Prey availability and habitat suitability assessment for birds of prey within the Brecon Beacons National Park, in the context of the reintroduction of golden eagles (Aquila chrysaetos) and white-tailed eagles (Haliaeetus albicilla) in Wales.

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Thesis summary

Successful eagle re-establishment schemes in Britain raise the possibility of reintroducing eagles to Wales. Recent studies by Williams (2020) and Lane (2021) with the conservation NGO Eagle Reintroduction Wales, identified the historical range of Welsh eagles and currently suitable release locations. However, prey species availability for raptors within Wales is poorly understood. To address this knowledge gap, prey species assessments, including rabbit, livestock carrion, and roadkill surveys, were carried out within the Brecon Beacons National Park observing existing raptor hunting habits.

Raptor sightings from mid-Wales roadside transects were recorded over eight months. Raptors (primarily common buzzards [*Buteo buteo*] and red kites [*Milvus* milvus]) were most seen during March, with a smaller October peak. Seasonal raptor sighting peaks followed roadkill biomass trends, suggesting raptors use roadkill to supplement their diet. Habitat selection models determined raptors selectively chose the 'Improved Grassland' habitat type, suggesting raptors are foraging preferentially in these areas.

Golden and white-tailed eagles consume carrion, similar to current Welsh raptors. Following EU regulation changes (2003), farmers are required to remove fallen livestock from shared grazing areas which may have negatively affected prey availability for raptors. Surveys in four 'shared common land' sites determined fallen livestock availability to scavenging raptors. No livestock remains were found on lowland sites, but some older remains were found on upland sites, suggesting that local farmers remove fallen livestock when accessible, however, less accessible sites provide intermittent prey for upland raptors.

Existing raptors within the Brecon Beacons National Park may use carrion as a major food source, from roadkill and fallen livestock in upland locations, that farmers have difficulty in accessing for carcass removal. Further study is needed within the National Park to determine the extent existing raptor species rely on supplementary feeding from local communities and official 'feeding centres' before reintroductions can be considered.

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1. Introduction

Pre-historically the land cover of the majority of Northern Europe, including the British Islands, has been temperate forest since the Last Interglacial and Holocene periods (Sandom et al., 2014). Wales, like most of what is now the United Kingdom, was at this time home to a wide range of temperate species including wild boar (*Sus scrofa*), beavers (*Castor fiber*), red deer (*Cervus elaphus*), and large carnivores such as the lynx (*Lynx lynx*) and grey wolves (*Canis lupus*) (Abyes and Yalden, 1995; Montgomery et al., 2014). Before modern humans started cultivating the land, the landscape of Britain was largely covered by some form of woodland or scrubland. During the mid-Holocene period upland areas of Wales, including parts of the Brecon Beacons National Park remained as open habitat following the Last Interglacial period. In South Wales, mixed woodland with a large proportion of hazel was believed to be up to 530 m in elevation, rising to open hazel woodland at 660 m elevation, and minimal to no tree cover above 715 m. The climate at the time suggests that higher elevations of the National Park would have at least been covered by some form of woodland, but may have been made up of birch or birch-hazel scrub as opposed to oak woodland (Simmons, 2003). On The Black Mountain within the National Park, it has been suggested that some of the open landscape was created by intensive grazing of wild herbivores, however, it is unknown if this was natural intensive grazing or encouraged by early human populations (Barton et al., 2014).

As the UK human population began to grow, and switched from hunter-gathering to cultivation, tree cover across Britain was slowly cleared to make way for agricultural land as well as providing building material for expanding villages (Innes et al., 2013; Griffiths and Gearey, 2017). As the human population increased across the British Islands, natural predator-prey interactions gave way to increased hunting and land management using livestock (Weisdorf, 2005; Cummings and Harris, 2011). This in turn further reduced woodland cover and increased open grassland, especially in upland areas where grazing livestock was more favourable than growing crops on the sloped ground (Hamilton et al., 2009). As the landscape was modified to suit an expanding human population, native species came under increasing pressure to survive in shrinking pockets of natural temperate woodland habitat. Species that were able to adapt to a more open landscape were able to survive in a rapidly changing environment.

Most change in ecological communities across the British Islands has been due to human influence, dating back to when modern humans first adopted agricultural practices in the Neolithic period (Woodbridge et al., 2014). Native wildlife populations have been greatly influenced by human recreation and agriculture, from grey wolves and lynx being eradicated due to overhunting and persecution (Abyes and Yalden, 1995; Hetherington et al., 2005), to European rabbits (*Oryctolagus cuniculus*) being introduced as a food source (Pimentel, 2002). Some introduced species like the rabbit have been established in the British environment for so long that they have become an important food source of many native British predators (Sainsbury et al., 2019). Rabbits are now a current common food source for many native British predators including native birds of prey such as red kites (*Milvus milvus*) and common buzzards (*Buteo buteo*). This, in debates considering ecological restoration in the British Isles, raises the question as to whether all non-native species should be eradicated to make way for species that were once native, but have subsequently become locally or regionally extinct, especially when the introduced species has been present longer than the native species has been extinct. There is also an argument as to what period should be considered when choosing species to re-introduce; some species like the beaver are believed to have become extinct several centuries ago. Although humans did have an influence on the extinction of the British beaver population through hunting, there are suggestions that habitat fragmentation also had an impact (Raye, 2014), raising the question as to whether a successful reintroduction into the current landscape is even possible. Despite this, beaver reintroduction projects in several parts of the British Isles have so far been successful in maintaining a small stable population, suggesting that species that have been long extinct from the British landscape have the potential to survive in the modern landscape, provided conditions are favourable (Campbell-Palmer et al., 2020). With the success of past reintroduction of red kites into England and Scotland (Wotton et al., 2002), combined with re-establishment of viable breeding populations of eagles in Scotland and Ireland (Evans et al., 2009; Mee, 2012) and a recently introduced population of white-tailed eagles on the Isle of Wight (Roy Dennis Wildlife Foundation, 2022), it is evident that parts of the modern British landscape are still favourable to native eagle species that have previously become regionally extinct.

Species reintroduction is defined as the process of translocating a species to parts of its natural range where it has become extinct or non-viable (IUCN, 2013). Reintroduction schemes can not only benefit the species being reintroduced, but when done correctly can have a positive influence on the whole ecosystem, increasing biodiversity and ecosystem resilience (Ripple and Beschta, 2012). Within the United Kingdom one of the most notable reintroduction schemes was re-establishing a viable red kite population in Britain outside its remaining ancestral range in mid-Wales, a scheme that was so successful the red kite is now one of the most abundant birds of prey in the UK (Wotton et al., 2002). The red kite population decreased rapidly over the 19th Century due to persecution and changing land use, reaching a low point of less than 15 breeding pairs in the 1930's when the remnant Welsh population went through a severe bottleneck (Davies, 1993). Nest protection, along with increased legislation for the protection of birds of prey, enabled the species to slowly increase in mid-Wales, and over the subsequent decades the population expanded its range through a "rolling front" strategy into the rest of the United Kingdom (Newton et al., 1994) bolstered by active reintroduction schemes in England and Scotland. The considerable success of red kite reintroduction schemes across Britain raises the possibility of reintroduction of golden and white-tailed eagles into Wales, using similar smaller-scale schemes, to support a wider viable population across the British Isles.

Raptor species reintroduction success relies on habitat conditions in the intended release location and the wider reintroduction region being suitable for survival, reproduction, and long-term population persistence (Kleiman et al., 1994). Before a release project can be considered, certain factors need to be investigated in the proposed reintroduction region to determine its suitability. The International Union for Conservation and Nature (IUCN) guidelines for reintroduction (2013) state that the first step in determining reintroduction feasibility is to identify the biotic and abiotic requirements of the species including: habitat type; climate; food source; and resources for reproduction. Once these have been identified, potential release areas can be assessed for reintroduction suitability. The Welsh landscape has changed considerably since golden and white-tailed eagles were both last present in the late 19th Century (Williams et al., 2020; Lane, 2021). Increased demand for food following the Second World War, coupled with advancements in agricultural technology resulted in land being farmed more intensively, putting increased pressure on soil and biodiversity

(Robinson and Sutherland, 2002). As intensive farming practices increased and agricultural land expanded, upland areas of Wales were more commonly used for grazing livestock, which reduced upland scrub coverage (Wathern et al., 1988) with upland heather moorland being reduced by 20% between 1947 and 1980 (Winter et al., 1998). Since eagles were last present in the Welsh landscape, changing land use has resulted in woodland cover in the United Kingdom dropping to only 17%, which is approximately half of the current European average of 37% (Burton et al., 2018). Even though golden eagles don't use closed woodland habitats and therefore would not be affected by reduced woodland cover, they do use upland scrubland habitats. White-tailed eagles tend to inhabit more coastal areas, but have been known to hold inland ranges near large bodies of freshwater. When occupying coastal habitats, white-tailed eagles nest in cliff faces. However, both white-tailed and golden eagles nest in large mature trees when occupying inland habitats, often trees known as 'standards' in semi-open scrubland with a preference for scots pine (*Pinus sylvestris*), larch (*Larix spp.*), or birch (*Betula spp.*) when they are available (Watson, 2010). White-tailed eagles are more likely to use wooded areas for nesting than golden eagles (Evans et al., 2010), especially in areas closer to water. Lowland areas closer to rivers are often flatter and are historically more likely than upland locations, to be deforested by humans for agricultural or residential use (Lewin and Macklin, 2010). Whereas large scale woodland clearance may have not directly impacted eagles, the loss of possible nesting trees and the lack of natural regeneration may have had a negative effect on eagle breeding capability (Zeiler, 2018).

