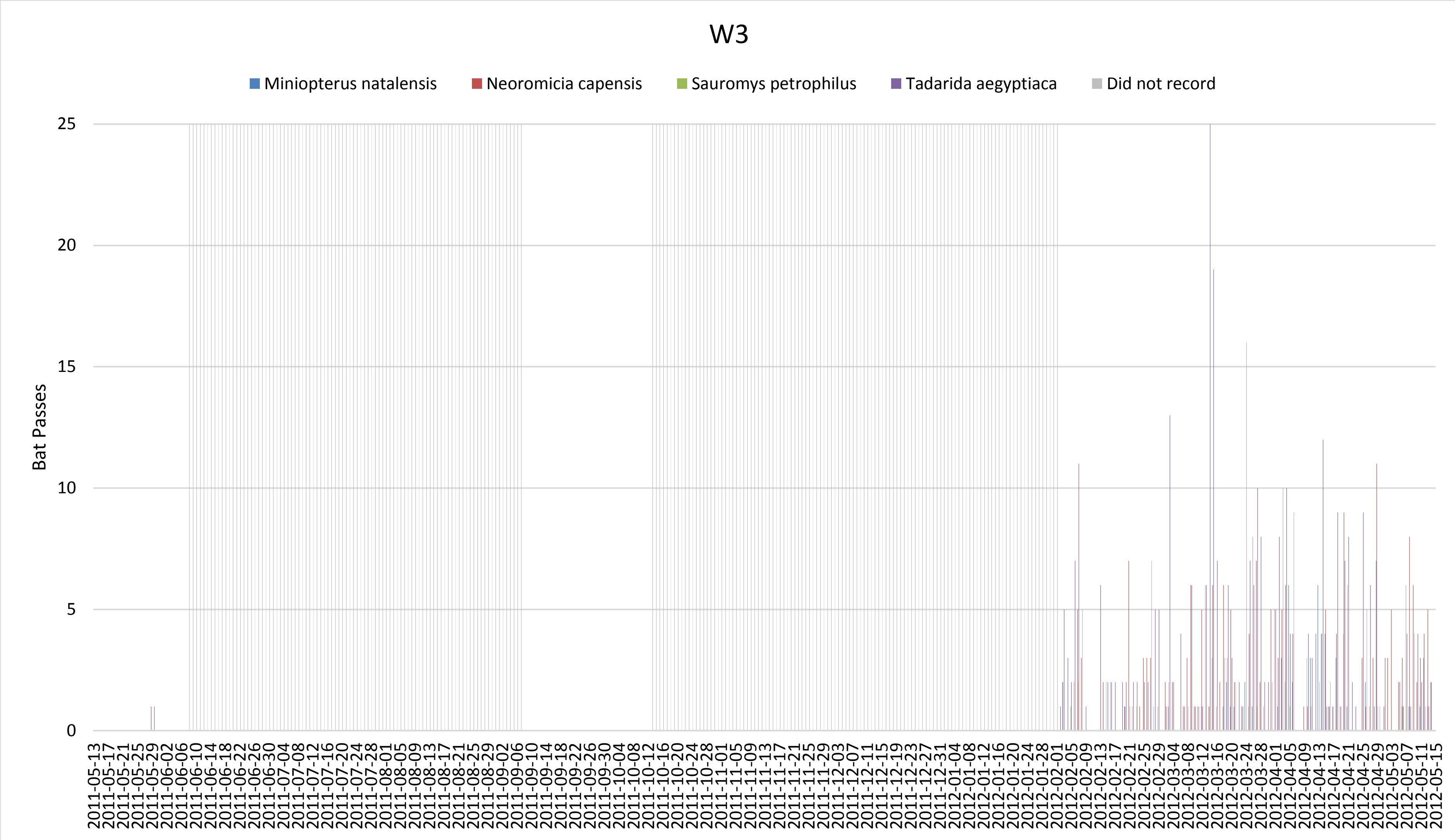


Figure 15: Temporal distribution of bat passes detected by W3 monitoring station

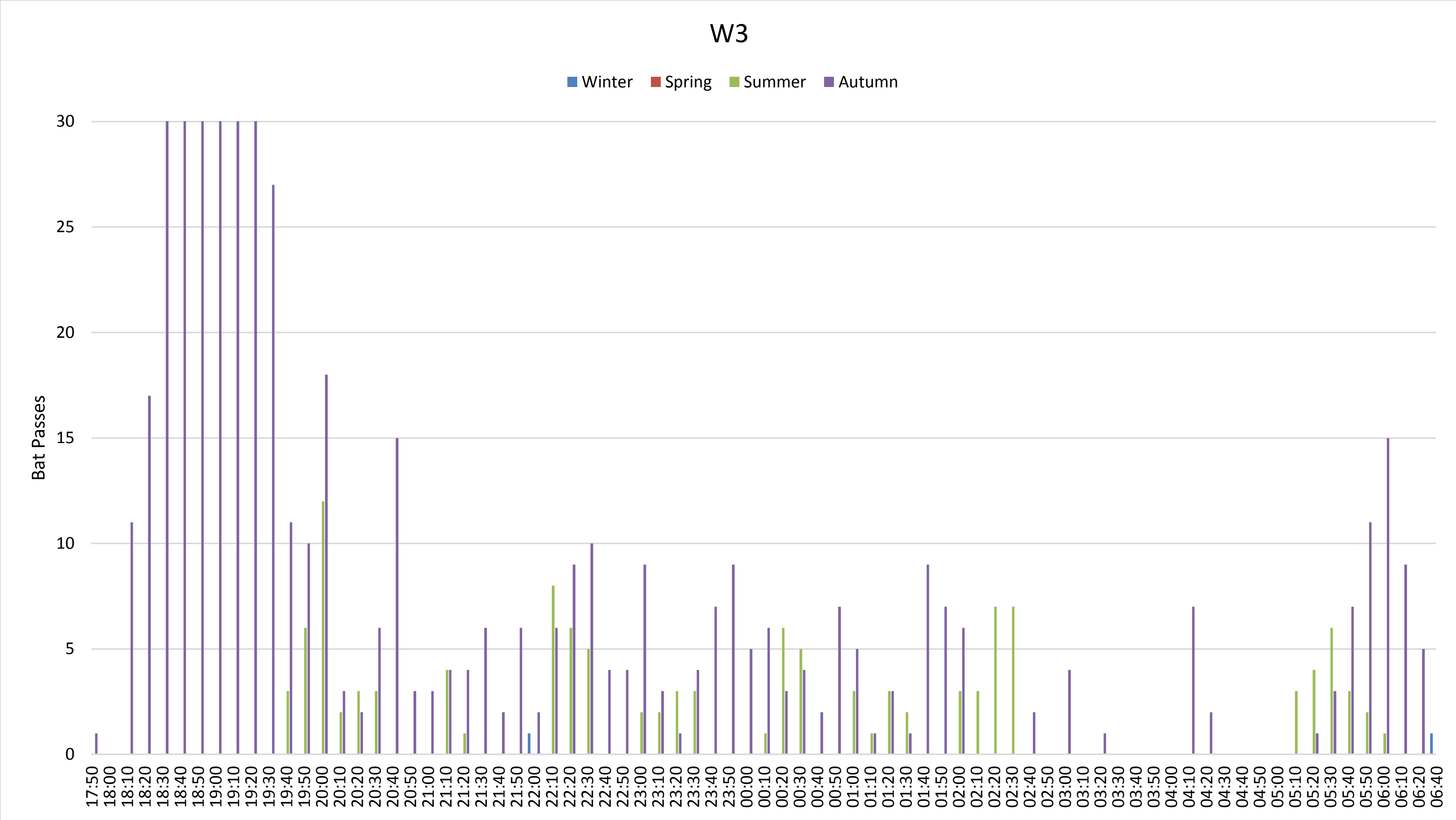


Figure 16: Bat passes detected over the night for each season from monitoring station W3.

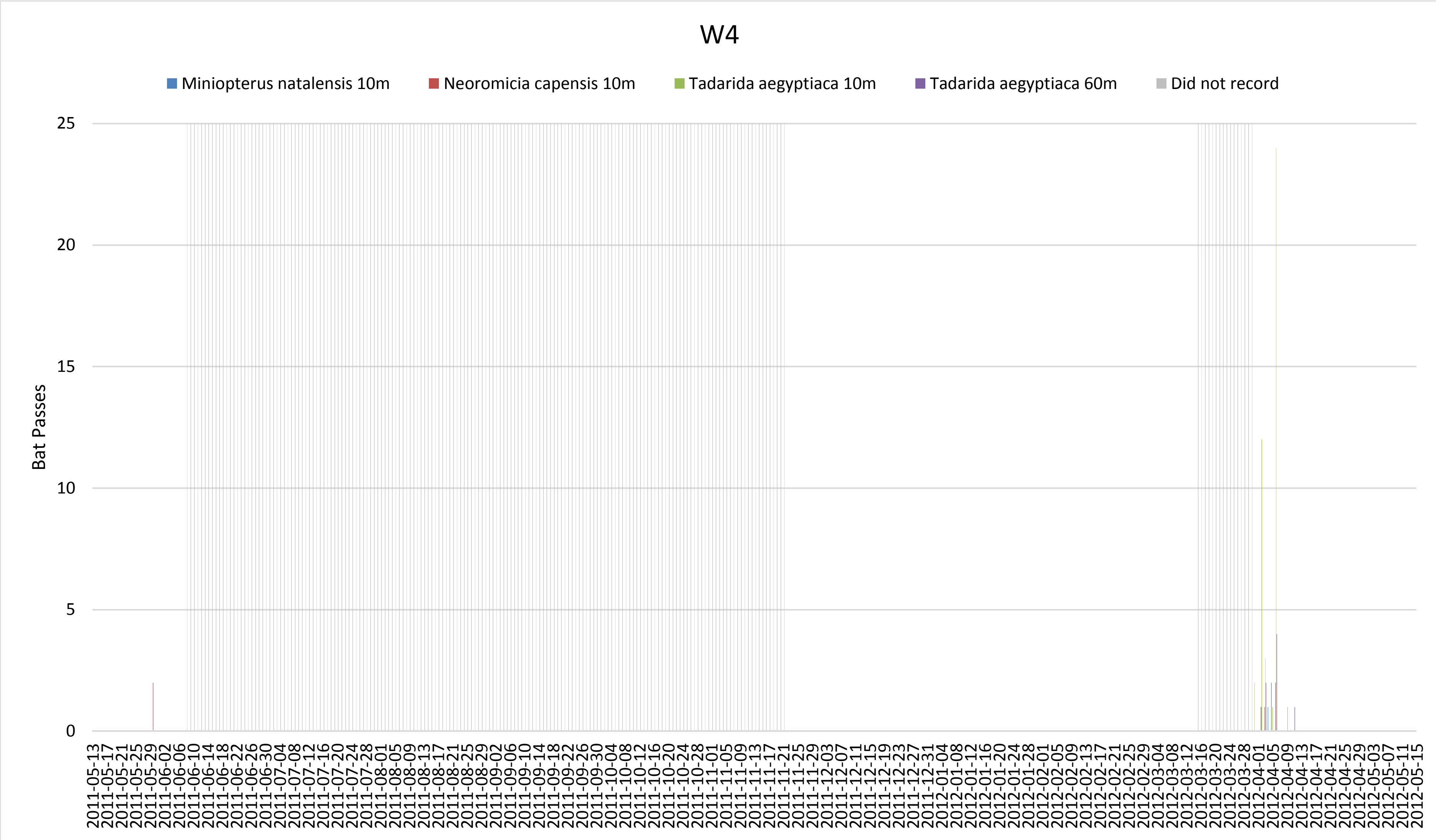


Figure 17: Temporal distribution of bat passes detected by W4 monitoring station

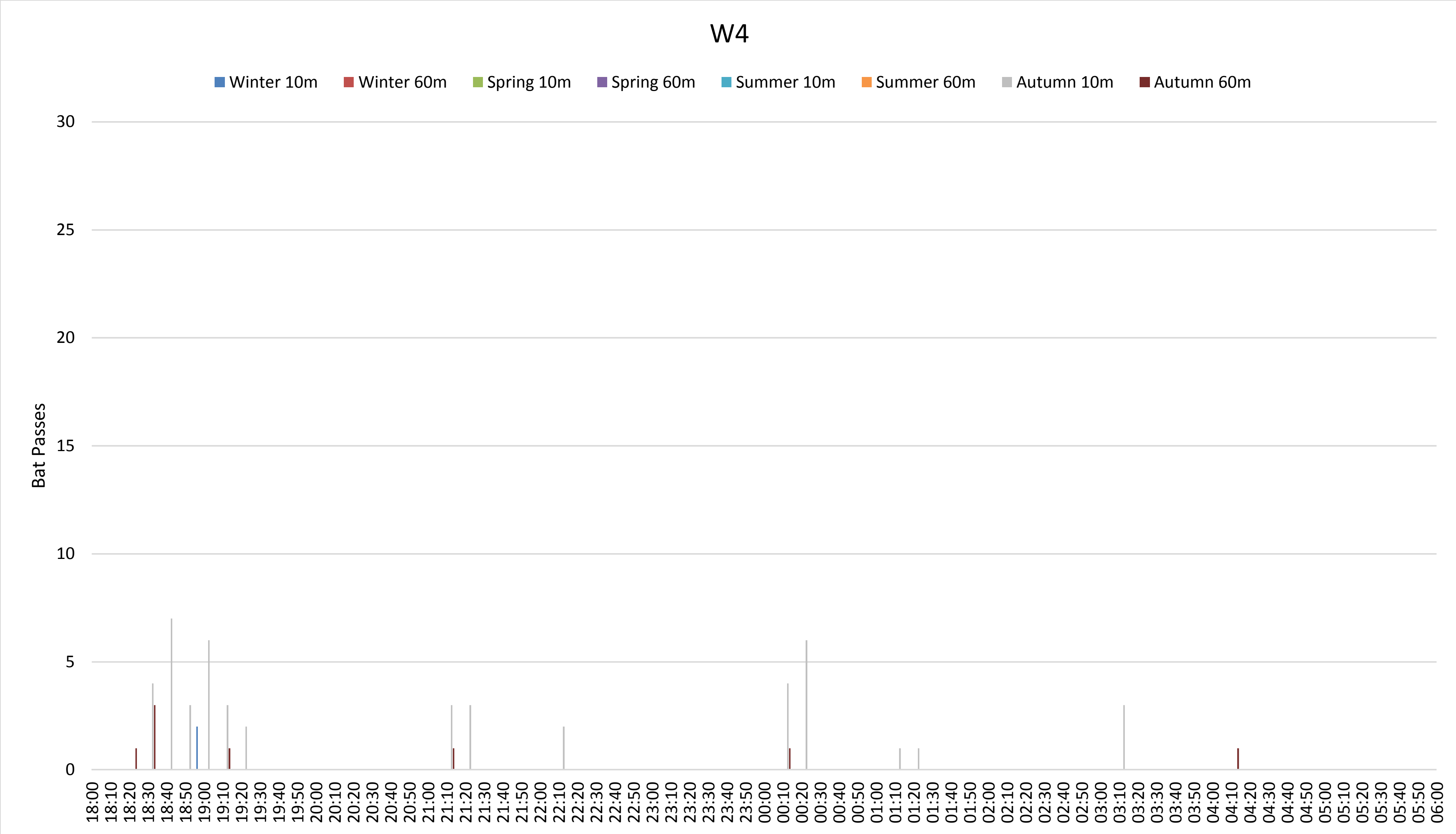


Figure 18: Bat passes detected over the night for each season from monitoring station W4.