There is evidence of both golden and white-tailed eagle presence in Britain since the Mesolithic period (Holmes, 2018), including many records within the Welsh landscape (Williams et al., 2020; Lane, 2021), inhabiting a range of mountainous and open landscape habitats across the region (Moss, 2015), but persecution, landscape change, and changes in prey populations resulted in both species being driven to breeding extinction by the late 19th Century (Evans et al., 2012). Although golden eagles have never become fully extinct from the UK, a stable breeding population has never re-established itself in Wales, with occasional records of individual golden eagles mainly being dispersing birds (usually juveniles) exploring from other countries, or birds that have escaped from falconers. The presence of eagles in Wales came back into the news in 2020, when the death of an escaped

falconer's golden eagle was announced to the public. The eagle, named "Edwina" by local observers was believed to have survived in the upland area of Mid Wales for around 12 years (CountryTimes, 2020). Her ability to survive for so long in the region was a striking demonstration of the suitability of the modern Welsh landscape for golden eagles, and has fuelled questions about the feasibility of reintroducing eagles into Wales. Initial studies by Williams et al. (2020) and Lane (2021) have recently been completed to identify where eagles historically resided in Wales, and the amount of suitable habitat in the modern Welsh landscape. Historical presence was discovered using archaeological records, literacy and anecdotal evidence, and locations of place names that reference the presence of eagles. Historical records of golden eagles along with distribution modelling inferred that the species existed in the upland mountainous areas of Wales, with a greater number of records around Snowdonia and northwest Wales. Historic distribution of the white-tailed eagle in Wales is more widespread. Sticking to more coastal regions the species ranged across northwest Wales, but also covered coastal regions of southwest Wales especially around the Swansea region. However, before any eagle reintroduction plans can be discussed other factors such as prey availability, inter-specific competition and threats also need to be assessed. Globally golden eagles have been known to be more associated with mountainous or open landscape habitat, generally avoiding areas with more human inhabitation, selecting upland habitat over lowland. However, they are adaptable to different habitats and have been known to use trees in lowland open areas if upland is not available (Moss, 2015). Lane (2021) suggested that the Black Mountains, situated in the northwest of the Brecon Beacons National Park has a high number of potential nest sites for golden eagles, which means the rest of the National Park could be potential feeding habitat for a future population. White-tailed eagles are more associated with lowland habitat, mainly coastal, wetlands, and estuaries, but also can be found at inland water habitat sites when sufficient food is available (Krone et al., 2013; Radovic and Mikuska, 2009). In the case of white-tailed eagles Lane, 2021 suggested that the Brecon Beacons National Park has very low availability for nesting sites. However, Caerfyrddin Bay and Pembrokeshire National Park are both located less than 100 miles from the Brecon Beacons, so there is a chance the eagles may use the Beacons as a feeding opportunity instead.

Golden and white-tailed eagles are both dietary generalists (Watson et al., 1992). Golden eagles within the United Kingdom reside mainly in the upland areas, feeding on a wide range of avian and mammalian live prey, from voles to deer calves, including red grouse (*Lagopus lagopus scotica*) and ptarmigan (*Lagopus mutus*) (Watson, 2010; Watson et al., 1993). On average golden eagles require around 300 g – 400 g which equals 5.5% - 6.5% of their body weight in food on a daily basis (Fevold and Craighead, 1958). In contrast, white-tailed eagles are mainly associated with coastlines and large bodies of water, taking both live mammals and birds as well as live fish from the water surface (Nadjafzadeh et al., 2015). White-tailed eagles on average require between 500 g – 600 g of food daily, which equates to roughly 8% - 10% of their body weight (Eriksen, 2016). Even though both species have different prey preferences, with golden eagles preferring mammalian prey and white-tailed eagles preferring fish. White-tailed eagles have been known to be opportunistic foragers and tend favour whichever prey species is more accessible, meaning when fish stocks are low they switch preference to bird or mammalian prey (Ekblad et al., 2016). Both species also rely on carrion to scavenge a proportion of their diet, especially in the winter months, as is the case for other British native birds of prey (Davis and Davis, 1981; Selva et al., 2019). Studies in western Scotland showed that when the two species live sympatrically their diets overlap by more than 90%, despite golden eagles hunting more lagomorphs and white-tailed eagles taking more fish and waterfowl (Watson et al., 1992). Golden eagles may exploit a wider range of prey when availability is low than white-tailed eagles. They also might be able to exist in environments where prey is sparse, as their larger body size and lower metabolic rate mean they can store more food reserves and fast for longer periods (Soutullo et al., 2013). Golden eagle home range size varies depending on prey availability, eagles in Scotland have been known to have home range sizes between 46-72 km^2, eagles in areas with higher food availability are able to maintain a smaller home range than eagles that have to explore a wider area to hunt (Brown and Watson, 1964). White-tailed eagles seem on average to hold a much wider range of home range sizes, across Europe white-tailed eagles have been known to hold home ranges from between 3-414 km^2 . The average home range size was around 50 km^2, with a preference to hold a range near coastal areas or near large bodies of inland freshwater (Krone et al., 2013).

The best way to successfully determine whether there is suitable prey available to eagles in Wales, is to observe what other birds of prey in the region are feeding on, where they are spending time, and to quantify the availability of potential food resources in these areas. To make a good assessment as to whether the Brecon Beacons are suitable for eagles it is important to look at ecologically similar species that already exist in the landscape. Common buzzards and inland breeding peregrine falcons (*Falco peregrinus*) share the most habitat use and diet similarities to golden eagles, with red kites and coastal breeding peregrine falcons having similarities to white-tailed eagles (Lane, 2021). Red kites and common buzzards are both prominent avian predators and scavengers within the Brecon Beacons National Park, which is one of three national parks within Wales. The peregrine falcon is a rarer breeder, specialising on avian prey up to the size of mallard duck (*Anas platyrhynchos*), and therefore showing potential dietary overlap with the two eagle species, especially the white-tailed eagle.

The Brecon Beacons National Park contains three main mountain ranges (The Central Beacons, The Black Mountains, and The Carmarthen Fans) (Appendix. 1) and consists of a mix of land uses, including agricultural, industrial, residential, and managed open hill country known as 'shared common land'. 'Shared common land' is land often owned by a national park association, local farmers have rights to graze their livestock if they abide by stocking level rules which are specific to both their farm and the common land used (Winter et al., 1998). The Hill Farming Act (1946) which was then superseded by The Agriculture Act (1967), in conjunction with the Commons Registration Act (1965) were once used to define the stocking limits on 'shared common land' in Wales and provided subsidies to hill farmers. However, the introduction of the Glastir scheme (2012) by the Welsh Government aimed to reduce stocking levels on this type of land. The introduction of 'livestock units', where species are allocated an impact value based on their ecology and age, reduced livestock numbers on common land by inducing minimum and maximum stocking rates. Sharing upland ‘shared common land’ areas with livestock means that birds of prey in Wales have a higher opportunity to feed on fallen livestock carcasses, increasing the likelihood of carrion being available in the landscape where eagles will likely be released. However, since 2003 following EU legislation, Animal Health & Local Authority recommend that deceased livestock be reported and removed from fields and ‘shared common land’ to prevent the

spread of disease (Gov.UK, 2021). Large proportions of the National Park is made up from 'Improved Grassland' for lowland areas, and 'Acid Grassland' for the upland areas (Appendix. 3). The region contains a small number of large water bodies, the largest of which being Llangorse Lake, the largest natural lake in South Wales (Duigan et al., 1999), it is also the only natural lake in the region likely to contain fish. There are three main smaller lakes in the region: Llyn y Fan Fach, Llyn y Fan Fawr (in the Carmarthen Fans range), and Llyn Cwm Llwch (in the Central Beacons range). The National Park also contains some unnatural large water bodies: Crai Reservoir, Usk Reservoir, Talybont-On-Usk Reservoir, and Grwyne Fawr Reservoir. These reservoirs, along with The Brecon and Monmouthshire Canal are popular fishing locations, and could also be possible fishing locations for future white-tailed eagles. Llangorse Lake reminds the most likely candidate for a potential hunting location for raptor species, it has been suggested that resident peregrine falcons regularly use the lake as a food source for waterfowl. Apart from Llangorse Lake and the four reservoirs in the region there is a lack of large water bodies to provide a large fish supply to future white-tailed eagles, but their diet might be supplemented elsewhere.

The range of land uses within the National Park provides a variety of habitats for many species that could be deemed as prey for the current bird of prey population and potential prey for reintroduced eagles. Understanding the habitat associations and feeding patterns of resident birds of prey, and the prey resources that are currently available for them, can help to quantify the potential prey availability for reintroduced eagles in the future. However, quantifying the availability of food resources also needs to consider the differences in habitat association, prey preference, and foraging strategies not just between eagles, peregrine falcons, red kites, and common buzzards, but also between golden eagles and white-tailed eagles. Predator-prey interaction studies between both eagle species and their prey have been carried out in Scotland (Whitfield et al., 2009), providing a framework for understanding which prey species populations should be assessed in the Brecon Beacons National Park.

Understanding how birds of prey currently existing within the Brecon Beacons National Park interact with their habitat, prey, and human disturbance is also important to determine whether eagle species could potentially survive in the landscape. The UK has a long history of bird of prey persecution, which resulted in the significant decline of red kite populations,

as well as being a factor in the extinction of eagles within Wales in the mid-1800's (Dennis et al., 1984; Smart et al., 2010). Persecution of birds of prey is illegal within the UK, as set out in the Wildlife and Countryside Act (1981). However, there are still regular cases of raptor persecution within the UK involving poisoning, shooting, and trapping of birds of prey. In 2020 alone there were 104 confirmed cases of raptor persecution within Britain. Five of these were confirmed within Wales (Wildlife and Countryside, 2021), but only one case resulted in a conviction. One of the biggest raptor persecution cases within Wales took place in 2013 on Glanusk Estate, a privately owned estate located Northwest of Crickhowell, Powys. A total of 15 dead birds (eight common buzzards, five red kites and two common ravens) and nine poisoned baits (dead ring-necked pheasants) were found, the case was considered to be "the second highest recovery of poisoned raptors in the UK in the last 40 years" (RSPB, 2013; Wales Online, 2016). Despite charges being made to the persecutors involved in the case, no successful prosecutions resulted. Even in cases where prosecutions are successful, repercussions for offenders are still comparatively low and finding enough evidence to prosecute is often hard. Bird of prey persecution is still an issue within Wales; even the post-mortem of "Edwina" the golden eagle found evidence of lead shot lodged in her corpse. The post-mortem showed that the injuries caused by the lead shot were old and did not directly cause her death (Wales Online, 2020). It did, however, suggest that bird of prey persecution is still an issue in Wales. Determining the impact of persecution on bird of prey populations with the Brecon Beacons National Park is integral to the success of a potential released eagle population. One of the key indicators of persecution impact is habitat use in current bird of prey populations, areas that seem suitable for raptors may not be supporting raptor species despite being ideal conditions.

1.2. Aims, Objectives and Hypotheses:

The overall aim of this study is to determine whether there is a suitable amount of prey available to support an introduced population of golden and/or white-tailed eagles, while still supporting existing bird of prey populations.

Specific objectives within this aim included:

1. Determining what habitat is available to birds of prey within the Brecon Beacons National Park, and what habitat types they preferentially use, testing for significant habitat preferences exhibited by common buzzards and red kites.
2. Calculating the amount of carrion available to scavenging birds of prey both on the roadside and on the hills, evaluate whether there is a reliable source of carrion available to scavenging birds of prey within the National Park all year round, to support existing populations.
3. Estimating the population of rabbits within the Brecon Beacons National Park, to evaluate whether rabbits may support the diet of existing bird of prey populations, especially within upland areas.
4. Quantifying whether there is overall enough prey available within the National Park to support a potential future introduced population of eagles alongside existing bird of prey populations in the National Park, by examining the feeding habits of existing birds of prey, namely red kites, common buzzards and peregrine falcons.
5. Discovering whether past/recent bird of prey persecution has affected the abundance and habitat use of existing raptor populations, with birds present at lower densities in areas where persecution has taken place in the past, and determining whether bird of prey persecution would impact reintroduced eagle populations in the future.

2. Methods

2.1. Raptor road transect survey:

A series of road transects across Wales were driven a minimum of twice a day between 4th March 2021 and 4th November 2021 (the whole study period), a total of 25 transect routes were driven, ranging from 4 km to 140 km. Recording on these transects included the frequency of how often each transect was driven along with the time at which it was driven. Raptor sightings along the transects were way marked using a Garmin eTrex 10 to record GPS data points.

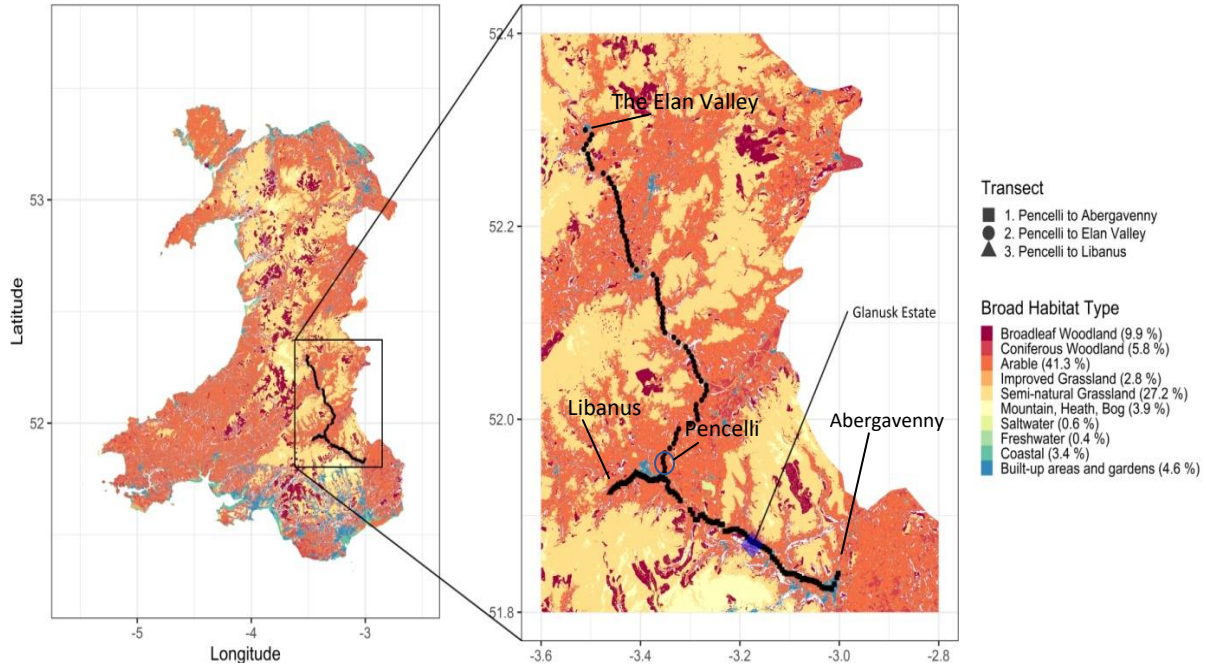

Figure 1: Landcover map displaying the three main transect routes driven from the starting point of Pencelli. Transect 1 marks the route from Pencelli to Abergavenny (squares), transect 2 marks the route from Pencelli to The Elan Valley (circles) and transect 3 marks the route from Pencelli to Libanus (triangles). The extent of the Glanusk Estate is marked in purple on the right hand panel.

A UK-wide land cover map (Landcover 2019, https://catalogue.ceh.ac.uk/documents/31f4887a-1691-4848-b07c-61cdc468ace7) was used to identify and assign habitat types along the route of the three most frequently used routes. Frequent routes were identified by being the most driven route in each compass direction from the starting location in Pencelli, Powys:

Route 1: Pencelli to Abergavenny. This route was calculated to be approximately 30 km long and was driven a minimum of twice a week throughout the whole study period between 4th March 2021 and 4th November 2021.

Route 2: Pencelli to the Elan Valley. This route was calculated to be approximately 64 km long and was driven four times a week between 29th September 2021 and 4th November 2021.

Route 3: Pencelli to Libanus. This route was calculated to be approximately 13 km long and was the most frequently driven route throughout the whole study period between 4th March 2021 and 4th November 2021, sometimes driven up to four times a day.

No route was selected for south as the direction was rarely driven. In an ideal situation routes would have been selected to coincide with all habitat types present within the National Park. However, due to Covid-19 restrictions at the beginning of the study period, route selection was limited due to travel restrictions within Wales. Route 3 was permitted to be driven throughout the whole study period and was driven daily due to the surveyor's animal commitments, Route 2 was also permitted throughout the whole study period and was driven weekly. Route 3 may have been the longest transect but wasn't permitted to be driven under original travel restrictions and wasn't present until the final three months of the study.

The habitat types used by birds of prey was then compared to the total habitat types available on these three key routes; this was used to determine whether birds of prey are selective of habitats when hunting, or whether they take advantage of all the habitat types available. The habitat composition within 500 m of each GPS recorded sighting on each route was compared with the habitat types within 500 m of regularly-spaced points generated along the same transect. The purpose of this comparison model was to determine if birds of prey were using all habitat types available to them, or if they were being selective as to where they were choosing to hunt.

2.2. Roadkill survey:

Recorded roadkill species data was used from the "Project Splatter" citizen science scheme from Cardiff University (https://projectsplatter.co.uk/, specifically using the species-specific data published by Raymond et al., 2021). The scheme encourages members of the public to report roadkill carrion using a website or mobile application, asking them to record the date, time, species, and location of the carrion. The data set was used in this study to estimate the biomass of carrion available to scavenging birds of prey. The overall dataset consists of a

wide range of species including roe deer (*Capreolus capreolus*) and muntjac deer (*Muntiacus reevesi*), both species that are not currently widespread (roe) or present (muntjac) within the Brecon Beacons National Park. These species were therefore discounted from the analysis as they would not contribute to prey availability for scavenging birds of prey within the study area. Biomass of each species reported as roadkill was calculated by collating from the literature (BTO - British Trust for Ornithology, 2021; The Mammal Society, 2021) the mean body weight of both males and females. As the sex of reported sightings are not given, the mean of male and female weights was also calculated for each species, as assumptions had to be made that 50% of reports were female and 50% were male. A UK-wide data set was used for this study to provide a large data set to calculate the biomass of each species available to scavenging birds of prey across the annual cycle. The relative amount of biomass available in each month was compared with seasonal variation in the frequency of observations of scavenging birds of prey along the road transect, to determine whether scavenging birds of prey are associated with peaks of roadkill biomass during the annual cycle. As the dataset was collected using a citizen science project, it was unclear as to what state roadkill was in when it was identified. Roadkill birds may have been identified by remains of feathers, or a rabbit by the remains of a pelt on the road, which would not provide a food source for a scavenging bird. As it is not known the condition of the roadkill individuals found, assumptions can only be made that every roadkill individual could potentially provide food. As it is unclear how much of roadkill is available to eagles, in this study it will be assumed that all of it is available. As eagles have also been observed switching prey preference depending on availability, it cannot be assumed that eagles wouldn't eat smaller carrion items if they were more available than larger items. Therefore, the dataset for each species was combined to provide 'total biomass available' instead of being split into sub-sets of possible prey types. Eagles might not preferentially feed on roadside carrion, deceased numbers on roads can also give an idea as to the number of live individuals present in the area. Higher numbers of deceased individuals may suggest higher numbers of live individuals, as when populations are higher there is a greater chance of individual road incidents. Therefore, analysing seasonal patterns in roadkill can give an idea as to population dynamics within prey species.

2.3. Peregrine falcon prey remains survey:

Saint Mary's Church, located within the centre of Brecon, an agricultural town in the Usk valley, just north of the Central Beacons mountain range, is a regular feeding station for a pair of peregrine falcons. The birds have been observed bringing prey items to the church tower and using the gargoyles as plucking posts and places to cache prey. Prey remains (feathers, bones, and other body parts) were collected from the base of the church tower each week, between November 2020 and October 2021. Collection of prey remains occurred from wherever public access was granted, including the lawn next to the War Memorial, though not all areas of the church premises could be accessed. Collected samples were dried and removed of debris before being identified to species level. Some bone samples were unable to be identified but the majority of feathers were identifiable. The Brecon dataset forms part of a larger dataset that has been collected from peregrine falcon roost sites across the UK since 1999, of which the data from the three available South Wales sites (Saint Mary's Church, Brecon; Llandaff Cathedral, Cardiff; Cardiff City Hall) was extracted. Although data from the South Wales sites dates back to March 2008, not all sites were consistently surveyed until the period of November 2020 to October 2021. Data within the period was collected by the study's main surveyor at Saint Mary's Church, Brecon, and two additional surveyors collected at Llandaff Cathedral, Cardiff and Cardiff City Hall, all remains were sent to an external expert for identification (Doctor Edward Drewitt, Bristol University). This data provided information as to potential dietary overlap with mainly white-tailed eagles, but it could also provide an overlap with golden eagles as the studied peregrine falcons were mainly inland feeders. Eagles are unlikely to catch the smaller bird species identified in this dataset, but some of the larger waterfowl that make up peregrine falcon diets may also be caught by both eagle species if the opportunity arose. White-tailed eagles would have the biggest dietary overlap in this region as the Brecon Beacons National Park contains no coastal habitat and only has a few inland lakes and reservoirs, meaning any possible white-tailed eagles may have a feeding preference for larger waterfowl if they are more available than fish species.