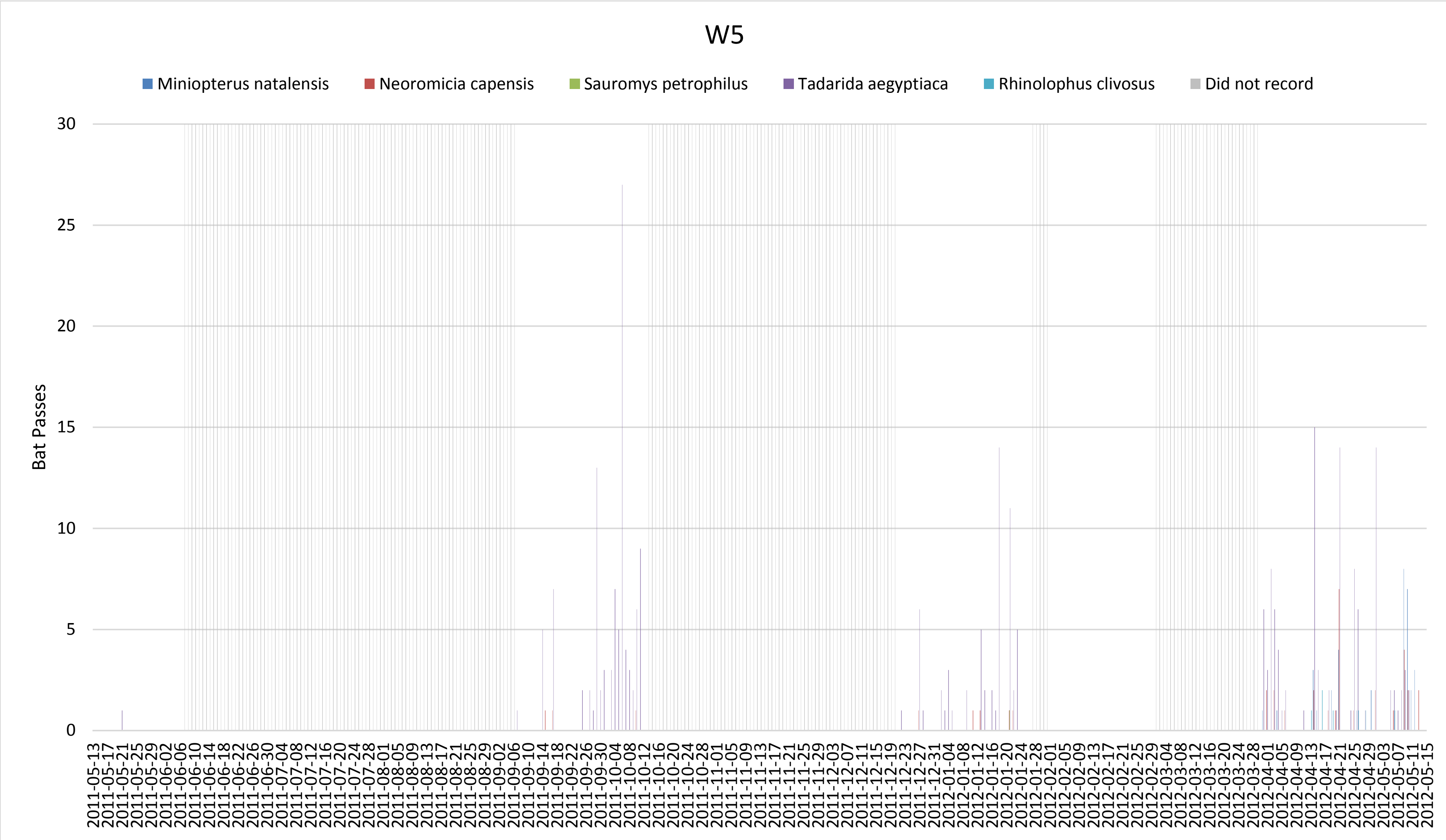


Figure 19: Temporal distribution of bat passes detected by W5 monitoring station

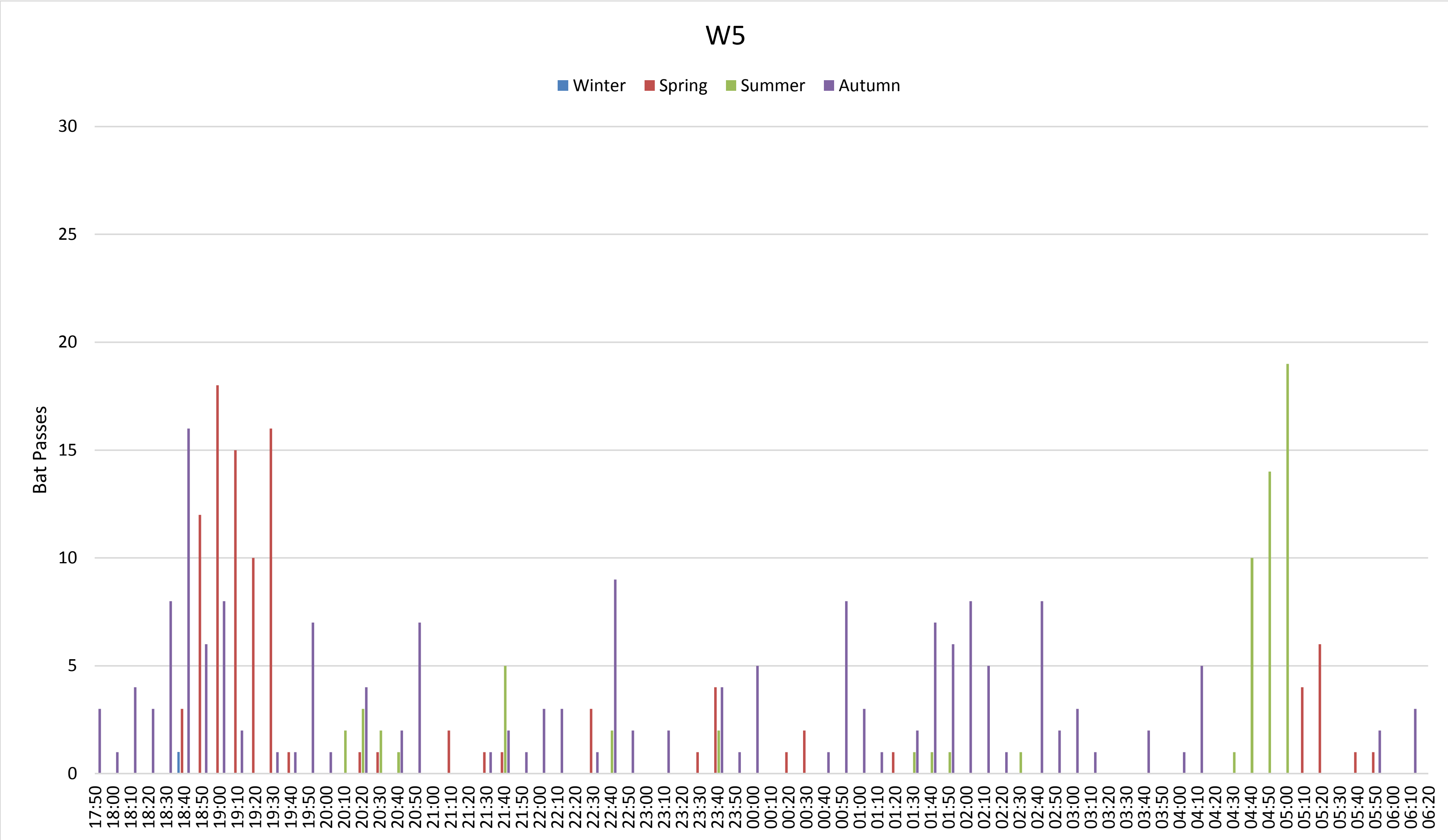


Figure 20: Bat passes detected over the night for each season from monitoring station W5.

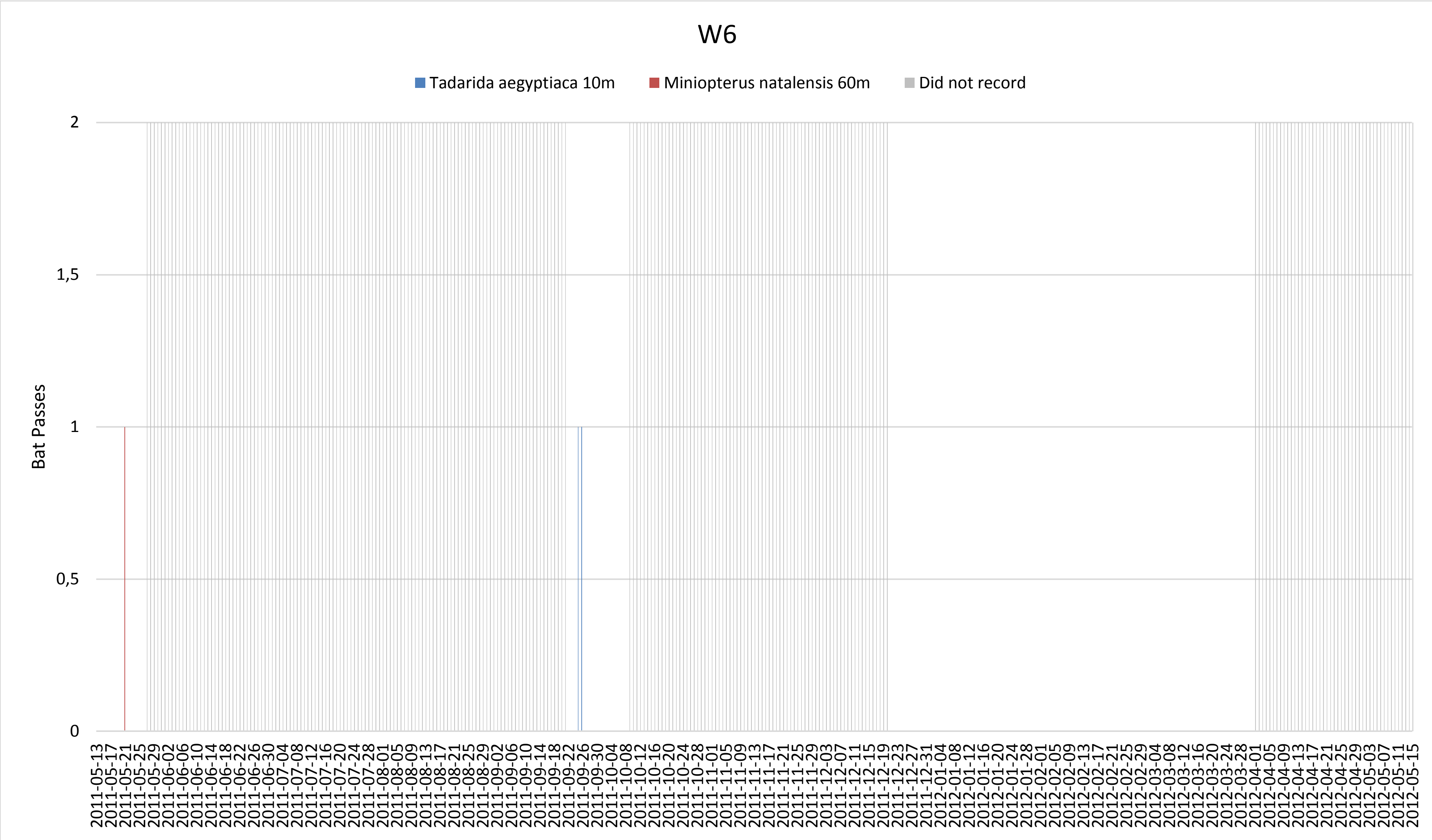


Figure 21: Temporal distribution of bat passes detected by W6 monitoring station

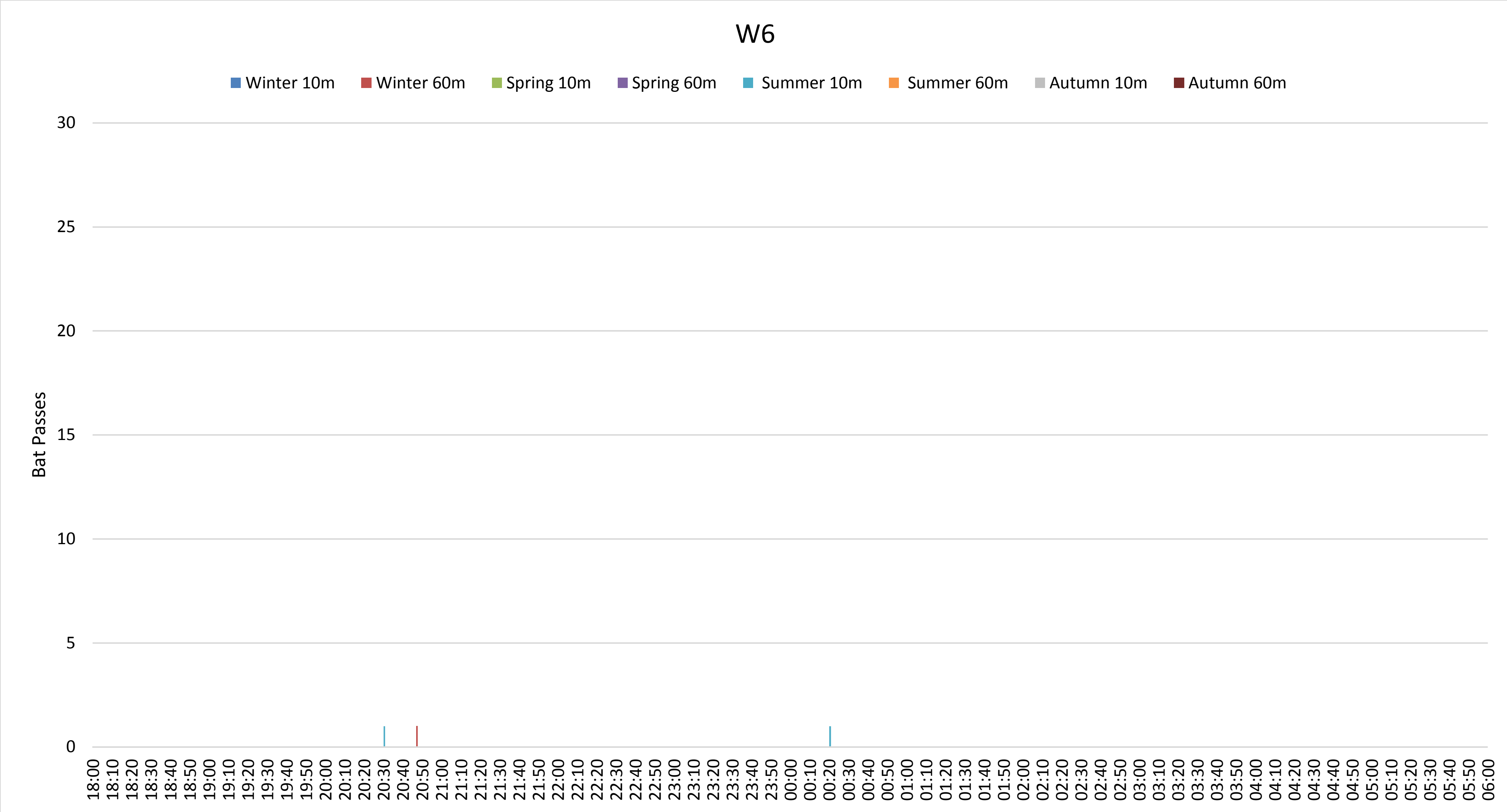


Figure 22: Bat passes detected over the night for each season from monitoring station W6.

4.5.3 Relation between Bat Activity and Weather Conditions

Several sources of literature describe how numerous bat species are influenced by weather conditions. Weather may influence bats in terms of lowering activity, changing time of emergence and flight time. It is also important to note the environmental factors are never isolated and therefore a combination of the environmental factors can have synergistic or otherwise contradictory influences on bat activity. For instance a combination of high temperatures and low wind speeds will be more favourable to bat activity than low temperatures and low wind speed, whereas low temperature and high wind speed will be the least favourable for bats. Below are short descriptions of how wind speed and temperature influence bat activity.

Wind speed

Some bat species show reduced activity in windy conditions. Strong winds have been found to suppress flight activity in bats by making flight difficult (O'Farrell *et al.* 1967). Several studies at proposed and operating wind facilities in the United States have documented discernibly lower bat activity during 'high' wind speeds (Arnett *et al*. 2010).

Wind speed and direction also affects availability of insect prey as insects on the wing often accumulate on the lee side of wind breaks such as tree lines (Peng *et al.* 1992).So at edges exposed to wind, flight activity of insects, and thus bats may be suppressed and at edges to the lee side of wind, bat activity may be greater. This relationship is used in the sensitivity map whereby the larger vegetation and man-made structures provide shelter from the wind. However the turbine localities are situated on the ridges of the site such that they will be in areas exposed to the wind and not protected by vegetation or structure.

Temperature

Flight activity of bats generally increases with temperature. Flights are of shorter duration on cooler nights and extended on warmer nights.