2.4. Visual surveys of prey availability:

Four sites (A,B,C and D) were identified within the Brecon Beacons National Park (Appendix. 1). The study was planned during the Covid-19 pandemic, during which time access to public spaces within the Brecon Beacons National Park was prohibited by the Welsh Government, and later restricted when full lockdown rules were lifted. With the uncertainty of Wales returning to restricted travel during the study period, site choice was limited to areas that were easy for the surveyor to reach. All sites were located within 15 miles of the surveyor's home and two were accessible without the use of a car. This meant that if Wales returned into full lockdown during the study period, at least half of the chosen sites could still be accessed for continued observation. The sites chosen were all known to the surveyor previously as sites that had livestock present all year round. Sites A and B were selected as characteristically upland hill "shared common land"; whereas sites C and D were chosen as characteristically open lowland "shared common land". Transects that took approximately an hour to complete were identified on each site, ranging from 3 km-6 km. Transects were checked weekly between 4th March 2021 and 4th November 2021, with a total of 36 surveys of each transect route. Evidence of fallen livestock was marked using a GPS unit and where possible evidence was identified as "sheep" or "lamb" if identification was possible, age assessment was made purely on carcass or bone size although no formal measurements were made. When incomplete skeletons were found, or if clear age or species identification was not possible, evidence was labelled as "remains". GPS points were mapped onto their respective transects to determine similarities in their location characteristics and frequency.

Ideally, more transects would have been chosen to cover different habitat types within the National Park, to quantify the different prey species available across the whole area. Travel restrictions prevented this and limited the surveyor to sites that were located closer together. Instead of doing more transect over a bigger area, the decision was made to focus on a limited number of sites and complete regular weekly surveys. Therefore, instead of quantifying the amount of carrion available across the whole National Park, it was possible to determine if cumulative carrion productivity was being used up. One of the reasons transects at each site followed fence lines was to ensure the same route was walked each time. Another reason was due to anecdotal observations before the study period by the surveyor that livestock remains were more often found along boundaries or sheltered areas,

this may have been because the ill animals have removed themselves from the group to die and have chosen a sheltered location.

In an ideal situation this transect data could be used to extrapolate the number of deaths per km^2 for the rest of the National Park. However, livestock populations within the National Park are fluid and not just seasonally with the lambing season but also with weekly markets, grazing rotations and changing stocking limits. Stocking limits for each area of 'shared common land' is dictated by the National Park Authority, with certain considerations as to historical grazing rights associated with local farms. This means that the amount of livestock on any area of 'shared common land' within the National Park could change even on a weekly basis. Therefore, the amount of livestock carrion found on a weekly basis on any site would not be a true representation of the number of livestock present in the National Park and the amount of potential carrion available to scavengers.

2.4.1. Visual surveys of prey availability: Study Locations:

Site A - The Bryn:

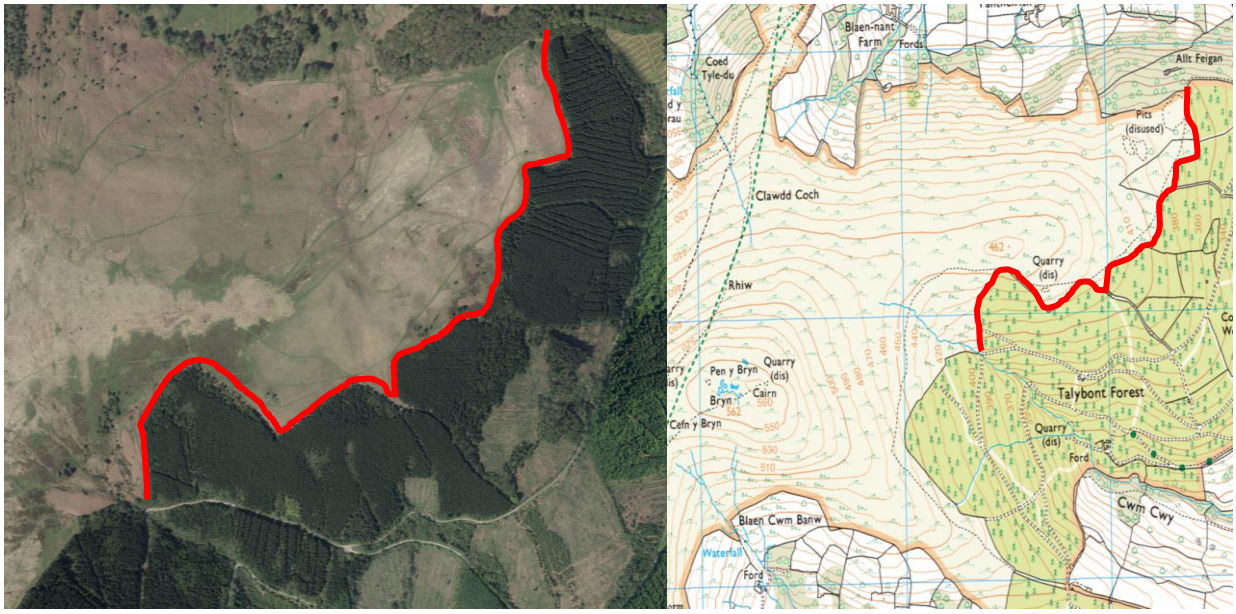

Figure 2: Aerial photograph from Google Maps and an excerpt from OS Map OL12 of Site A, the red line shows the transect walked along the boundary wall between The Bryn and Talybont Forest.

The Bryn is a hill located on the edge of the Central Beacons mountain range, above the villages of Llanfrynach and Pencelli, it stands at 562 m tall. The Bryn is classed as upland shared common land, it's habitat mainly consists of open scrubland with very little tree cover. The hillside is grazed February - November by approximately three separate herds of

sheep. The transect was chosen to follow a boundary wall marking the edge of Talybont Forest, this was because preliminary observations found that remains were more likely to be found by boundary edges (fences and walls). The transect was approximately 2 km in length from the hill boundary gate to the Talybont Forestry access gate, a route that took one hour to walk (Fig. 2).

Site B - Mynydd Llangorse:

Figure 3: An aerial photograph from Google Maps and an excerpt from OS Map OL13 of Site B, the red line shows the transect walked along the boundary fence line at the base of Mynydd Llangorse.

Mynydd Llangorse is located above Llangors Lake, alongside the village of Llangors, it stands at 515 m tall. Mynydd Llangors is classed as shared common land, it's habitat mainly consists of open scrubland covered with a large area of bracken and very little tree cover. The hillside is grazed in the spring and summer months by herds of sheep owned by local farmers. The chosen transect follows the boundary fence line along the base of the mountain, similar to Site A preliminary observations found remains were more likely located along the bottom fence-line. The transect followed the fence from the base of Mynydd Llangorse and Mynydd Troed, to the intersection with the logging road from Gilfach. The transect was approximately 3.5 km in length and took one hour to walk (Fig. 3).

Site C - Brecon Mountain Centre and Mynydd Illtyd:

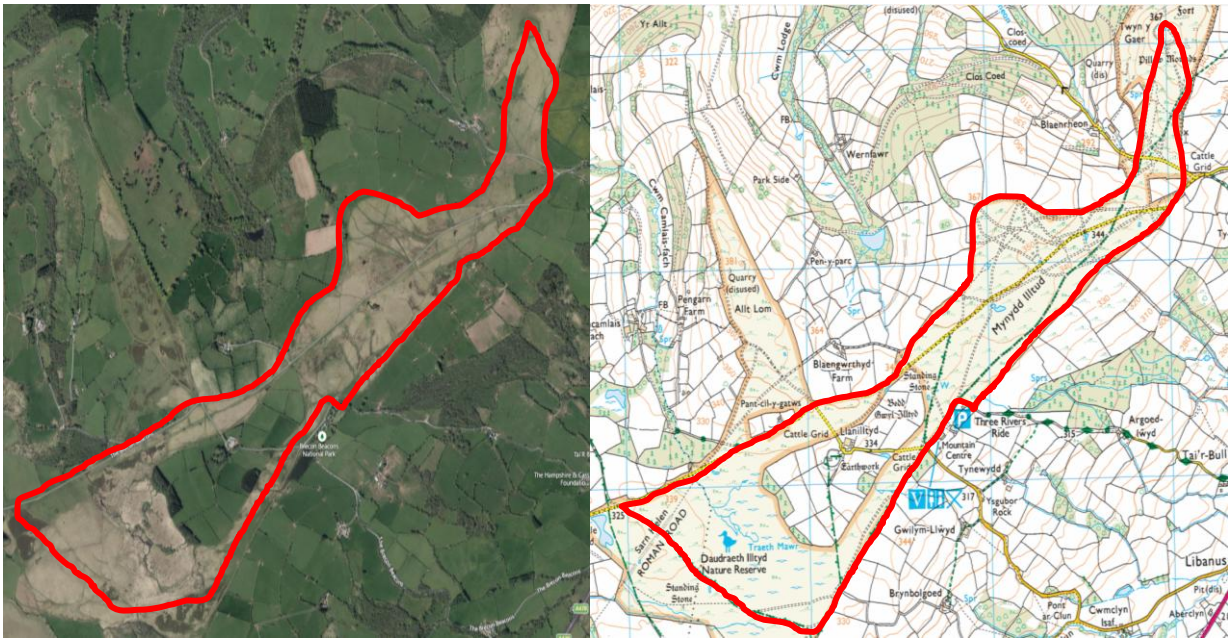

Figure 4: Aerial photograph taken from Google Maps and an excerpt from OS Map OL12 of Site C; the red line shows the circular transect ridden around the edge of Brecon Mountain Centre.

Brecon Mountain Centre and Mynydd Illtyd is located above the village of Libanus and includes the main visitors' centre for the Brecon Beacons. The site is classed as lowland open shared common land, it is grazed through the spring and summer months by sheep herds, the land is also managed by rolling and baling bracken (*Pteridium aquilinum*) in the autumn. The land mainly consists of improved grassland with extensive bracken cover and some patches of common gorse (*Ulex europaeus*). The transect was chosen to follow the marked bridleway that goes round the edge of the whole common land area, it took approximately one hour to ride on horseback and is estimated at 9 km in length (Fig. 4).

Site D - Rhos Fach/Fawr Common:

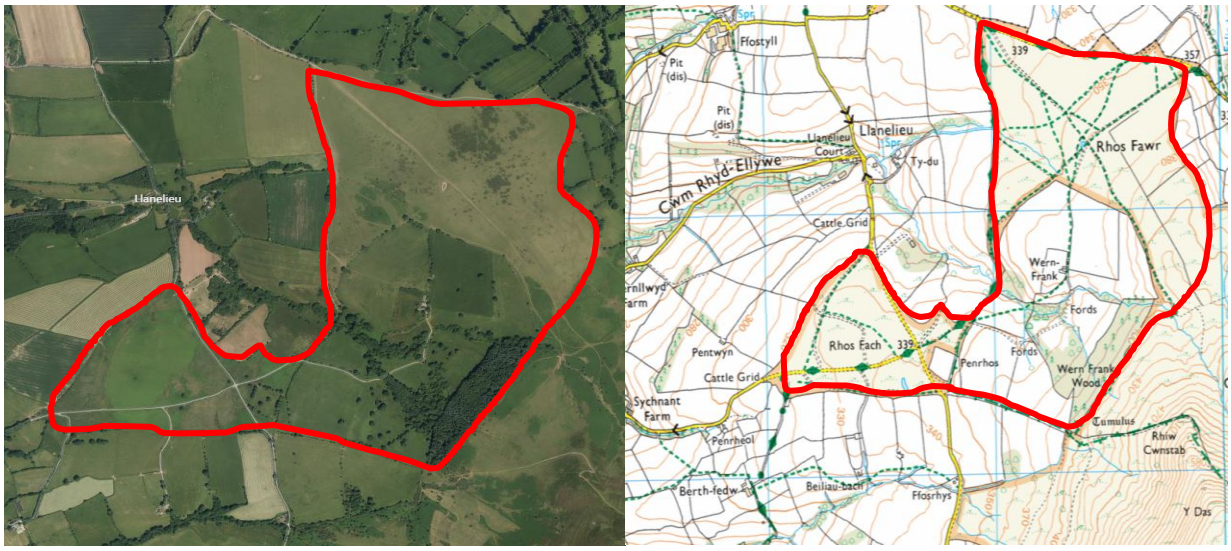

Figure 5: Aerial photograph taken from Google Maps and an excerpt from OS Map OL12 of Site D; the red line shows the circular transect walked around the fence line of Rhos Fach/Rhos Fawr common.

Rhos Fach and Rhos Fawr Common are located next to each other, above the village of Talgarth in the Northern end of the Brecon Beacons National Park. The site is considered lowland open shared common land, it is grazed through the spring and summer months by herds of sheep and two semi-feral herds of Welsh Mountain ponies, owned by the surrounding farms. The transect was chosen to follow a collection of footpaths that remained within sight of the fence-line around both commons. The route took approximately one hour to walk, and was around 5.5 km in length (Fig. 5).

2.5. Fallen livestock questionnaire survey:

Removal of "fallen" (i.e. dead) livestock has been a legal requirement in the United Kingdom since 2003 following EU regulations (Gov.UK, 2021). In collaboration with Sophie-lee Lane of the Durrell Institute, a short survey was created on the website 'Survey Monkey', consisting of ten questions, eight questions were multiple choice and two required only short one-sentence answers (Appendix. 4). Responses to the survey were kept anonymous to promote honesty with answers. Questions requested information on the removal of livestock carrion from "shared common land". To protect anonymity, no location data were requested from respondents, meaning that the data collection was not necessarily limited to farmers within the National Park. Questions asked respondents to comment on the number of livestock they typically graze on "shared common land", the average fallen livestock number they find

and the potential reasons for the animals' deaths. The survey, created on 'Survey Monkey' in November 2021 remained online for two weeks. The survey link was shared to the surveyor's personal social media network within the South and Mid Wales farming community. A total of 18 responses were gathered during this time, but the number of farmers using land within the National Park was unknown to the surveyor, so it is unclear as to what percentage of farmers were represented by the response amount. Requesting information about the number of farmers in the National Park would go against the anonymity promise given to the respondents. Therefore, the results from the questionnaire were used as only anecdotal evidence to support results from other surveys within the discussion.

2.6. Rabbit and hare density: preliminary observations

The outlined transects of sites A,B,C and D were also used to look for presence signs of European rabbits (*Oryctolagus cuniculus*) and brown hares (*Lepus europaeus*). Several survey types were attempted including stratified randomised quadrat surveys, mapping of burrows, and camera trapping. However, despite some observational sightings of footprints and a small amount of video footage from a trail camera at site C, no data were gained from the attempted surveys. Burrows were observed within farmers' fields and private land neighbouring sites C and D, but no burrow locations were found in the recorded sites. There is also a lack of records on NBN Atlas Wales, with only one site (Site A, The Bryn) having a single record from 1978, records within the National Park as a whole are patchy and inconsistent with a large jump in records from 1990 to 2020 (NBN Atlas Wales, 2022).

2.7. Data analysis:

All data analysis was carried out in R Studio (R Core Team, 2020) except for some basic calculations and simple bar charts which were completed in Microsoft Excel (Microsoft Corporation, 2018). A variety of R packages were used including lubridate (Grolemund and Wickham, 2011), mgcv (Wood, 2011), ggplot2 (Wickham, 2016), and econullnetR (Vaughan et al., 2017). Some data such as the results from the farmer questionnaire were left in their raw form with just some basic percentage calculations made for reference.

Generalised linear models (GLM) were used in a range of data analysis methods. Number of raptors observed per route was calculated by averaging the number of individual birds seen

per journey, accounting for route frequency. A GLM was used to determine if there was a seasonal pattern of raptor observations across the whole study period. Roadkill biomass was calculated, using data from 'Project Splatter', by finding the mean weight of each roadkill species (https://projectsplatter.co.uk, specifically using the species-specific data published by Raymond et al., 2021), based on the average weight of male and females, and multiplying this by the number of individuals found. For this data set, a GLM was also used to determine if there was a seasonal pattern of roadkill biomass available for feeding raptors. A similar GLM model was used to analyse the monthly prey remains found at the three peregrine falcon feeding sites. Data from all three sites were combined to give a larger dataset for analysis. A, GLM was used to determine the seasonal variation in peregrine prey remains.

Observed habitat use of red kites and common buzzards was calculated using the Landcover 2019 database (Landcover 2019, https://catalogue.ceh.ac.uk/documents/31f4887a-1691-4848-b07c-61cdc468ace7). This is a database that associates every 20m in the United Kingdom with a habitat type that are assigned a numerical value as a reference point. The database was used to assign each GPS point of a raptor observation with a numerical value that can be cross referenced with the habitat type definitions (Appendix. 2). This was applied to both the red kite and common buzzard datasets separately, to give an overall view of the types of habitats that both species are using while searching for food.

EconullnetR analysis models (Vaughan et al., 2017) were used to test whether red kites and common buzzards were selectively choosing or avoiding certain habitat types, or if they were just using all the habitat available to them proportionally. The model considered what habitat types were associated 500 m from regularly-spaced GPS points (every 0.005° of either longitudinal or latitudinal points) extracted from the Landcover, 2019 map. It then compared what habitat types were available at these regular points to the habitat types that the raptors were recorded in. Lines on the model output represent the expected number of observations in each habitat type if the birds were using the landscape freely, dots represent actual observations. White dots represent when there is no significant difference between observed and expected value. Orange dots represent when observed values were significantly higher than expected values, where raptors selectively chose to be in that habitat type. Blue dots represent when observed values were significantly lower than expected values, where raptors selectively avoided that habitat type.

3. Results

3.1. Road transect survey:

3.1.1. Number of raptor sightings monthly:

There were two main peaks in mean number of common buzzard individuals, the first within March (0.9 individuals) and the second between September and October (0.85 individuals), there was a third smaller peak within July (0.8 individuals). There was a dip in mean number of individuals observed in August (0.2 individuals) and a smaller dip between April and May (0.3 individuals) (Fig. 6).

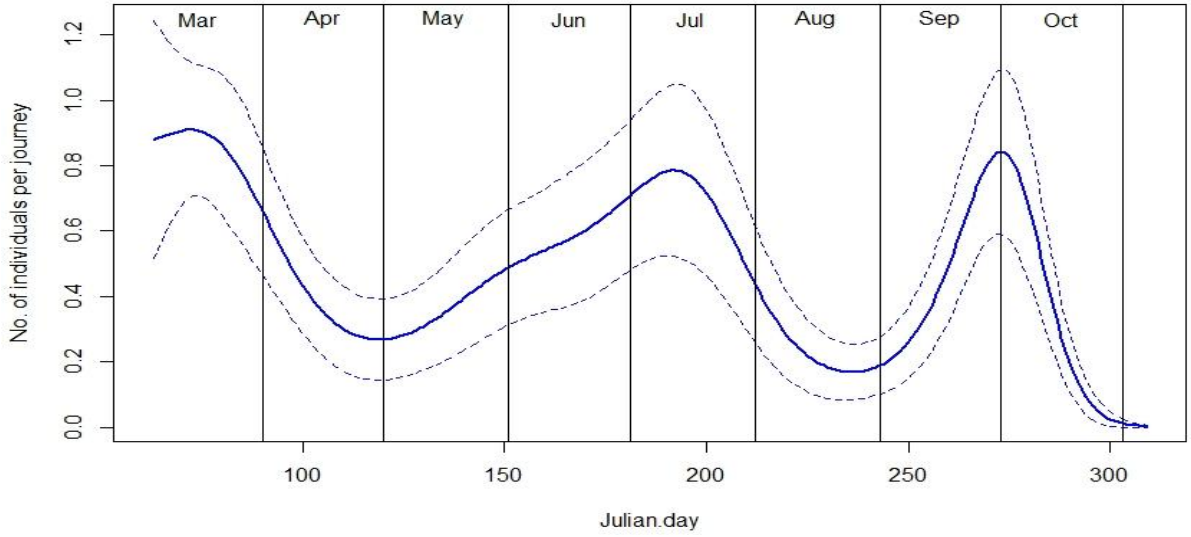

Figure 6: Mean number of common buzzard individuals observed per journey based on GPS point data (controlling statistically for journey length) across all routes relative to Julian day, split into months. Julian day values refer to the number of days from the start of the year, with 1st January being 1 and 31st December being 365. The mean number of individuals is represented by the solid blue line, with 95% confidence ratios represented by the dotted blue lines above and below the solid line.

Higher mean numbers of red kite individuals per journey were observed across all routes than for common buzzards. There were two main peaks, the first in March (2.2 individuals) and the second in October (2.0 individuals), a much smaller peak was also observed in June (1.0 individuals). A small dip in mean numbers of observed individuals occurred within early September (0.4 individuals). Journey length was controlled for statistically but not journey frequency, the second main peak in October coincided with the addition of Route 2 (Pencelli to the Elan Valley) which had a red kite feeding centre situated along the route (Fig. 7).