Rachwald (1992) noted that distinct peaks of activity disappeared in warm weather such that activity was mostly continuous through the night. During nights of low temperatures bats intensified foraging shortly after sunset (Corbet and Harris 1991).

Peng (1991) found that many families of aerial dipteran (flies) insects preferred warm conditions for flight. A preference among insects for warm conditions has been reported by many authors suggesting that temperature is an important regulator of bat activity, through its effects on insect prey availability.

The aim of the below analysis is to determine the wind speed and temperature range within which 80% of bat passes are detected. The time periods used for the calculations are the high bat activity periods elicited in Section 4.5.2. Ultimately these values of wind speed and temperature will be used to mitigate turbine operation based on conserving 80% of detected bat passes during high activity periods, keeping in mind the synergistic or otherwise contradictory effects that the combination of wind speeds and temperatures can have on bat activity.

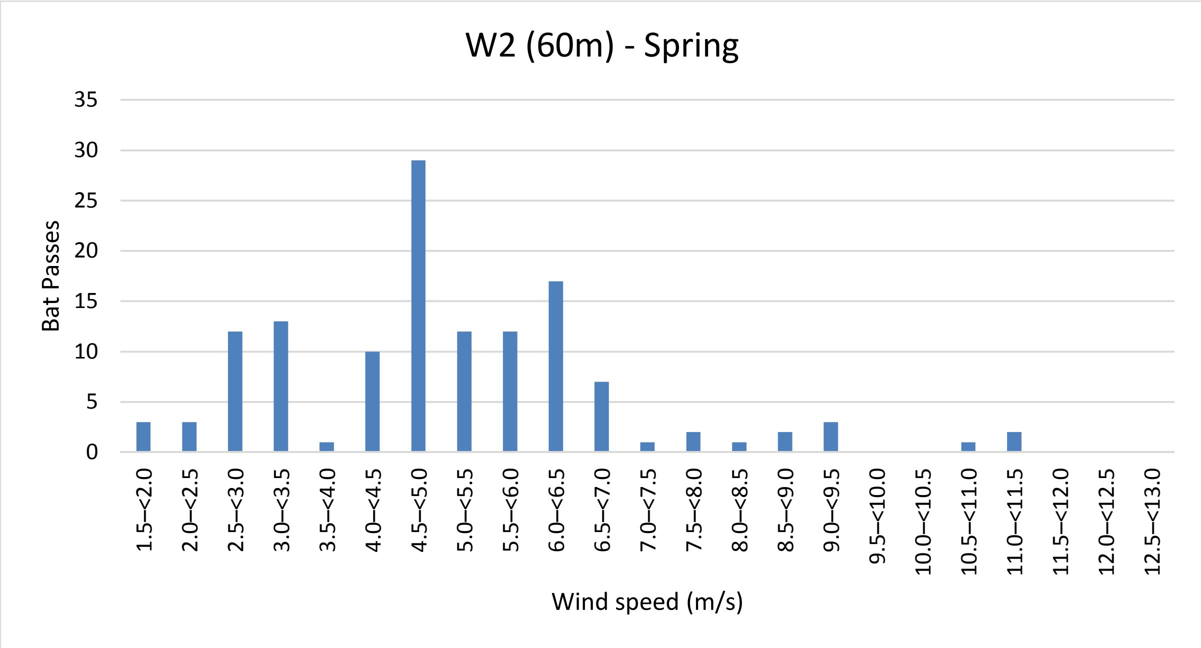
The wind speed (m/s) and temperature (°C) data recorded by loggers of the met masts on site were used for the analysis. Wind speed measured at 15m height on the met masts was used for analysis of 10m bat data. Wind speed measured at 60m height on the met masts was used for analysis of 60m bat data. Temperature data recorded at 60m height on the met mast was used for the analysis of 10m and 60m bat data. The figures below display the sum of bat passes per wind speed and temperature category, as well as the normalised number of bat passes per wind speed and temperature category.

The normalised number of bat passes is derived from the sum of bat passes by factoring in the frequency of occurrence of the particular wind speed and temperature categories. This serves the purpose of removing a bias of a wind speed or temperature category due to a higher prevalence of the category on site. The normalised data was used in mitigation parameter selection.

Figures of the cumulative percentage of bat passes per wind speed and temperature category were used to elicit weather parameters at which 80% of bat activity is present.

Table 9: Periods and monitoring stations used for the below analysis

Monitoring station	Season	Dates	Turbine applies to	
			27 layout	**22 layout**
W2 60m	Spring	Mid September – mid October	WTG25	
W3	Autumn	Early February – mid May	WTG10	
W4	Autumn	Early – mid April	WTG06, 07, 08	WTG08, 10



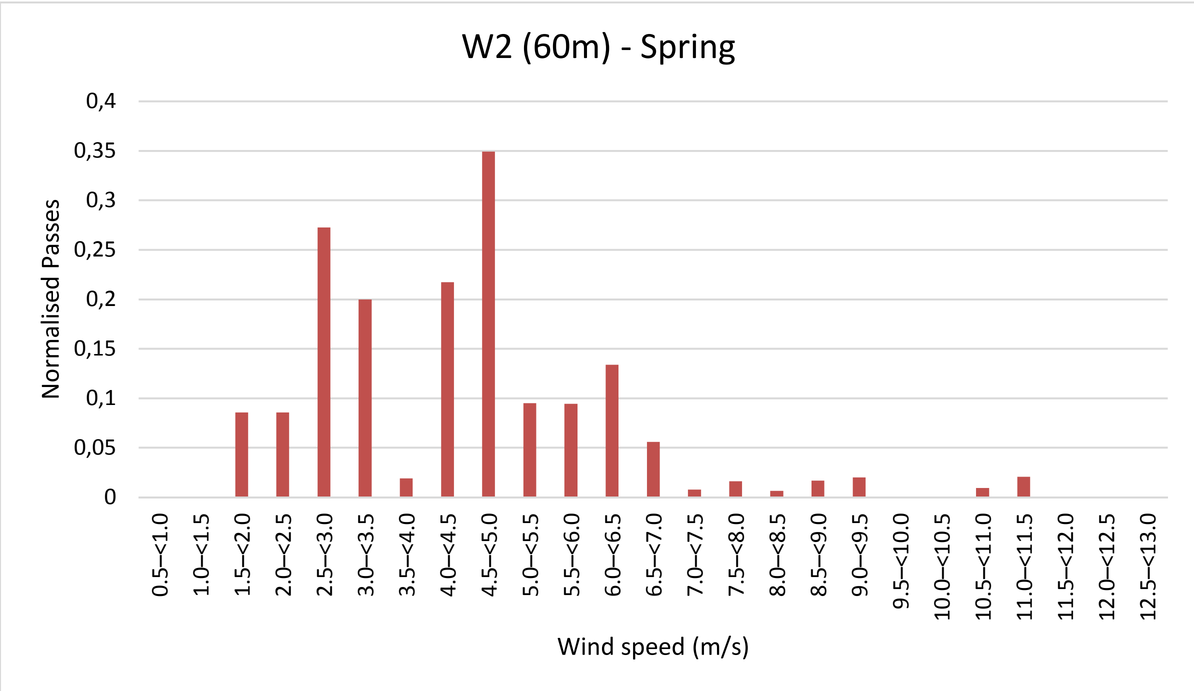


Figure 23: Bat passes and normalised passes per wind speed range for W2 (60m) (spring)

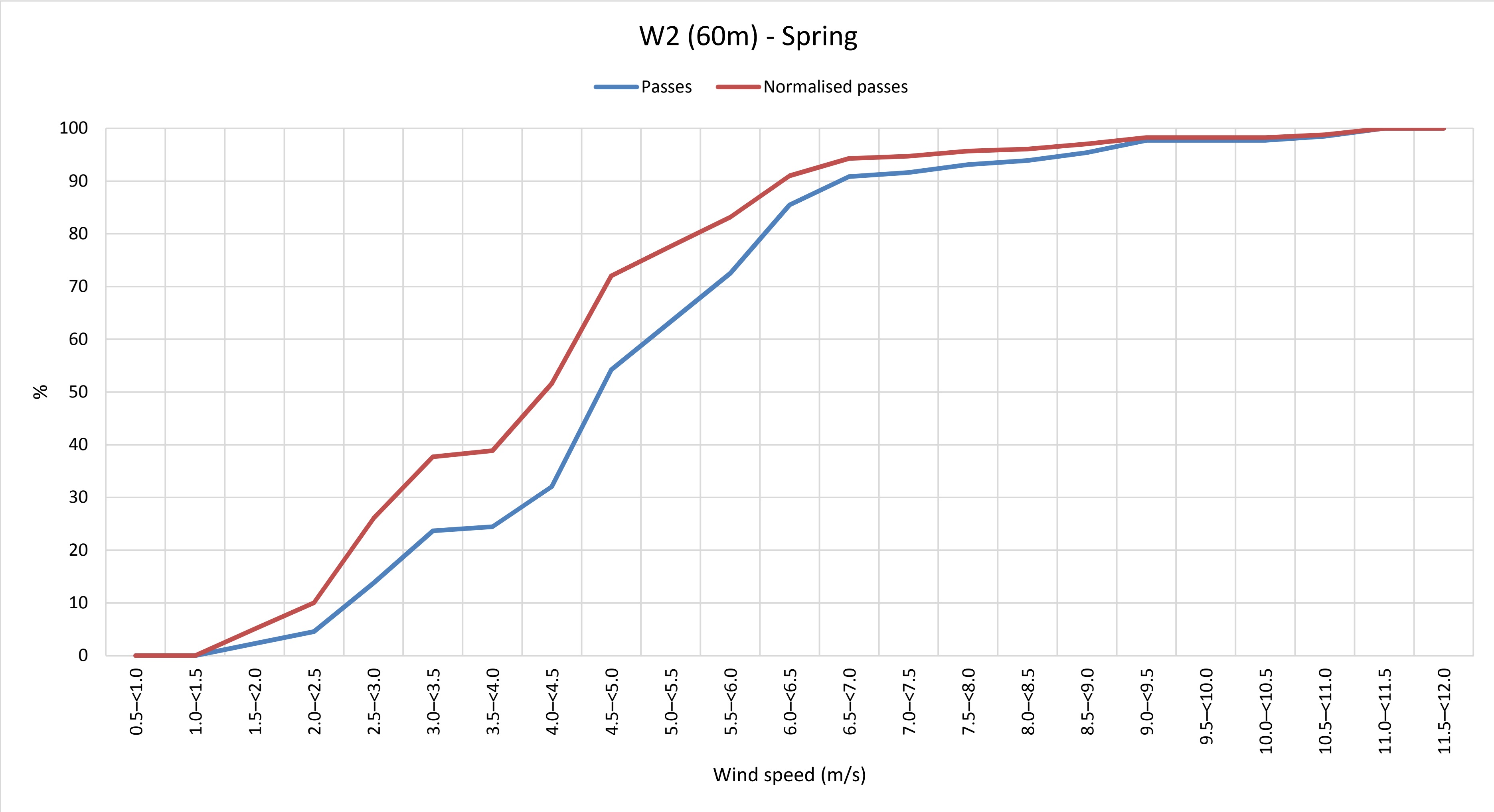
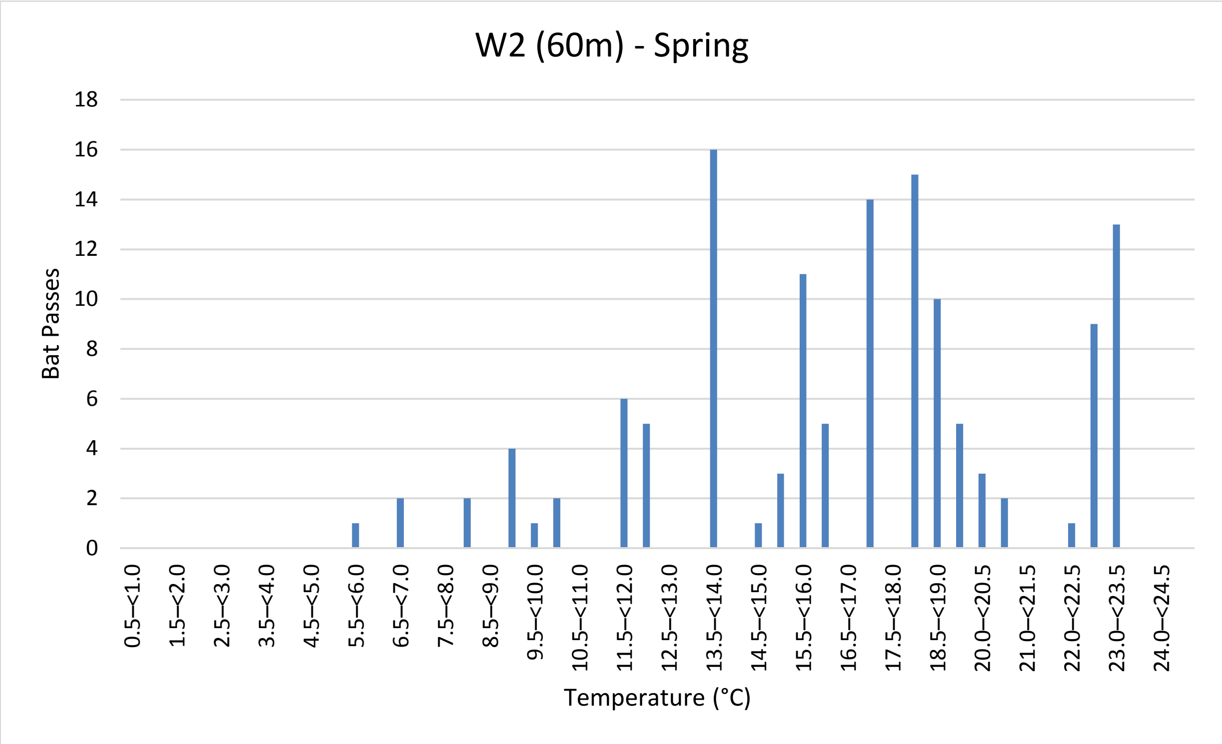


Figure 24: Cumulative percent of bat passes and normalised passes per wind speed range for W2 (60m) (spring)



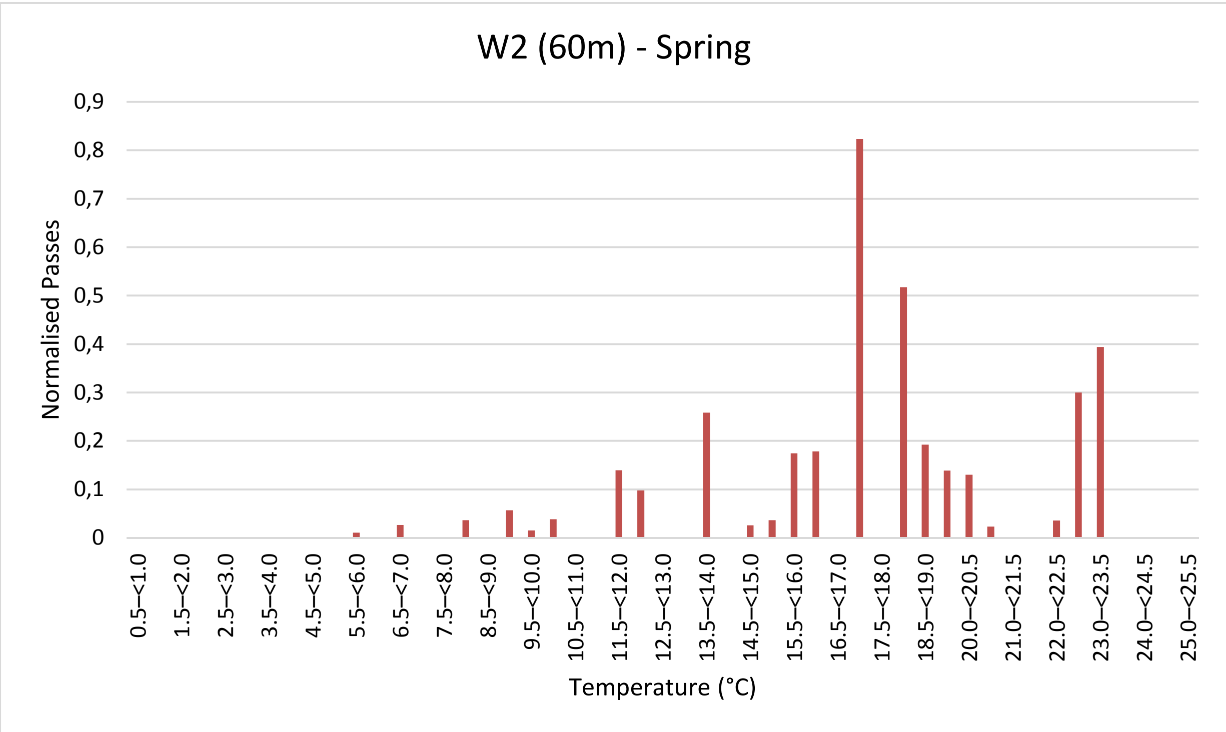


Figure 25: Bat passes and normalised passes per temperature range for W2 (60m) (spring)