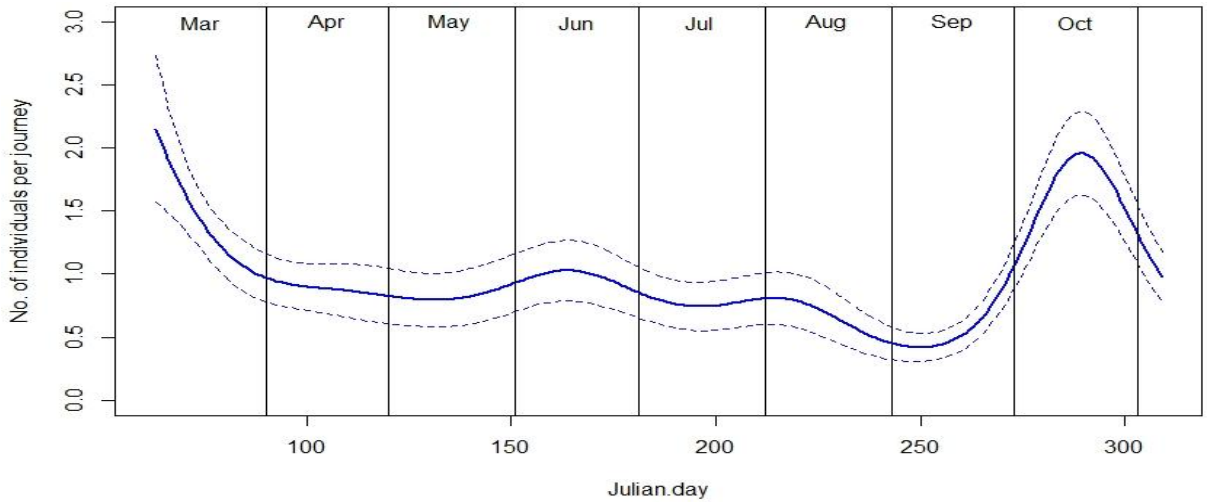

Figure 7: Mean number of red kites individuals observed per journey based on GPS point data (controlling statistically for journey length) across all routes relative to Julian day, split into months. Julian day values refer to the number of days from the start of the year, with 1st January being 1 and 31st December being 365. The mean number of individuals is represented by the solid blue line, with 95% confidence ratios represented by the dotted blue lines above and below the solid line.

3.1.2. Observed habitat use:

The most common habitat type used by common buzzards within the study was habitat type '4'; 'Improved Grassland', with the second most common being habitat type '1'; 'Broadleaf Woodland'. The habitat type used the least by common buzzards was habitat type '10'; 'Heather Grassland' (Fig. 8).

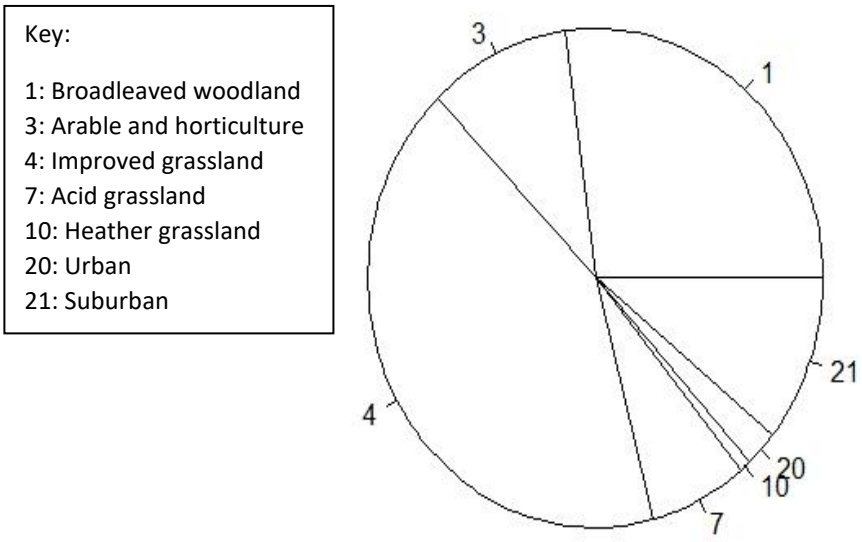

Figure 8: Habitat types identified within 20m of common buzzard sightings. Numbers represent the number coding system used by Land Cover 2019 to identify habitat types (Appendix. 2), the given key shows the numerical value and its associated habitat type description.

The most common habitat type used by red kites in the overall data set is habitat type ‘21’; ‘Suburban’, this made up 36% of the total habitat points. The second most common habitat type was type ‘4’; ‘Improved Grassland’. The least common habitat type used by red kites was habitat type ‘10’; ‘Heather Grassland’ (Fig. 9).

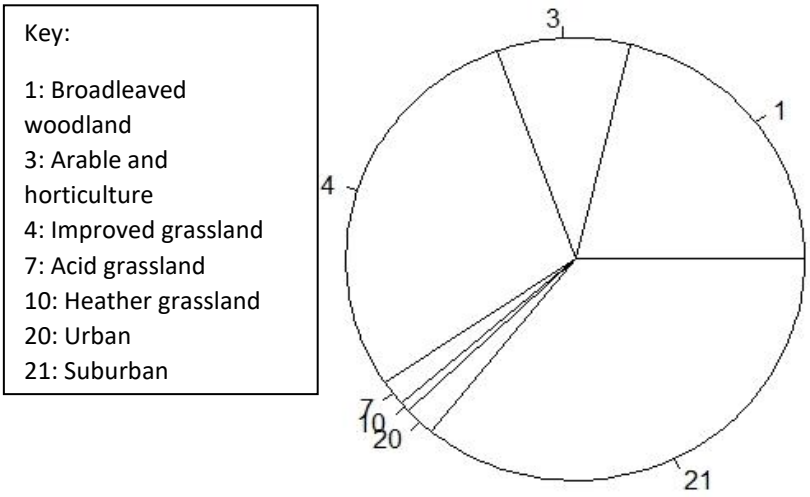

Figure 9: Habitat types identified within 20m of red rite sightings. Numbers represent the number coding system used by Land Cover 2019 to identify habitat types (Appendix. 2). This chart represents all red kite data, the given key shows the numerical value and its associated habitat type description.

Unlike Fig. 9 this figure discounts the route between Pencelli and The Elan Valley which makes up almost half of the total red kite sightings. The most common habitat type within this representation is habitat type ‘4’; ‘Improved Grassland’ and habitat type ‘21’; 'Suburban' has dropped to the second most common. The least common habitat type used by red kites within this representation is still ’10’; ‘Heather Grassland’ (Fig. 10).

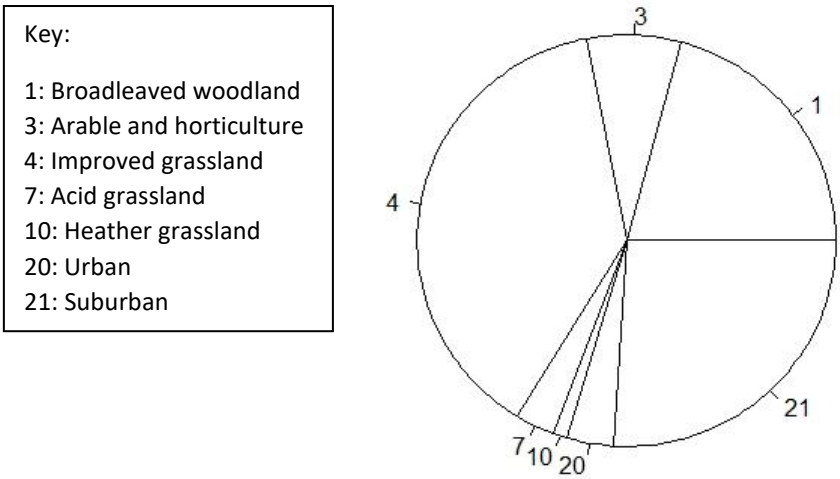

Figure 10: Habitat types identified within 20m of red kite sightings. Numbers represent the number coding system used by Land Cover 2019 to identify habitat types (Appendix. 2). This chart does not include the data for the route between Pencelli and The Elan Valley, the given key shows the numerical value and its associated habitat type description.

3.1.3. Habitat preferences along three main transects:

Route 1:

Improved grassland was the most used habitat type by common buzzards on route 1 and was the only habitat type that was used significantly more than expected. Both heather grassland and coniferous woodland were used significantly less by common buzzards than expected, with no bird of prey sightings being recorded in either habitat type. There was no significant difference between the expected and observed habitat use for the urban, suburban, broadleaf woodland, arable and acid grassland habitat types. No common buzzard sightings were recorded within urban and acid grassland habitat types on route 1 (Fig. 11).

The most sightings of red kites on route 1 were within the improved grassland habitat type but there was no significant difference between the observed and expected numbers of sightings. Both coniferous woodland and acid grassland had significantly more observed sightings than expected. The urban environment was the only habitat type where observations of red kites were significantly lower than expected, with no sightings occurring. There was no significant difference between the observed and expected sightings within the suburban, improved grassland, heather grassland, broadleaf woodland, and arable habitat types (Fig. 11).

Route 2:

The habitat type with the most common buzzard sightings on route 2 was improved grassland and the observed sightings were significantly higher than expected. Improved grassland was also the only habitat type where the observed common buzzard sightings were significantly higher than the expected values. Both heather grassland and arable habitat types had significantly fewer observed sightings recorded than expected along route 2. There was no significant difference between the observed and expected sightings within the urban, suburban, coniferous woodland, broadleaf woodland, and acid grassland habitat types (Fig. 11).

The improved grassland habitat type contained the largest amount of red kite sightings on route 2, the observed sightings were also significantly higher than the expected value. The

only other habitat type where the observed sightings were significantly higher than the expected value is within coniferous woodland. Heather grassland, broadleaf woodland and arable habitat types all had significantly lower observed recorded sightings than the expected values, with heather grassland having no observed sightings. There was no significant difference between the observed and expected values within the urban, suburban, and acid grassland habitat types (Fig. 11).

Route 3:

The largest amount of common buzzard sightings along route 3 were within the improved grassland habitat type, where the observed recorded sightings were also significantly higher than the expected value. The only other habitat type where the observed sightings were significantly higher than expected was within the coniferous woodland habitat type. Both the heather grassland and broadleaf woodland habitat types had significantly fewer observed sightings than expected, with there being no heather grassland sightings along the route. There was no significant difference between the observed and expected values within the urban, suburban, arable, and acid grassland habitat types (Fig. 11).

Improved grassland was the most common observed habitat type of red kites on route 3 and the observed sightings were significantly higher than the expected values. The only other habitat type where the observed sightings were significantly higher than the expected value was within the urban habitat type. Both the broadleaf woodland and heather grassland habitat types had significantly fewer observed sightings than the expected value, with no sightings being recorded within the heather grassland habitat type. There was no significant difference between the observed recorded sightings and the expected values within the suburban, coniferous woodland, arable, and acid grassland habitat types (Fig. 11).

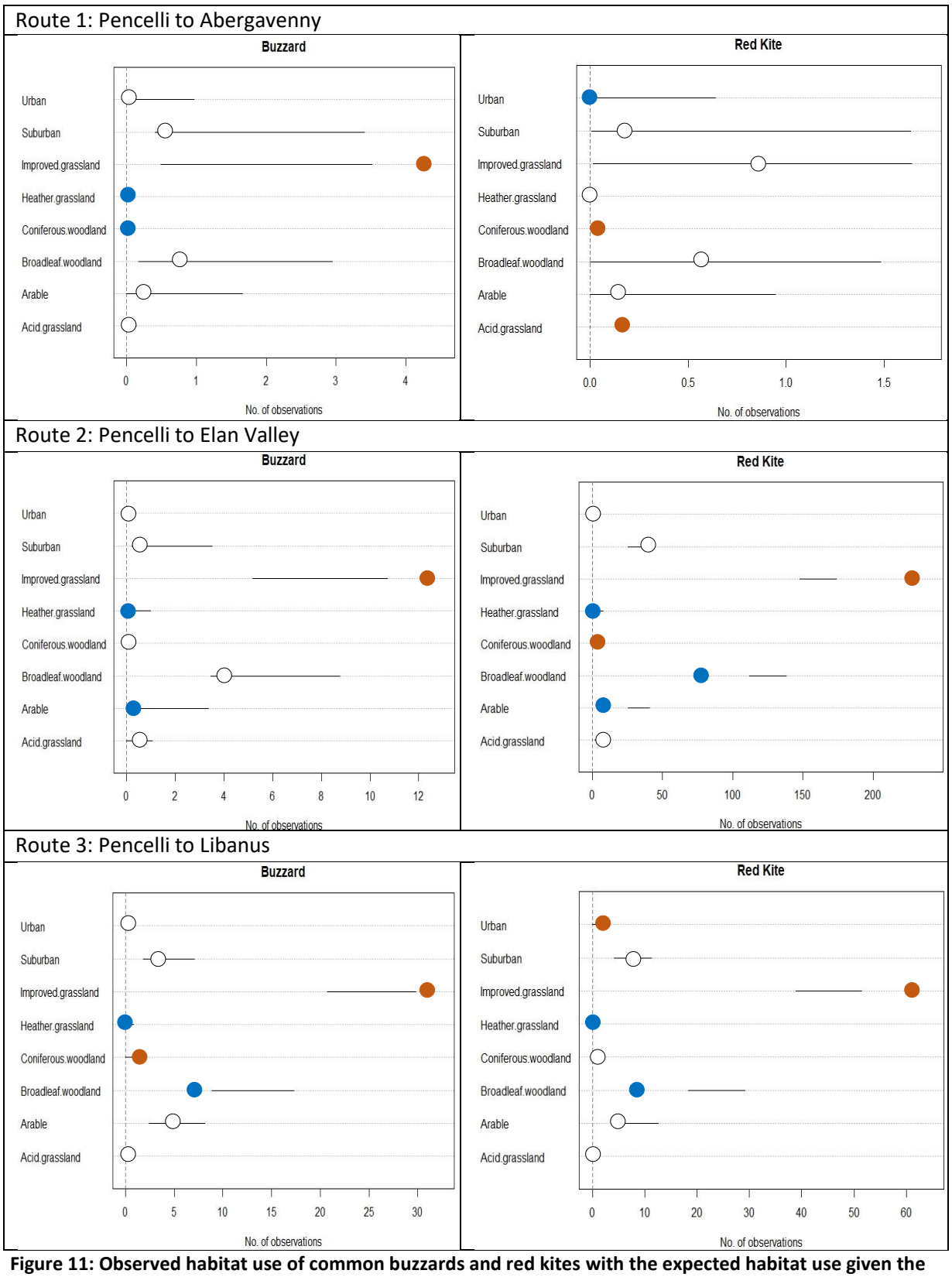

Figure 11: Observed habitat use of common buzzards and red kites with the expected habitat use given the availability of the different habitat categories along all three transect routes.

3.2. Roadkill Biomass:

The biomass of prey species available was calculated by averaging the body mass of each species (taking the mean of male and female mass), and multiplying it by the number of sightings recorded each month. Only species present within the Brecon Beacons National Park were included in the graph; excluded species included muntjac and roe deer that are currently not present or widespread within the National Park. Total biomass available was higher in the spring months between February and April, with the highest on average being in March. Another smaller increase occurred around the autumn months of October to November. Biomass available was at its lowest in the winter months of December, with the second lowest average being in January (Fig. 12).

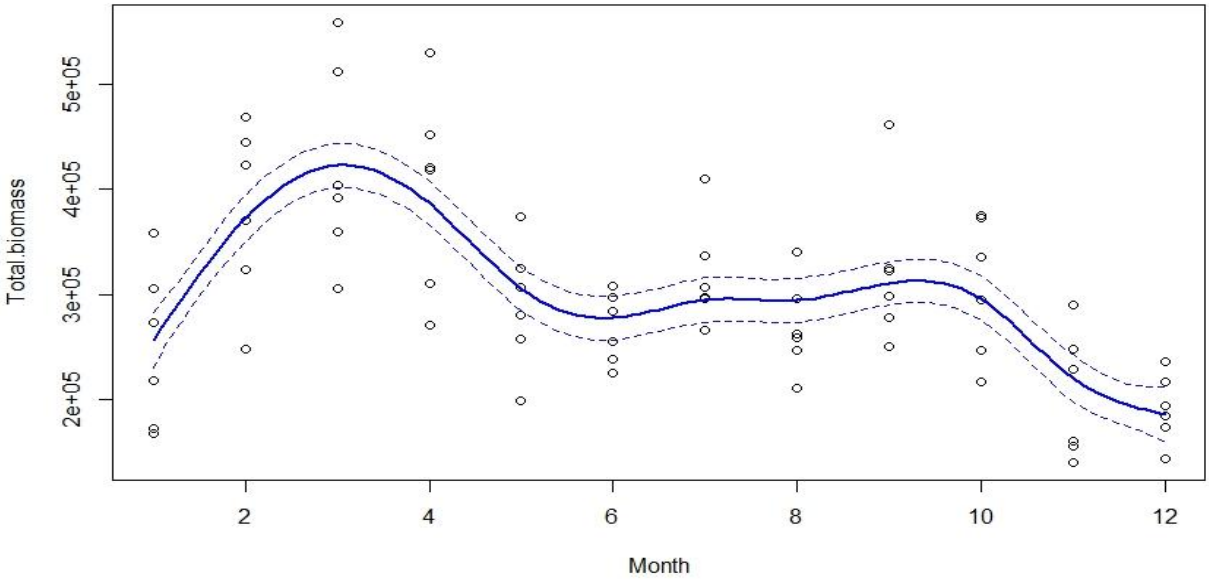

Figure 12: Total kilograms (calculated by multiplying number of individuals by mean weight for each species) of animal biomass found on UK roads monthly, using data combined from the years 2014-2019, extracted from Schwartz et al., 2021. Species included were: European badger (*Meles meles*), barn owl (*Tyto alba*), common blackbird (*Turdus merula*), brown rat (*Rattus norvegicus*), red fox (*Vulpes vulpes*), grey squirrel (*Sciurus carolinensis*), gull species (*Laridae*), European hare (*Lepus europaeus*), European hedgehog (*Erinaceus europaeus*), Eurasian magpie (*Pica pica*), Eurasian otter (*Lutra lutra*), ring-necked pheasant (*Phasianus colchicus*), European polecat (*Mustela putorius*), European rabbit (*Oryctolagus cuniculus*), tawny owl (*Strix aluco*) and common woodpigeon (*Columba palumbus*). Month names are represented by numerical values with 1 being January and 12 being December.

3.3. Peregrine falcon prey remains:

3.3.1. Remains found monthly:

The total remains from peregrine falcon feeding sites was calculated by adding together number of remains found at each of the three sites (Cardiff City Hall, Llandaff Cathedral and Saint Mary's Church, Brecon). There was no significant linear monthly trend over the course of the study period (*p* value = 0.12), but numbers of prey remains tended to be higher in Spring (February to April), with overall numbers being higher in the summer months compared to the winter months (Fig. 13).

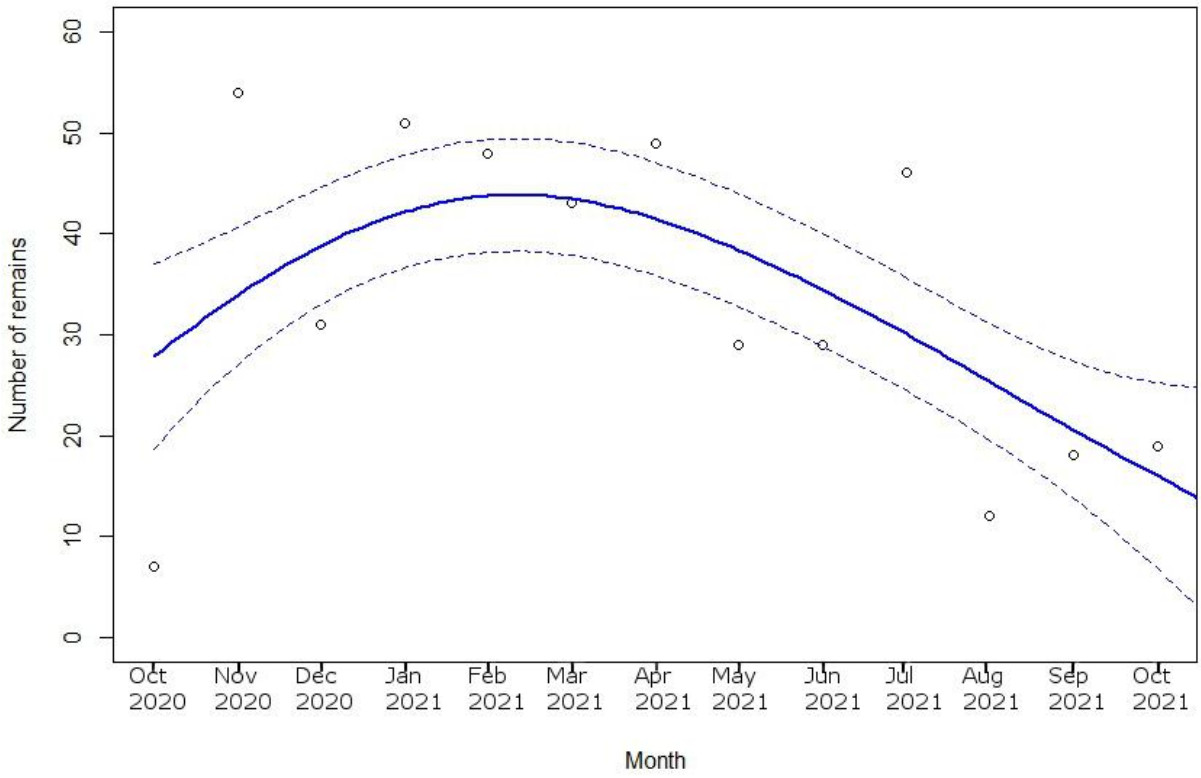

Figure 13: Total number of peregrine falcon prey remains found at all three South Wales sites monthly. Data collection spanned from October 2020 to October 2021. The solid blue line represents the mean number of remains found per month, with the 95% confidence intervals represented by the blue dotted lines above and below the solid.