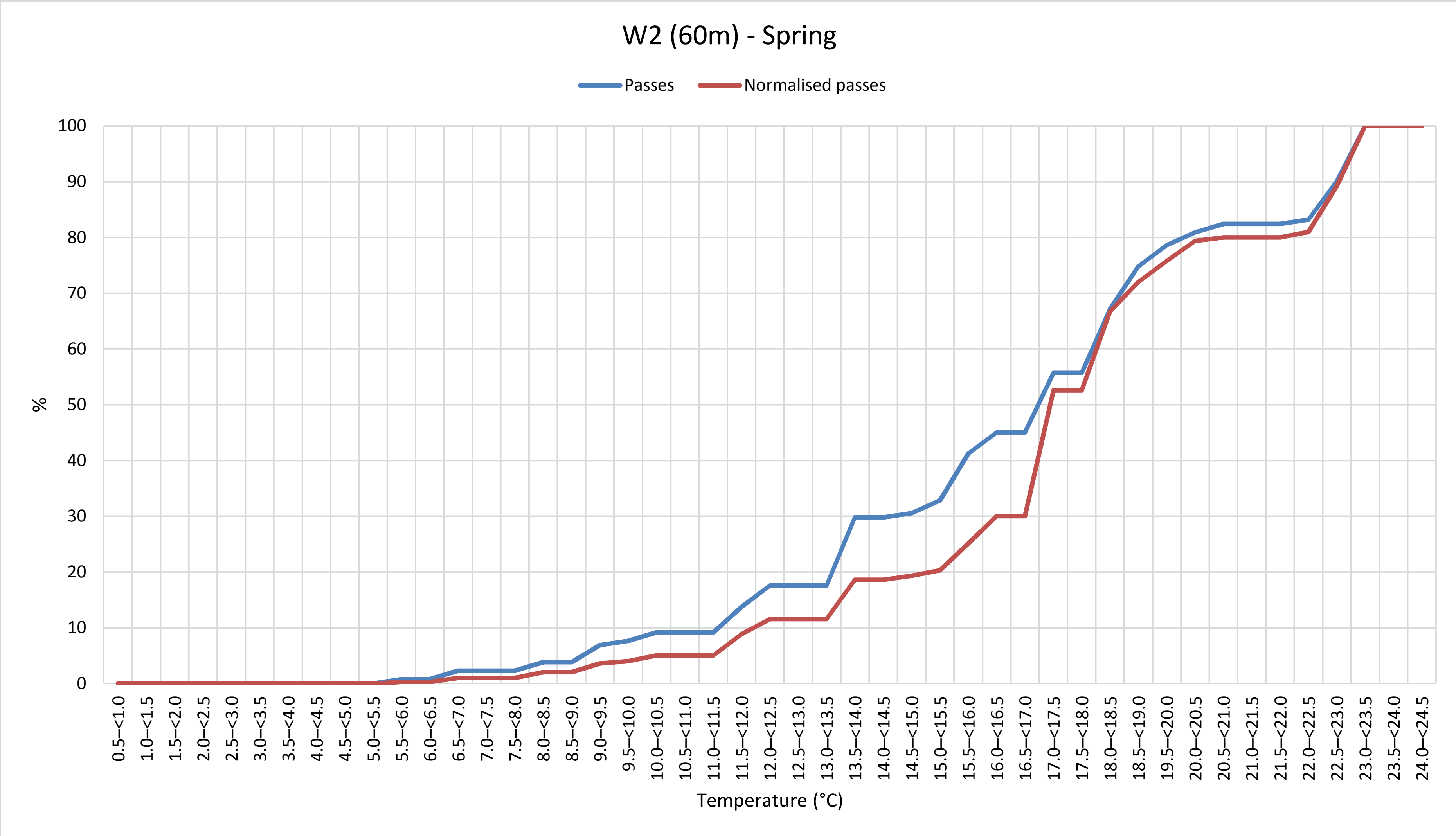
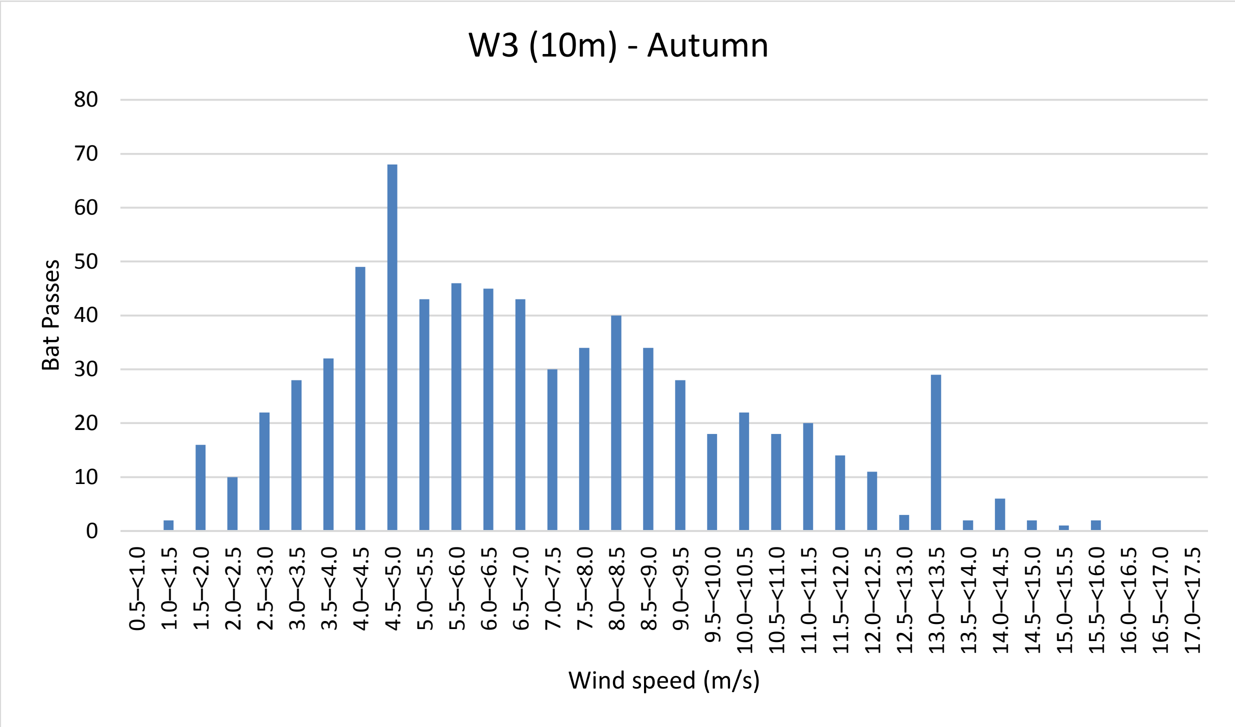


Figure 26: Cumulative percent of bat passes and normalised passes per temperature range for W2 (60m) (spring)



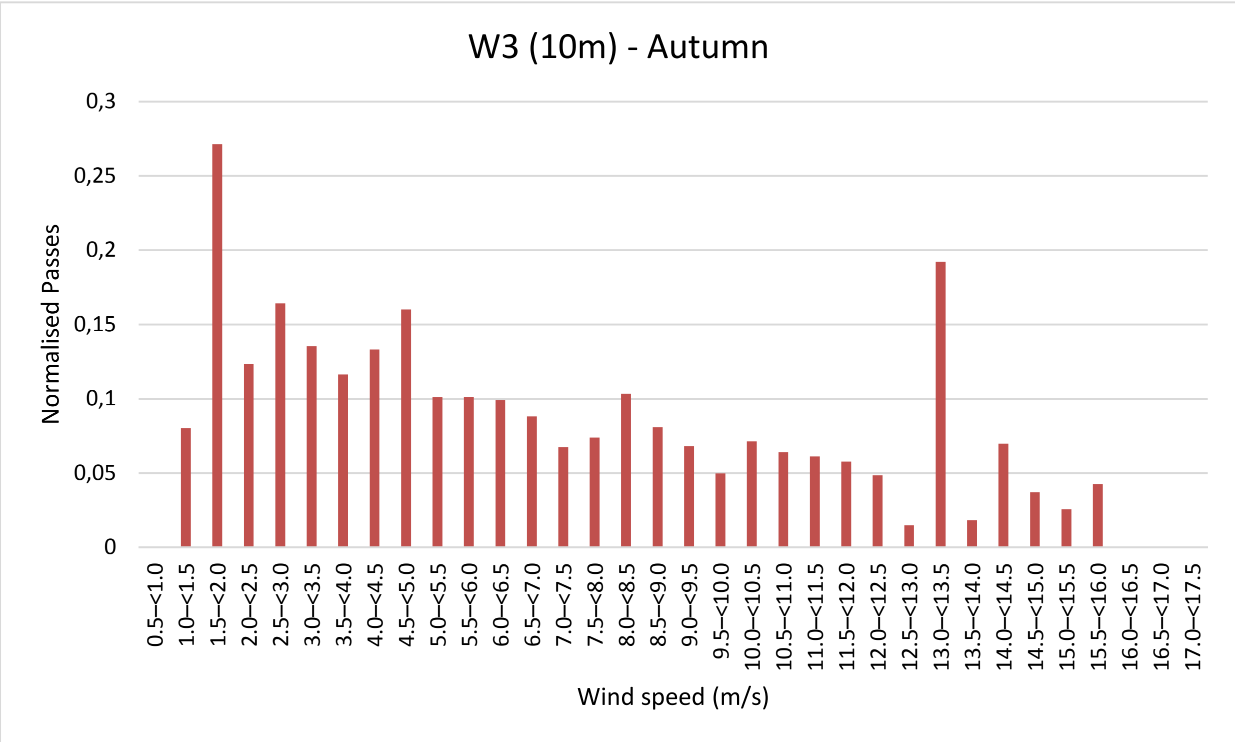


Figure 27: Bat passes and normalised passes per wind speed range for W3 (10m) (autumn)

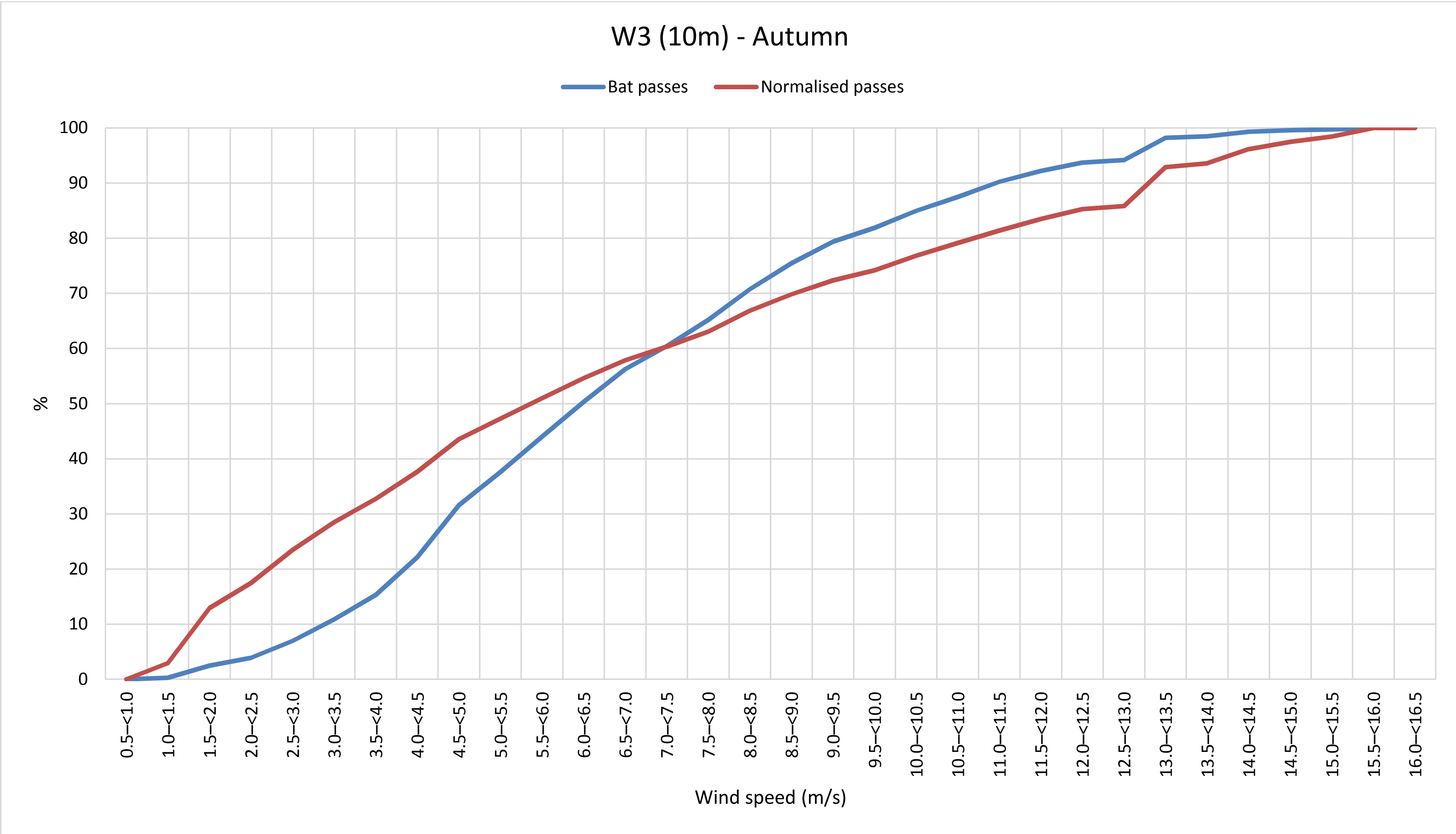
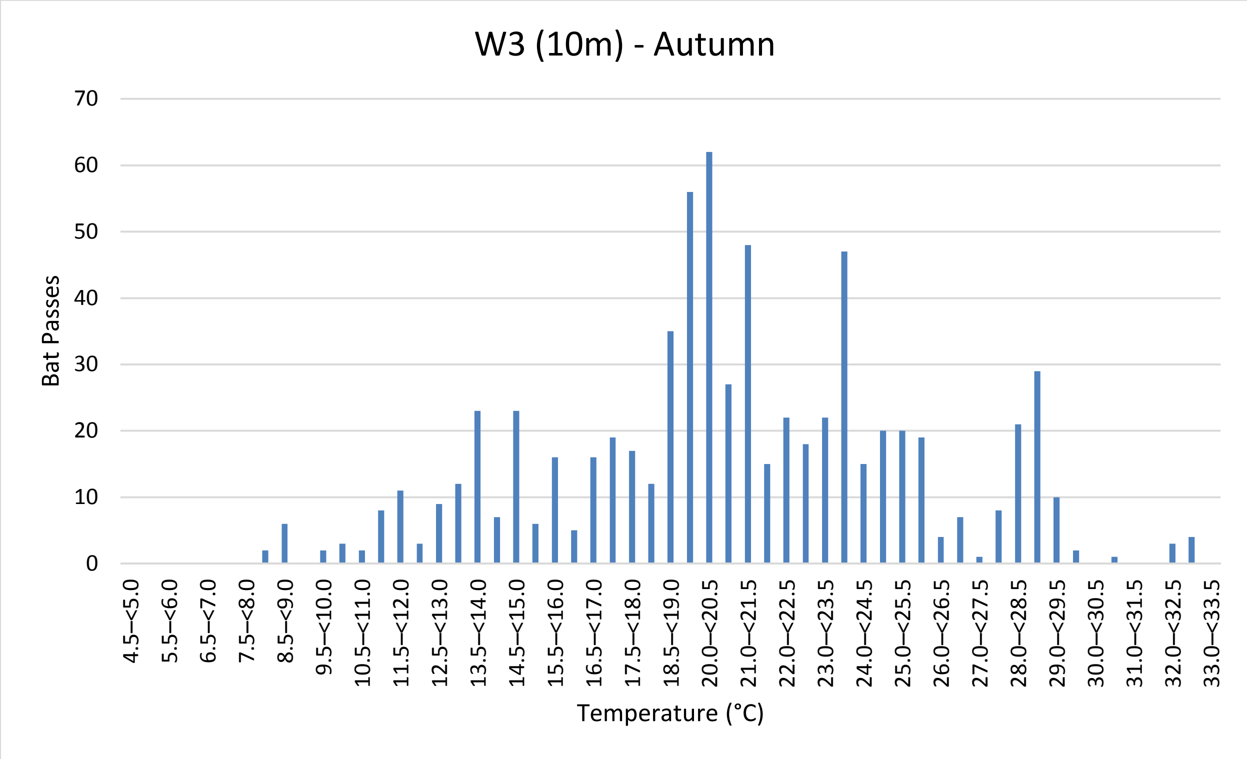


Figure 28: Cumulative percent of bat passes and normalised passes per wind speed range for W3 (10m) (autumn)



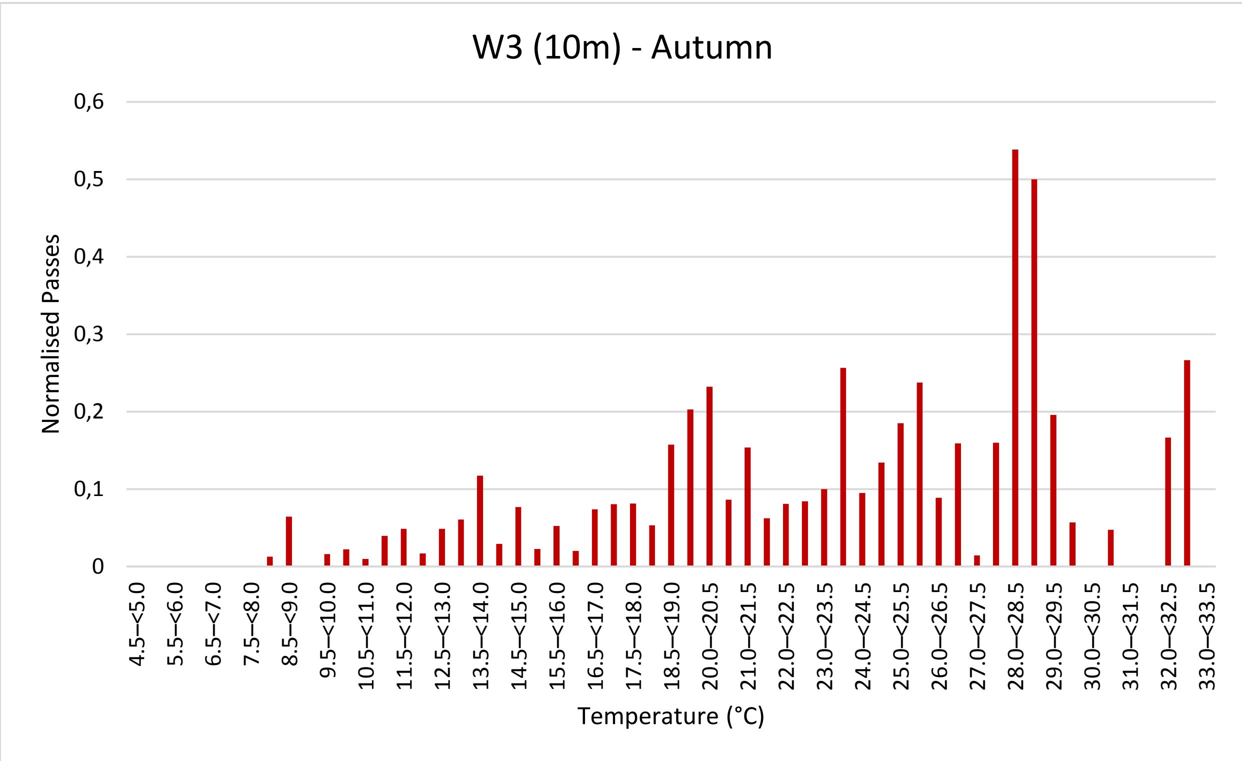


Figure 29: Bat passes and normalised passes per temperature range for W3 (10m) (autumn)

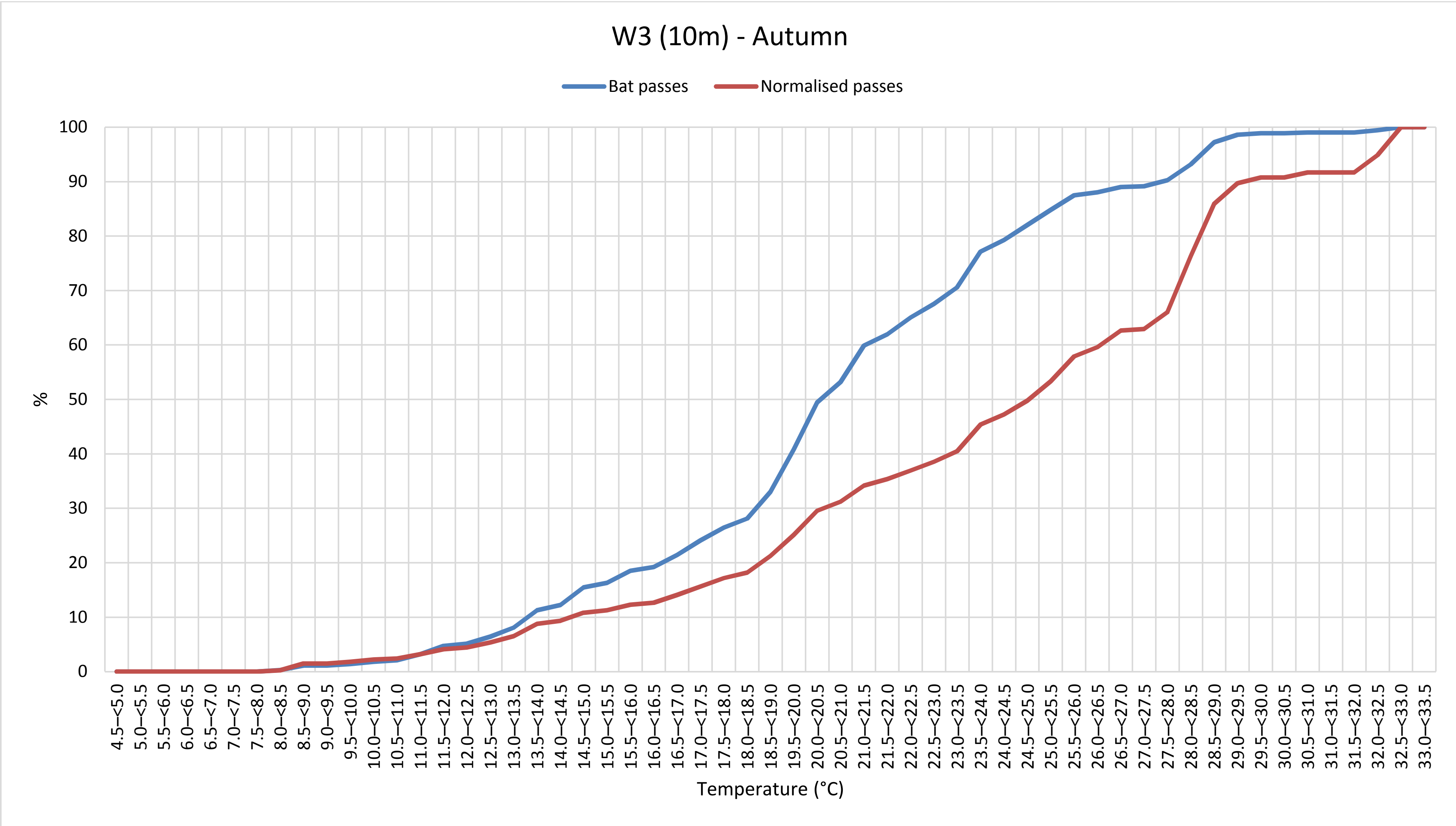
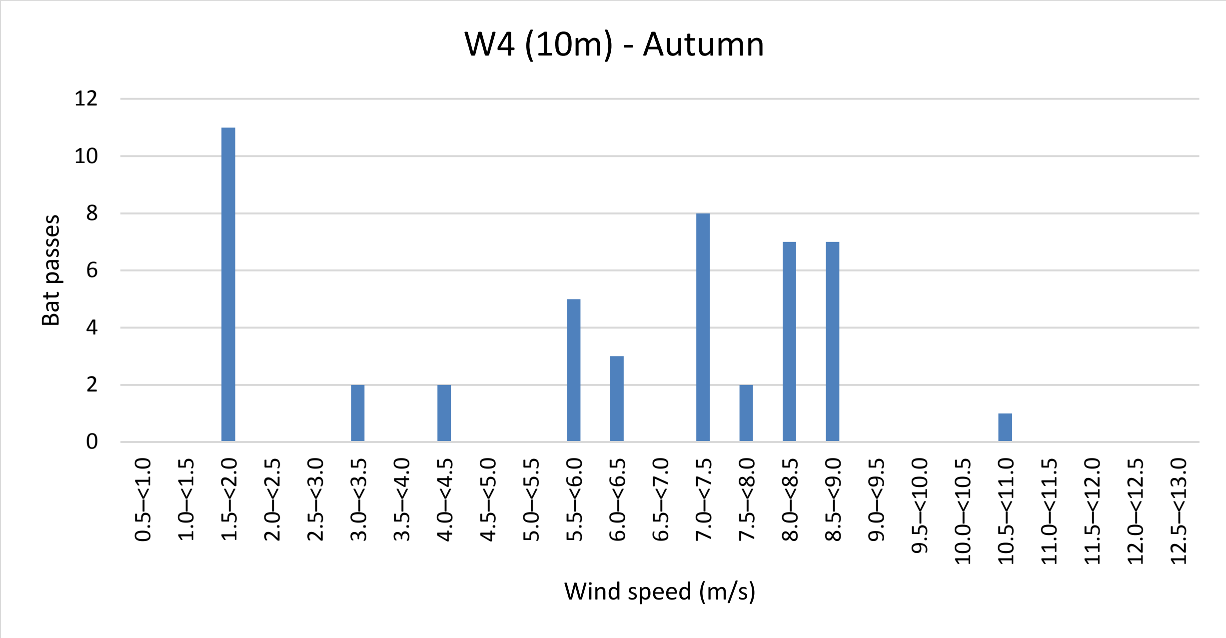


Figure 30: Cumulative percent of bat passes and normalised passes per temperature range for W3 (10m) (autumn)



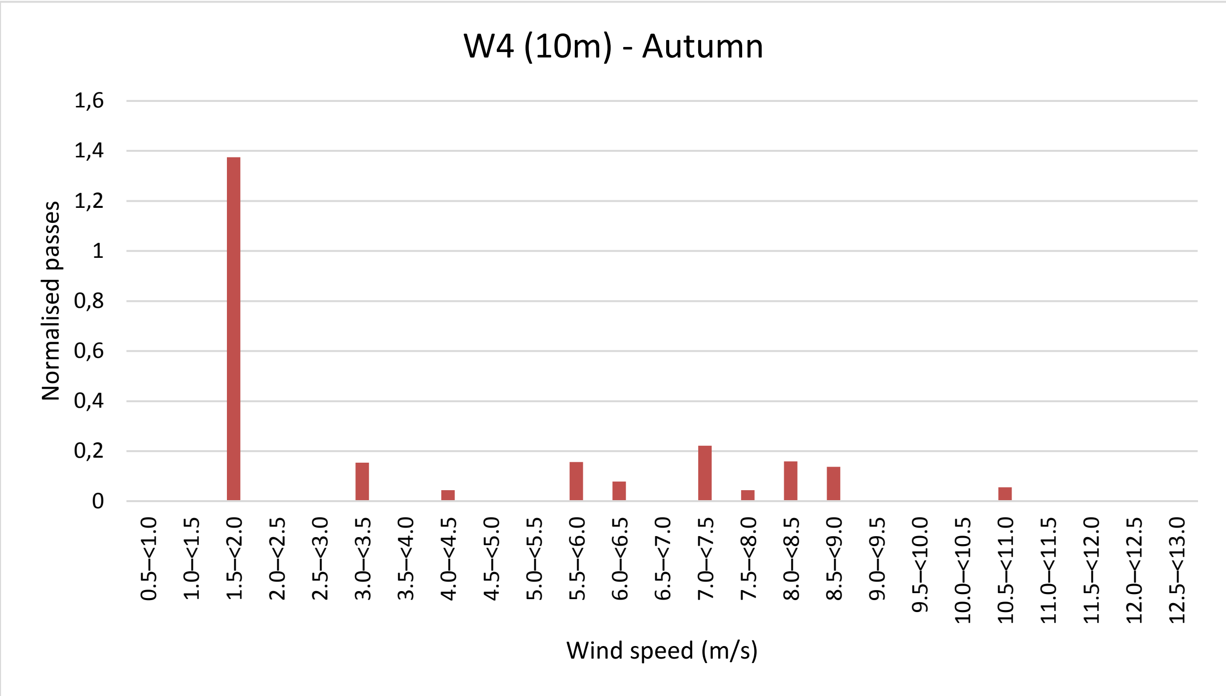


Figure 31: Bat passes and normalised passes per wind speed range for W2 (60m) (spring)

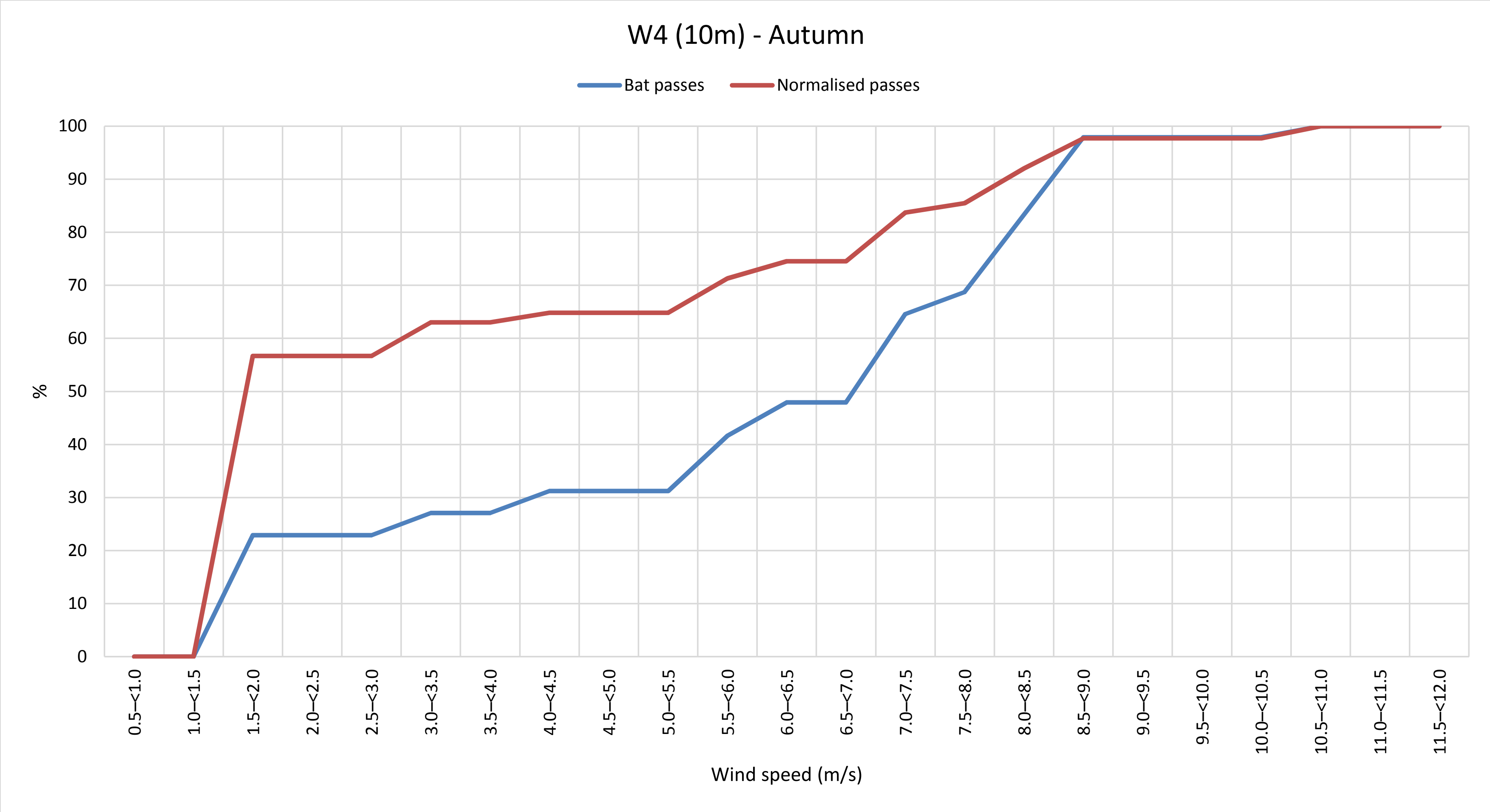
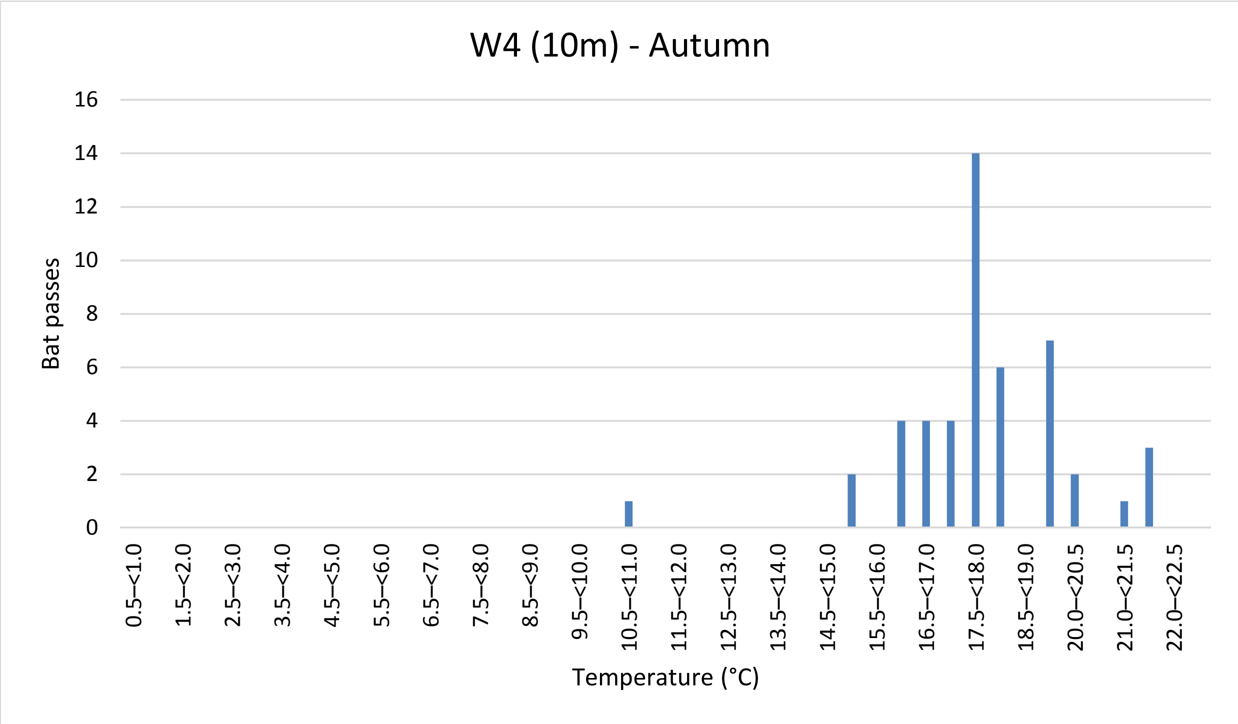


Figure 32: Cumulative percent of bat passes and normalised passes per wind speed range for W4 (10m) (autumn)



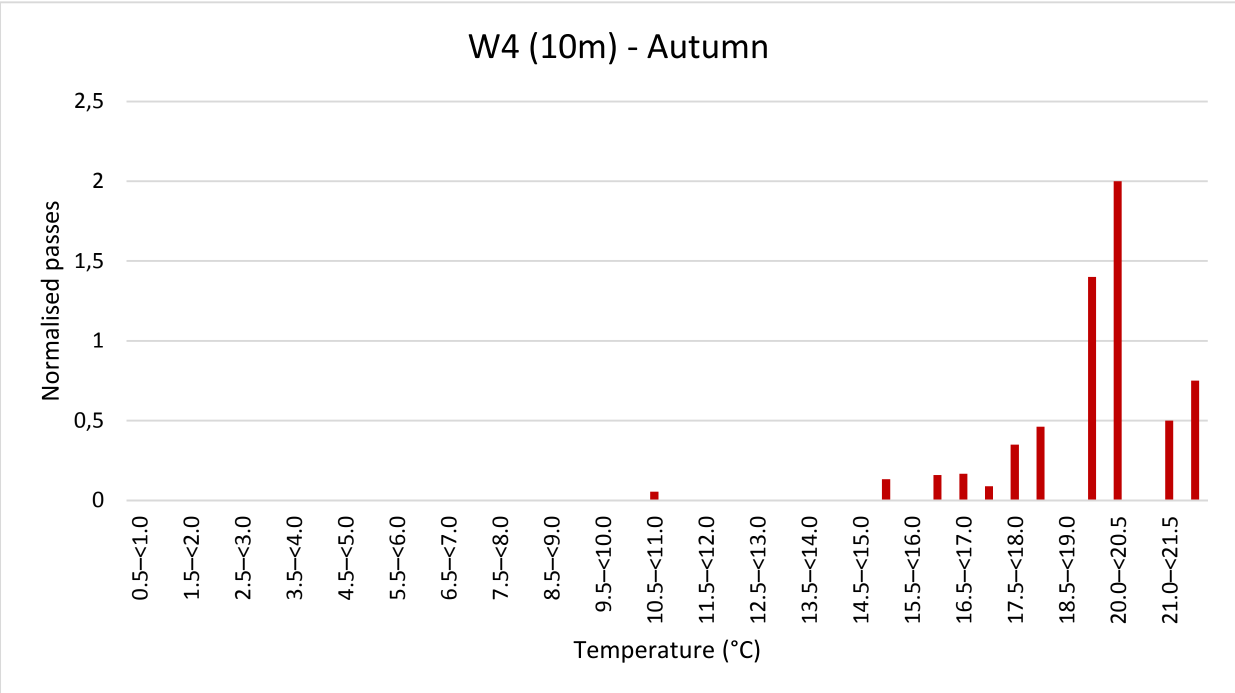


Figure 33: Bat passes and normalised passes per temperature range for W4 (10m) (autumn)

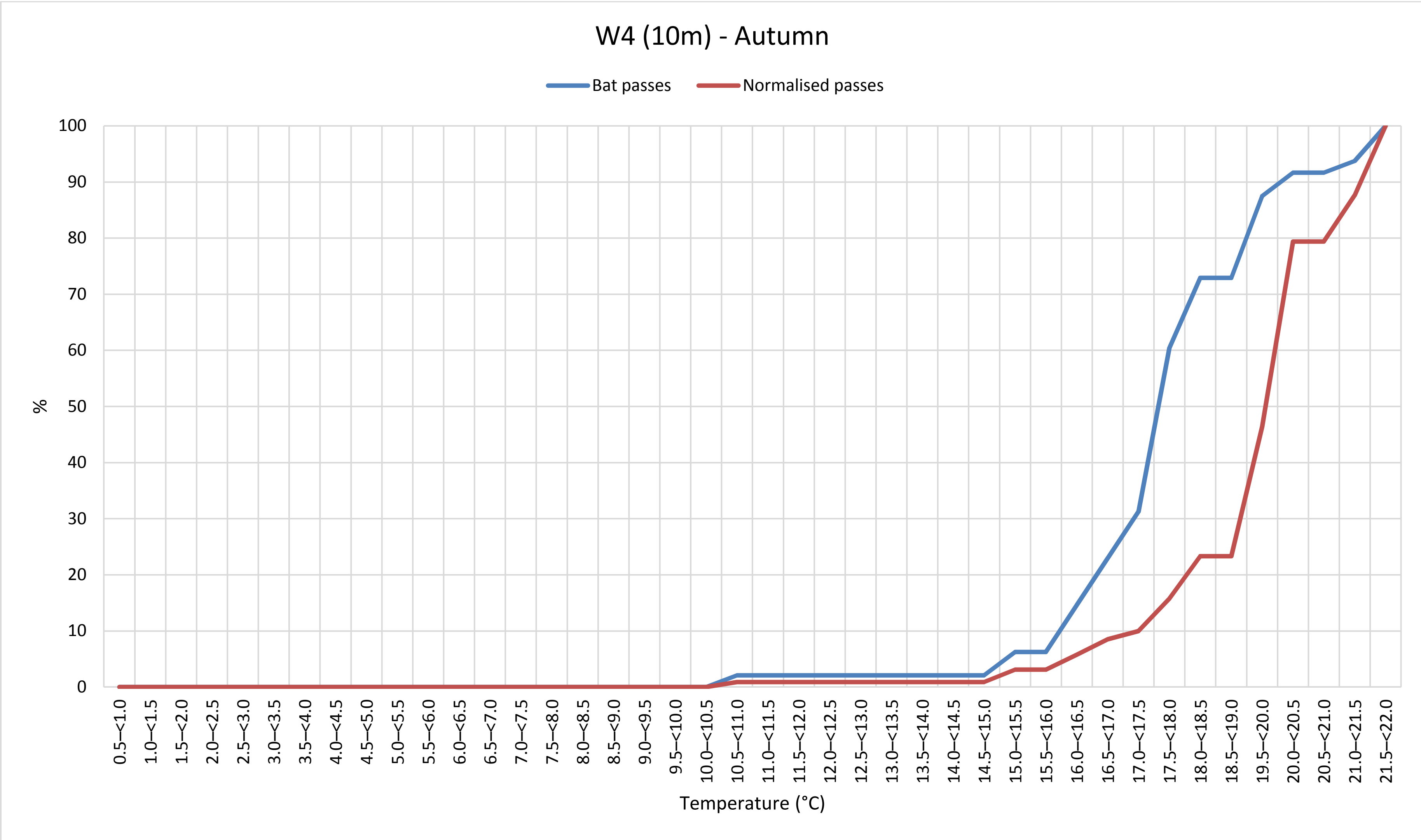
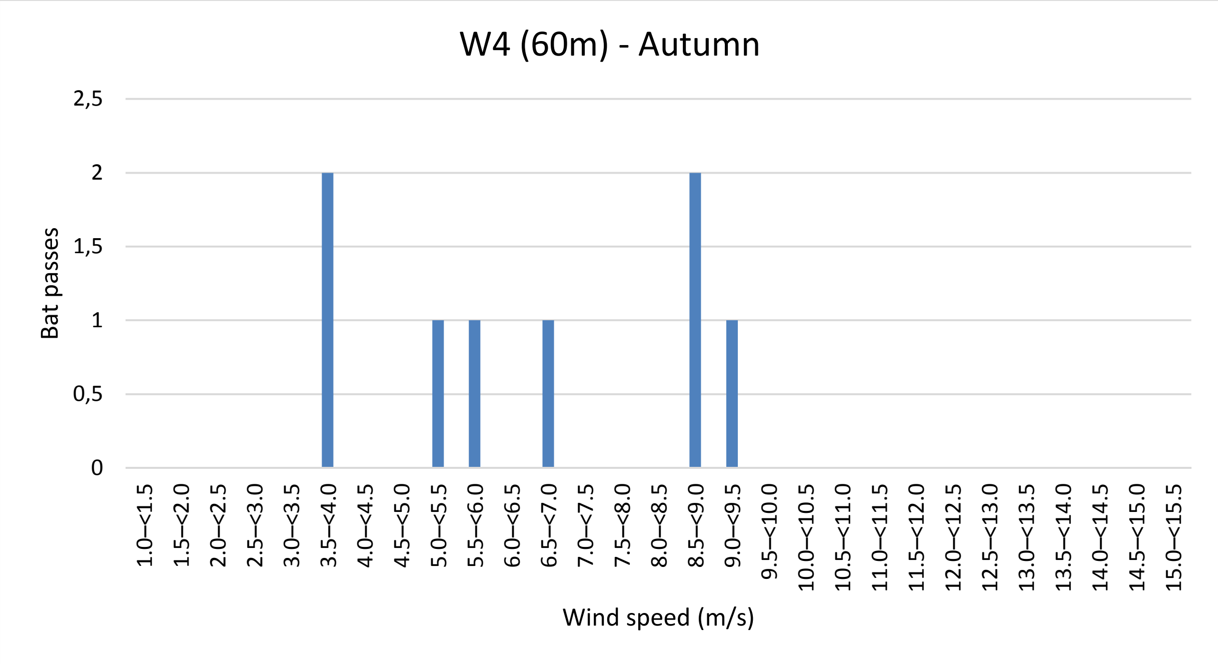


Figure 34: Cumulative percent of bat passes and normalised passes per temperature range for W4 (10m) (autumn)



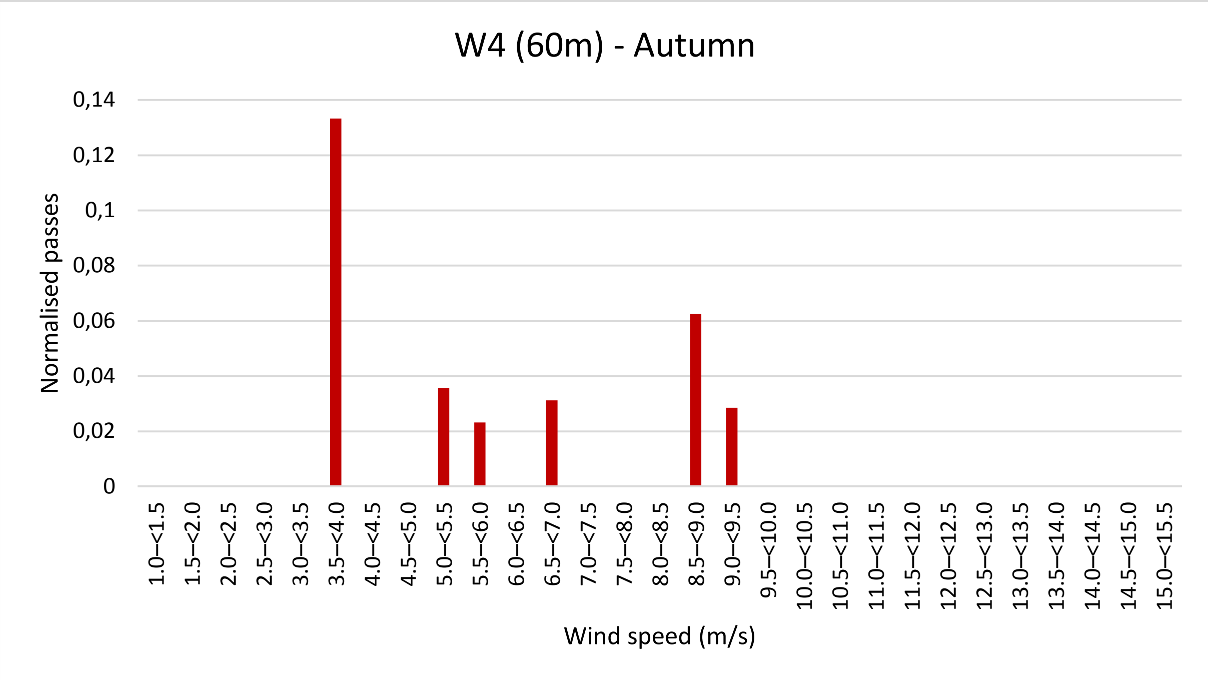


Figure 35: Bat passes and normalised passes per wind speed range for W4 (60m) (autumn)

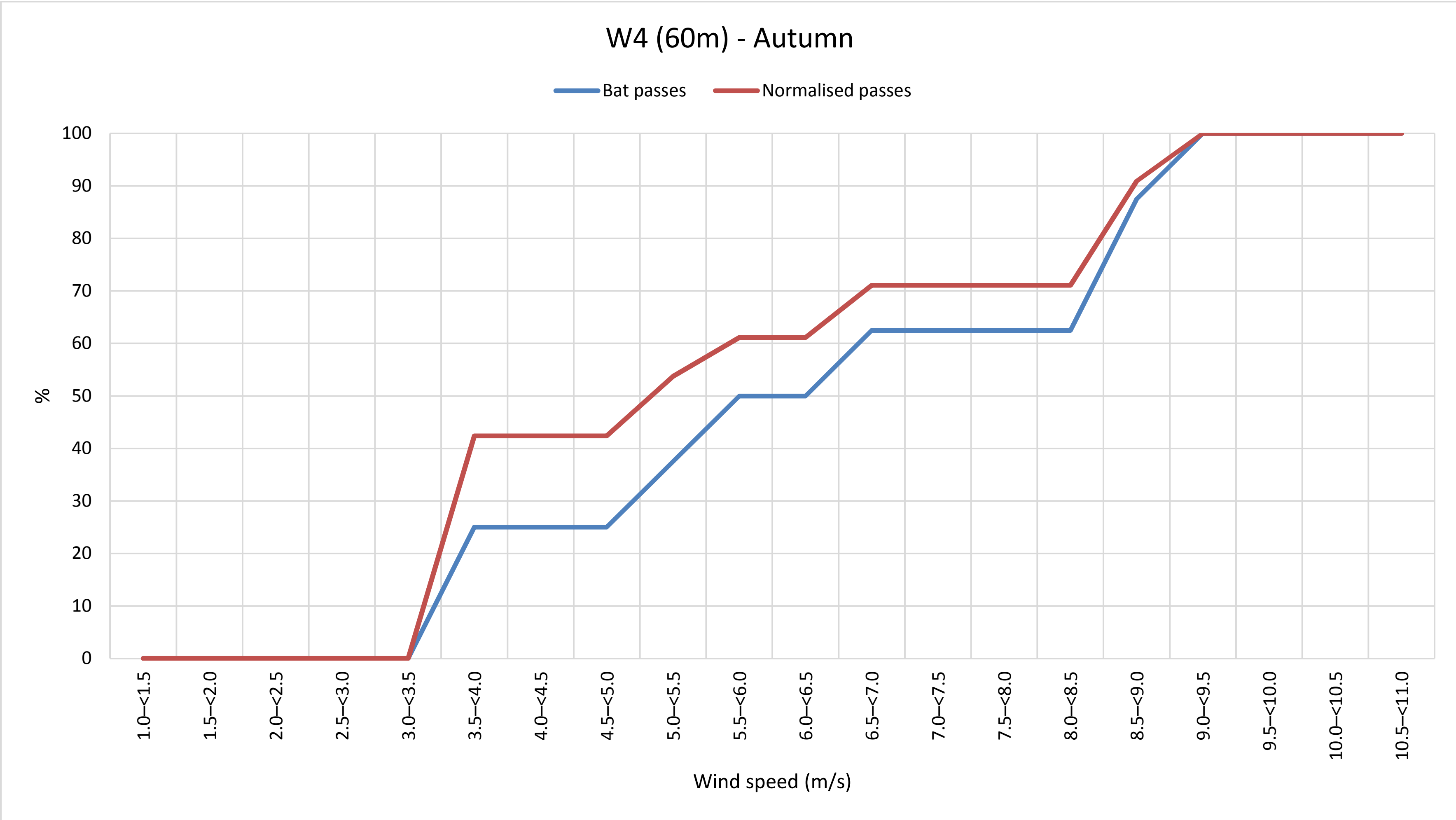
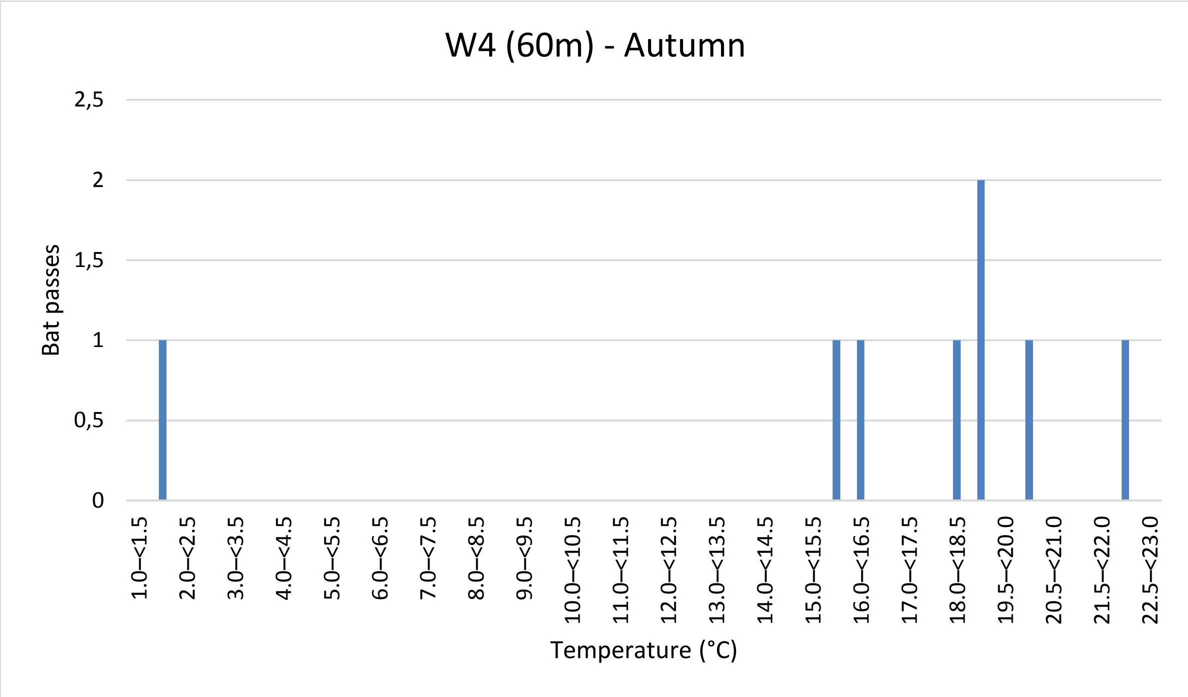


Figure 36: Cumulative percent of bat passes and normalised passes per wind speed range for W4 (60m) (autumn)



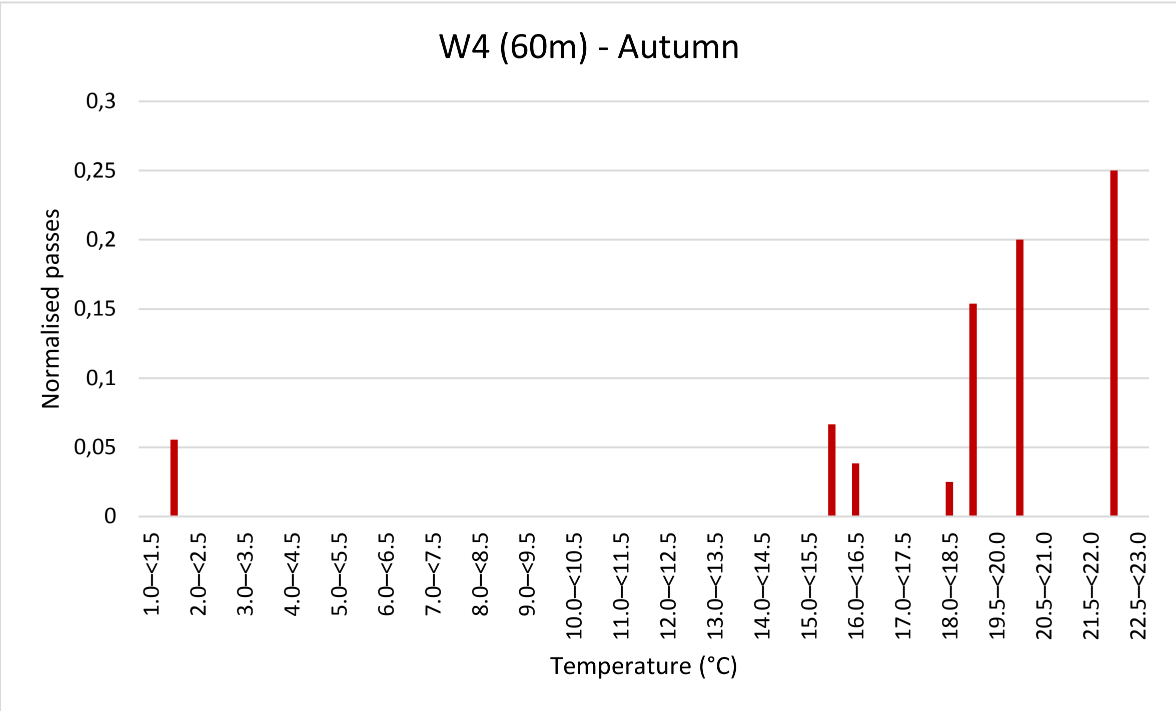


Figure 37: Bat passes and normalised passes per temperature range for W4 (60m) (autumn)

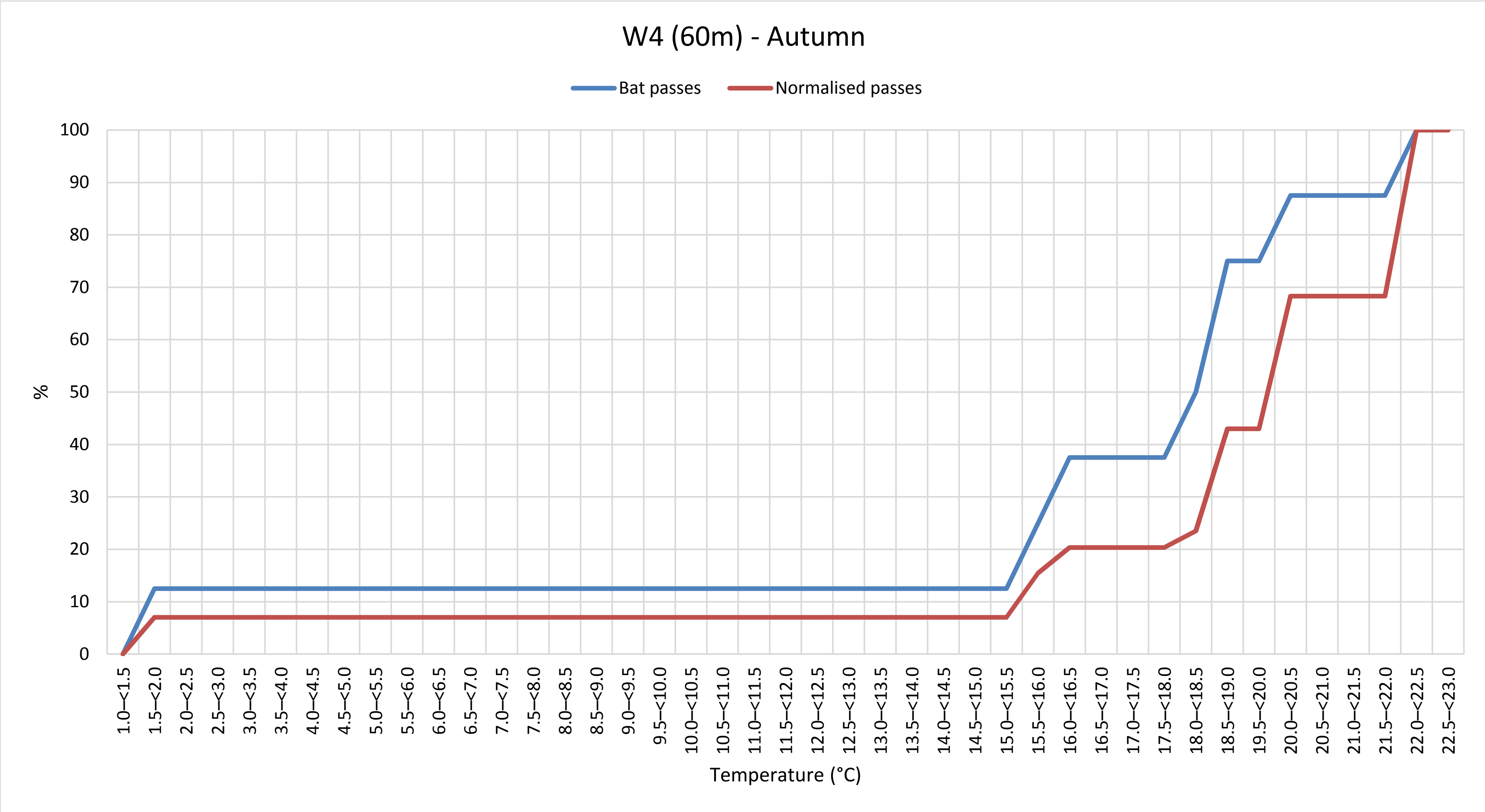


Figure 38: Cumulative percent of bat passes and normalised passes per temperature range for W4 (60m) (autumn)

5 PROPOSED MITIGATION MEASURES AND DETAILS

The correct placement of wind farms and of individual turbines can significantly lessen the impacts on bat fauna in an area, and should be considered as the preferred option for mitigation.

The mitigations are based on the passive data collected over the 12 month pre-construction monitoring study. They infer mitigation be applied during the peak activity periods and times, and when the advised wind speed and temperature ranges are prevailing (considering conditions in which 80% of bat activity occurred). Both the temperature and wind speed parameters indicated in the table must be experienced simultaneously to infer mitigation. This is due to the fact that they have synergistic or otherwise contradictory influences on bat activity and are never considered in isolation. In general bat activity is negatively correlated to wind speed and positively correlated to temperature. Mitigations will be advised on a seasonal basis when more data is collected.

Curtailment:

Curtailment is the act of limiting the supply of electricity to the grid during conditions when it would normally be supplied. This is usually accomplished by locking or feathering the turbine blades.

Cut-in speed:

Cut-in speed is defined as the wind speed at which the generator is connected to the grid and producing electricity. For some turbines, their blades will spin at full or partial RPMs below cut-in speed when no electricity is being produced.

Feathering or Feathered:

Adjusting the angle/pitch of the rotor blade parallel to the wind, or turning the whole unit out of the wind, to slow or stop blade rotation. Normally operating turbine blades are angled almost perpendicular to the wind at all times.

Free-wheeling:

Free-wheeling occurs when the blades are allowed to rotate below the cut-in speed or even when fully feathered and parallel to the wind. In contrast, blades can be “locked” and cannot rotate, which is a mandatory situation when turbines are being accessed by operations personnel.

Increasing cut-in speed:

The turbine's computer system (referred to as the Supervisory Control and Data Acquisitions or SCADA system) is programmed to a cut-in speed higher than the manufacturer's set speed, and turbines are programmed to stay locked or feathered at 90° until the increased cut-in speed is reached over some average number of minutes (usually 5 – 10 min), thus triggering the turbine blades to pitch back "into the wind" and begin to spin normally and producing power.

Blade locking or full feathering below the manufacturers cut in speed, that locks or significantly reduces the speed the blades turn, is more desirable for the conservation of bats than allowing free rotation with no feathering below the manufacturers cut in speed.

Acoustic deterrents are a developing technology and will need investigation as a possible option for mitigation if during operation mitigation is found to be required

Light lures refer to the concept where strong lights are placed on the periphery (or only a few sides) of the wind farm to lure insects and therefore bats away from the turbines. The long term effects on bat populations and local ecology of this method is unknown.

Habitat modification, with the aim of augmenting bat habitat around the wind farm in an effort to lure bats away from turbines, is not recommended. Such a method can be adversely intrusive on other fauna and flora and the ecology of the areas being modified. Additionally it is unknown whether such a method may actually increase the bat numbers of the broader area, causing them to move into the wind farm site due to resource pressure.

Power modes for turbines are the various operational modes linked to cut in and cut out and tip speeds for turbines that the turbines are designed to be able to operate at without overstraining the turbines. Different modes are used to reduce the noise output of the turbines (which also reduces the energy output) and the greater the reduction in noise the slightly slower the tip speeds are. Thus using lower noise modes will reduce the tip speed of the turbines

Currently the most effective method of mitigation, after correct turbine placement, is alteration of blade speeds and cut-in speeds under environmental conditions favourable to bats.

A basic "6 levels of mitigation" (by blade manipulation or curtailment), from light to aggressive mitigation is presented below:

1. No curtailment (free-wheeling is unhindered below manufacturers cut in speed so all momentum is retained, thus normal operation).

2. Feathering blades below manufacturers cut-in speed to as close to 70 degrees as possible or more so as to reduce the free-wheeling blade rotation
3. Feathering of blades below manufacturers cut-in speed to as close to 90 degrees as possible so as to minimise free-wheeling blade rotation as much as possible without locking the blades.
4. 90 Degree feathering of blades below manufacturers cut in speed, with reduced power mode settings between manufacturers' cut-in speed and mitigation cut-in conditions.
5. 90 Degree feathering of blades below mitigation cut in conditions.
6. 90 Degree feathering throughout the entire night.

It is recommended that curtailment initially start off at Level 3 during the dates and times set out in Table 10. Then depending on the results of the post construction mortality monitoring the curtailment can be either relaxed or intensified (moving down or up in the levels) up to a maximum intensity of Level 5. This is an adaptive mitigation management approach that will require changes in the mitigation plan to be implemented immediately and in real time during the post construction monitoring.

6 MITIGATION SCHEDULE

The correct placement of wind farms and of individual turbines can significantly lessen the impacts on bat fauna in an area, and should be considered as the preferred option for mitigation. Turbines should be removed from high bat sensitivity areas and buffer zones. However specific peak activity time frames were detected, bat species active over these time frames need to be protected from the impacts of wind turbines. Thus mitigations are advised for all remaining turbines according to the parameters listed in the table below. The tables infer mitigation be applied during the peak activity periods and times.

This schedule is intended to be used initially at the start of the operational phase, however the exact mitigation parameters will be adjusted and adapted as determined by the operational monitoring data. These changes may be applied within a few weeks after operation commenced.

Wind speed measured at 15m height on the met masts was used for analysis of 10m bat data. Wind speed measured at 60m height on the met masts was used for analysis of 60m bat data. Temperature data recorded at 60m height on the met mast was used for the analysis of 10m and 60m bat data.

The times of implementation of mitigation measures is preliminarily recommended as follows:

Table 10: The times and date periods when mitigations should be applied initially at the start of the facilities operational life.

	Terms of mitigation implementation
Spring peak activity (times to implement curtailment/ mitigation)	**Applies to WTG25 in 27 Turbine layout.** **Based on monitoring station W2 60m data:** 15 September - 15 October Sunset – 00:00; and 5:00 – 6:00
Environmental conditions in which to implement curtailment/ mitigation	Below 5.5m/s measured at 60 height Above 15.5°C measured at 60m height

Autumn peak activity (times to implement curtailment/ mitigation)	**Applies to WTG10 in 27 Turbine layout.** **W3 monitoring station data:** 01 February to 15 May Sunset – 00:00; and 5:00 – 6:30	**Applies to WTG06, 07 and 08 in 27 Turbine layout.** **Applies to WTG08 and 10 in 22 Turbine layout.** **W4 monitoring station data:** 01 - 15 April Sunset – 19:30
Environmental conditions in which to implement curtailment/ mitigation	Below 11m/s measured at 15m Above 18.5°C measured at 60m	Below 7m/s measured at 15m Above 18°C measured at 60m

7 IMPACT ASSESSMENT RATING

7.1 Construction phase

Impact: Destruction of bat roosts due to earthworks and blasting

During construction, the earthworks and especially blasting can damage bat roosts in rock crevices. Intense blasting close to a rock crevice roost can cause mortality to the inhabitants of the roost.

Pre-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	On-site	Only turbine footprints and access roads will contribute to possible roost destruction
Duration	Long term	Roosts will be permanently destroyed forcing bats to relocate
Intensity	Medium	Rocky habitat forms a significant roosting habitat for several bat species in the larger site area. Roost destruction leads to increased inter and intra-specific competition resulting in decreased bat population sizes. Bat populations may be slow to recover resulting in depressed bat numbers over several years.

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	Negligible	Minor	Minor
	Medium	22 Turbine Layout: Minor (low confidence)	27 Turbine layout: Moderate (low confidence)	Moderate
	High	Moderate	Major	Major

Mitigation: Adhere to the sensitivity map during turbine placement. Blasting should be minimised and used only when necessary.

Post-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	On-site	Only turbine footprints and access roads will contribute to possible roost destruction
Duration	Long term	Roosts will be permanently destroyed forcing bats to relocate
Intensity	Low	If blasting is not conducted in bat sensitive areas, the impact on bat roosting habitat is significantly lower.

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	**22 and 27 Turbine layout: Negligible (low confidence)**	Minor	Minor
	Medium	Minor	Moderate	Moderate
	High	Moderate	Major	Major

Impact: Artificial lighting

During construction strong artificial lights used at the work environment during night time will attract insects and thereby also bats. However only certain species of bats will readily forage around strong lights, whereas others avoid such lights even if there is insect prey available.

This can draw insect prey away from other natural areas and thereby artificially favour certain species, affecting bat diversity in the area.

Pre-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	On-site	Impact is limited to within the site boundary
Duration	Temporary	Impact will persist only through the construction phase
Intensity	Low	The use of artificial lighting during construction will change the diversity and abundances of bat species within the immediate vicinity

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	Negligible	22 and 27 Turbine layout: Minor (medium confidence)	Minor
	Medium	Minor	Moderate	Moderate
	High	Moderate	Major	Major

Mitigation: Utilise lights with wavelengths that attract less insects (low thermal/infrared signature), such lights generally have a colour temperature of 5000k (Kelvin) or more. If not required for safety or security purposes, lights should be switched off when not in use.

Post-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	On-site	Impact is limited to within the site boundary
Duration	Temporary	Impact will persist only through the construction phase
Intensity	Very low	The use of artificial lighting during construction will change the diversity and abundances of bat species within the immediate vicinity

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	**22 and 27 Turbine layout: Negligible**	Minor
	Low	Negligible	Minor	Minor
	Medium	Minor	Moderate	Moderate
	High	Moderate	Major	Major

Impact: Loss of foraging habitat

Some foraging habitat will be permanently lost by construction of turbines and access roads. Temporary foraging habitat loss will occur during construction due to storage areas and movement of heavy vehicles.

Pre-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	On-site	Turbine footprints, access roads and storage areas will contribute to habitat loss
Duration	Long term	Will persist as long as structures and roads are present.
Intensity	Medium	Loss of foraging habitat will modify bat activity

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	Negligible	Minor	Minor
	Medium	Minor	22 Turbine layout: Moderate (medium confidence)	27 Turbine layout: Moderate (Medium confidence)
	High	Moderate	Major	Major

Mitigation: Adhere to the sensitivity map. Keep to designated areas when storing building materials, resources, turbine components and/or construction vehicles and keep to designated roads with all construction vehicles. Damaged areas not required after construction should be rehabilitated by an experienced vegetation succession specialist.

Post-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	On-site	Turbine footprints, access roads and storage areas will contribute to habitat loss
Duration	Long term	Will persist as long as structures and roads are present.
Intensity	Low	Rehabilitating vegetation may restore normal bat activity

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	22 Turbine layout: Negligible (medium confidence)	27 Turbine layout: Minor (medium confidence)
	Low	Negligible	Minor	Minor
	Medium	Minor	Moderate	Moderate
	High	Moderate	Major	Major

7.2 Operational phase

Impact: Bat mortalities due to direct blade impact or barotrauma during foraging activities (not migration)

The concerns of foraging bats in relation to wind turbines is discussed in Section 2.3. If the impact is too severe (e.g. in the case of no mitigation) local bat populations will not recover from mortalities.

Pre-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	Local	All bat populations in the local ecosystem will be affected.
Duration	Long term	Impact can persist during operation for the lifetime of the WEF.
Intensity	High	The ecological roles of local bat species affected will temporarily or permanently cease. There is a significant potential for a long-term reduction in the size of the population of all impacted bat species due to the low birth rates of bat populations.

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	Negligible	Minor	Minor
	Medium	Minor	Moderate	Moderate
	High	Moderate	22 and 27 Turbine layout: Major (high confidence)	Major

Mitigation*:* Adhere to the sensitivity maps, apply proposed mitigations to any further layout revisions, avoid areas of High bat sensitivity and their buffers as well as preferably avoid areas of Moderate bat sensitivity and their buffers. Also see Section 6 above on mitigation options and recommendations for minimising risk of mortalities.

Post-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	Local	All bat populations in the local ecosystem will be affected.
Duration	Long term	Impact can persist during operation for the lifetime of the WEF.
Intensity	Low - Medium	If mitigations are implemented the potential for a significant reduction in the size of the population of all impacted bat species is largely reduced.

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	Negligible	22 Turbine layout: Minor (medium confidence)	27 Turbine layout: Minor (medium confidence)
	Medium	Minor	Moderate	Moderate
	High	Moderate	Major	Major

Impact: Bat mortalities due to direct blade impact or barotrauma during foraging – cumulative impact (resident and migrating bats affected).

Mortalities of bats due to wind turbines during foraging and migration can have significant ecological consequences as the bat species at risk are insectivorous and thereby contribute significantly to the control of flying insects at night. On a project specific level insect numbers in a certain habitat can increase if significant numbers of bats are killed off. But if such an impact is present on multiple projects in close vicinity of each other, insect numbers can increase regionally and possibly cause outbreaks of colonies of certain insect species.

Additionally if migrating bats are killed off it can have detrimental effects on the cave ecology of the caves that a specific colony utilises. This is due to the fact that bat guano is the primary form of energy input into a cave ecology system, given that no sunshine that allows photosynthesis exists in cave ecosystems.

Pre-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	National	Mortality of migratory bats will affect population levels in all areas they inhabit and migrate to
Duration	Long term	Impact can persist during operation for the lifetime of the WEF.
Intensity	High	The ecological roles of these bat species affected will temporarily or permanently cease. There is a significant potential for a long-term reduction in the size of the population of all impacted bat species.

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	Negligible	Minor	Minor
	Medium	Minor	Moderate	Moderate
	High	Moderate	22 and 27 Turbine layout: Major (medium confidence)	Major

Mitigation*:* Adhere to the sensitivity map during any further turbine layout revisions, and preferably do not move any turbines into even Moderate sensitivity areas, where possible. The High sensitivity valley areas can serve as commuting corridors for bats in the larger area, potentially lowering the cumulative effects of several WEF's in an area. Also adhere to recommended mitigation measures for this project during operation. It is essential that project specific mitigations be applied and adhered to for each project, as there is no overarching mitigation that can be recommended on a regional level due to habitat and ecological differences between project sites.

Post-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	National	Mortality of migratory bats will affect population levels in all areas they inhabit and migrate to
Duration	Long term	Impact can persist during operation for the lifetime of the WEF.
Intensity	Low - Medium	If mitigations are implemented the potential for a significant reduction in the size of the population of all impacted bat species is largely reduced.

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	Negligible	Minor	Minor
	Medium	Minor	22 and 27 Turbine layout: Moderate (medium confidence)	Moderate
	High	Moderate	Major	Major

Impact: Artificial lighting at turbines

During operation artificial lights used continuously or installed permanently for security and/or other purposes at the turbines will attract insects and thereby also bats. However only certain species of bats will readily forage around strong lights, whereas others avoid such lights even if there is insect prey available.

If bats are drawn towards turbines it will increase the probability of mortalities significantly, this is especially true for the more visible colour lights (as opposed to red light) installed at the turbine base/tower door.

Pre-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	On-site	Impact is limited to within the site boundary
Duration	Long term	Impact will persist throughout operation
Intensity	High	The use of artificial lighting for prolonged periods will create bat feeding spots and thereby also areas of increased probability of mortalities.

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	Negligible	Minor	Minor
	Medium	Minor	Moderate	Moderate
	High	Moderate	22 and 27 Turbine layout: Major (high confidence)	Major

Mitigation: Utilise lights with wavelengths that attract less insects (low thermal/infrared signature), such lights generally have a colour temperature of 5000k (Kelvin) or more. If not required for safety or security purposes, lights should be switched off when not in use or connected to standard passive infrared motion sensors.

Post-mitigation:

Characteristics of impact that inform magnitude informants		
Characteristic	**Nature of impact and score**	**Rationale/Explanation**
Extent	On-site	Impact is limited to within the site boundary
Duration	Short term	Impact will persist throughout operation but only for short durations at a time.
Intensity	Very low	If mitigated lights will remain off long enough to prevent bat feeding spots to form at turbine bases.

SIGNIFICANCE				
		Unlikely	**Likely**	**Definite**
MAGNITUDE	**Negligible**	Negligible	Negligible	Minor
	Low	**22 and 27 Turbine layout: Negligible (high confidence)**	Minor	Minor
	Medium	Minor	Moderate	Moderate
	High	Moderate	Major	Major

8 CONCLUSION

The data collection and field work aspects of this study were carried out by Natural Scientific Services CC over the time period of May 2011 to May 2012. Six bat monitoring stations were used to monitor bat activity levels (described in Section 3. Methodology). During the study time frame the South African Good Practice Guidelines for Surveying Bats in Wind Farm Developments 2nd edition (April 2011) was in use, and undergoing refinement to the 3rd edition (Sowler and Stoffberg, 2012). The study was conducted in accordance with the guidelines that were current at that time. The study design differs from the current 3rd edition guidelines (Sowler and Stoffberg, 2014) in that monitoring was carried out for only 15-25% of the likely bat activity periods over the year. This limitation were factored in to the reanalysis of the study data.

A total of five different species were detected across the site namely, *Miniopterus natalensis, Neoromicia capensis, Tadarida aegyptiaca, Sauromys petrophilus* and *Rhinolophus clivosus*. Of the five detected species, *Miniopterus natalensis* has a Near Threatened conservation status.

W3 (10m) monitoring station detected the highest number of total bat passes over the year. This is most likely due to its location near the slope of the mountain ridge and its close proximity too exfoliating rock. Fewer bat passes were detected by the microphones at 60m of the met mast monitoring stations than at 10m height. This shows a vertical gradient in bat activity however, the monitoring station W2 is an exception to this as a higher number of bat passes were detected at 60m height. This may have been due to a microphone fault that was not clearly specified. The monitoring station W6 detected significantly low numbers across the entire monitoring period, the reason for this is unknown. It may have been a system failure.

An activity index of the average number of bat passes detected per night was used in Figure 10. This graph displays the seasonal trends in bat activity per monitoring station. The autumn season shows a generally higher activity index compared to the other seasons, with lowest activity over winter. Considerable levels of activity were detected over spring and summer months. This graphical representation will be influenced by the intermittent monitoring regime and system failures experienced over the year, and thus should only be taken as a guideline representation of seasonal bat activity.

The common and abundant species detected on site, *Neoromicia capensis* and *Tadarida aegyptiaca*, are of a larger value to the local ecosystems as they provide a greater contribution to most ecological services than the more rare species due to their higher numbers. Thus the activity of these species will be used to infer mitigation measures.

The Horseshoe bat, *Rhinolophus clivosus*, was detected in low numbers by only two monitoring stations, W2 and W5. This species is at lower risk of impact by the wind farm due its ecology and behaviour.

The migratory species, *Miniopterus natalensis*, was detected by all six monitoring stations and is rather prevalent on site. This species is at high risk of mortality if a wind farm is located within its migratory path. The monitoring on this site was not continuous across the year, so it cannot be concluded with full confidence that the wind farm is not located within a migratory pathway. However, no migratory event was detected over the monitoring time frames of this study.

A 27 turbine layout for the wind farm has received environmental authorisation (Figure 2), and an amended 22 turbine layout has been proposed (Figure 3). Both turbine layouts were assessed in this report. A number of turbines are located very near to the border of the high sensitivity buffers, but not within these buffers. Due to their location, it is advised that they be mitigated and not necessarily removed or relocated. **This applies to turbines WTG10 and 25** (27 turbine layout) and **WTG10** (22 turbine layout). All turbines located within moderate sensitivity buffers must also receive the outlined mitigation.

The 27 turbine layout have 3 turbines within Moderate sensitivity buffer, 2 very close to High sensitivity buffers.

The proposed 22 turbine layout has 1 turbine on the border of a High sensitivity buffer and 1 turbine within a Moderate sensitivity buffer.

It is therefore recommended that the proposed 22 turbine layout be used/authorised instead of the currently authorised 27 turbine layout, the 22 turbine layout is expected to have a lower potential impact on bat fauna.

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