3.3.2. Most common peregrine falcon prey remain species:

The most common species found within the summer months, across all three South Wales sites, were 'Feral pigeon' remains, with 65 confirmed identified remains. The two least common prey remains found within the summer months were 'Teal' and 'Woodcock', no remains of either species were found. The second most common species found was 'Starling' where 19 confirmed identified remains were found, closely followed by 'Blackbird' with 18 confirmed identified remains (Fig. 14).

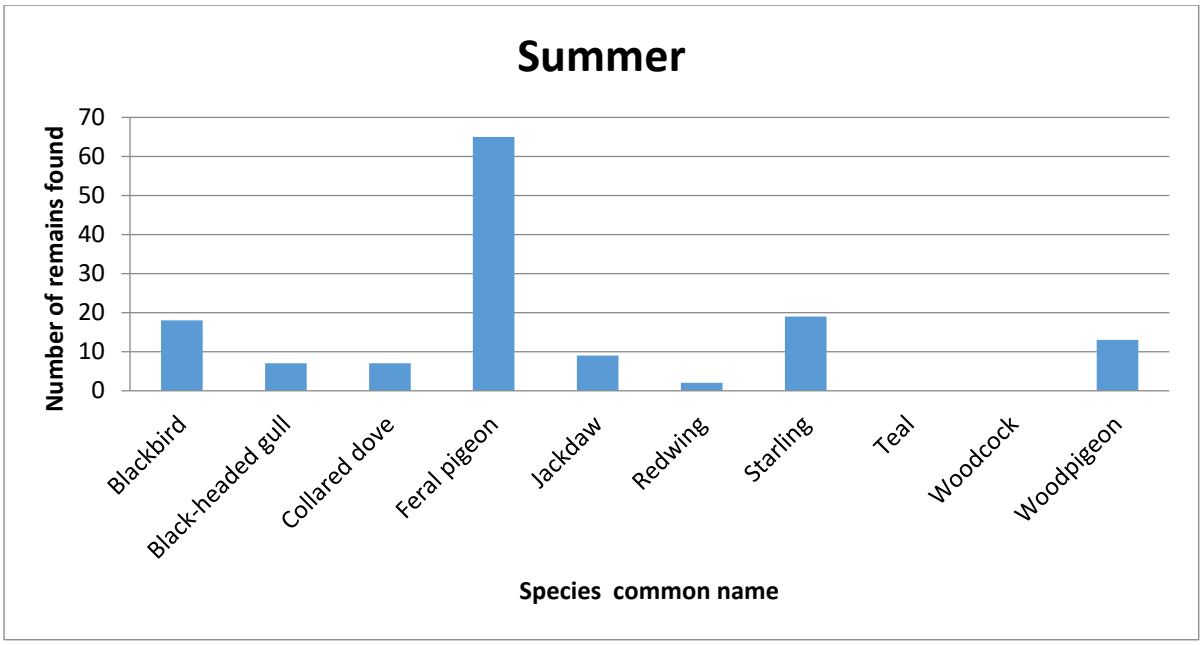

Figure 14: The ten most common peregrine falcon prey species remains found at the three South Wales (Saint Mary's Brecon, Llandaff Cathedral, and Cardiff City Hall) within the summer months (April - September).

The most common species within the winter months were 'Feral pigeon' (*Columba livia domestica*), with 71 confirmed remains. The least common remains found were 'Collared dove' (*Streptopelia decaocto*) with only 6 confirmed remains. The second most common species found was 'Redwing' (*Turdus iliacus*) with 27 confirmed remains (Fig. 15).

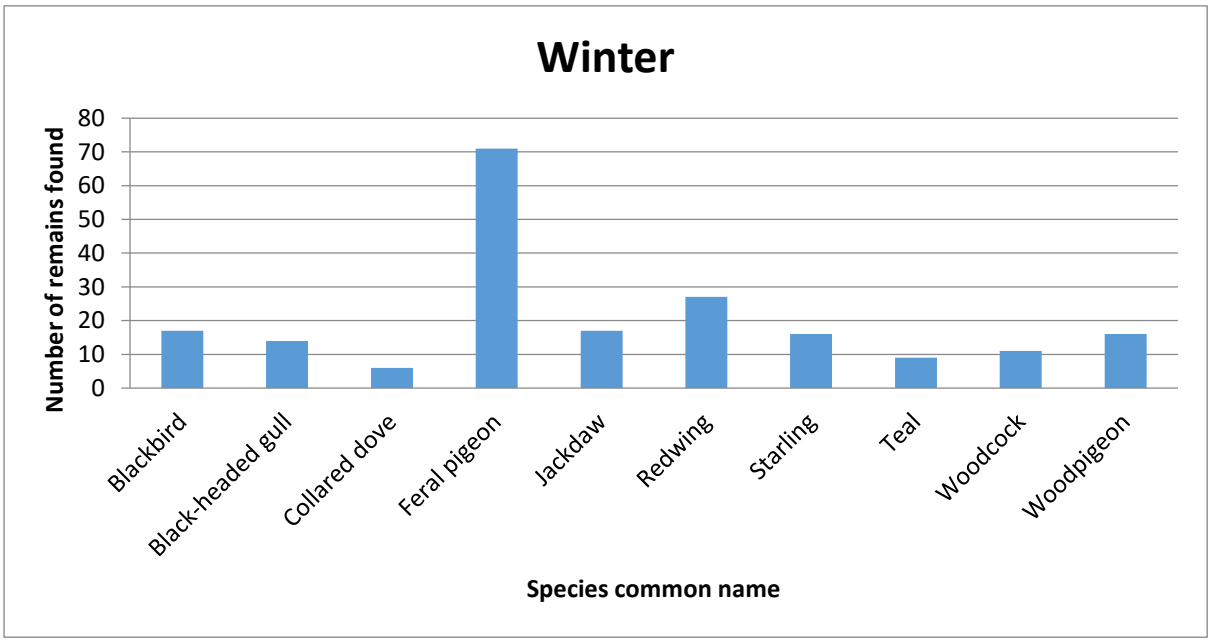

Figure 15: The ten most common peregrine falcon prey species remains found at the three South Wales (Saint Mary's Brecon, Llandaff Cathedral, and Cardiff City Hall) within the winter months (November - March).

3.4. Fallen livestock farmer questionnaire:

16 out of 18 respondents farmed either sheep or cattle, or a combination of the two species, three respondents farmed horses or pigs which was represented in the 'other' category, and two respondents farmed poultry. 15 of the respondents used 'shared common land' at some point of the year to graze their animals, 12 of these used the grazing in summer and autumn months, 11 used it in spring months and only 7 within the winter months. 13 of the 18 respondents used upland 'shared common land' areas, whereas, only 2 respondents used lowland 'shared common land' areas. Only 7 respondents actually used 'shared common land' within the Brecon Beacons National Park, with 10 using 'shared common land' outside the National Park.

10 respondents were unable to tell the cause of death for fallen livestock with many reporting that fallen livestock were never found, their absence was just recorded in

gatherings. 9 respondents reported livestock died due to illness, 3 reported due to weather and 5 reported death by dog attacks. 16 respondents reported the main reason for removing fallen livestock was due to legislation requirements and 12 reported it was due to complaints from the public, none reported it was to prevent wildlife from consuming it. 17 respondents reported the reason for not removing fallen livestock is that animals were in inaccessible locations and 2 reported that it was due to removal costs (Table. 1). Not all respondents answered every question, but the most respondents only skipped one question on average.

Question	Answer Option					
What type of livestock do you farm?	Sheep 89%	Cattle 89%	Poultry 11%	Goats 0%	Other 17%	
Do you use shared common land to graze your livestock annually?	Yes 83%	No 17%				
If yes, do you use shared common land within the Brecon Beacons National Park?	Yes 41%	No 59%				
What do you class the shared common land you use as?	Upland 87%	Lowland 13%				
At what time of year do you graze your livestock on shared common land?	Spring 73%	Summer 80%	Autumn 80%	Winter 40%		
What was the likely/suspected cause of death?	Weather 14%	Illness 50%	Attack 29%	Old 7%	Unknown 57%	
What is your motivation for removing fallen livestock?	Required 89%	Wildlife 0%	Disease 33%	Dogs 33%	Aesthetic 11%	Public 67%
If fallen livestock cannot be removed, what is the main reason?	Inaccessible 94%	Wildlife 0%	Time 0%	Removal 12%	Other 18%	

Table 1: Closed question results from 'Survey Monkey' questionnaire given out to farmers. Note that questions had the option to select more than one answer, so percentages reported were from the total number of responses and are not accumulative to 100% within each question.

3.5. Additional Observations:

Even though walking transects on sites A,B,C, and D didn't yield quantitative evidence as to the presence of rabbits, or camera trap evidence as to what scavengers were feeding on livestock carrion, they did yield some observational evidence. More livestock remains were found on sites A (Fig. 2) and B (Fig. 3) then on sites C (Fig. 4) and D (Fig. 5), in fact sites C (Fig. 4) and D (Fig. 5) had no livestock remains evident at all. Most livestock remains consisted of bones that were already clean, identification of species was done via skull shape and teeth when possible. Remains that consisted of just a sheep fleece were not counted, even though farmers do not shear sheep on the hills, instead bringing the animals down to a farm site, sheep may lose fleece against abrasive objects on the mountain. Therefore, it is unclear whether fleece left on the transect was from a previous carcass or has been pulled from the fleece of a live sheep.

Site D also contained evidence of old rabbit warrens between the boundary fence and a neighbouring field, no fresh signs of rabbits presence were found at the warrens, so it was believed that the rabbits had moved on from the area a while beforehand. There were also two occasions when walking the transect on site C where rabbits were observed crossing the path, with additional lagomorph footprints being left in the snow. No regular signs of rabbits were found on site C, but the brief observations and the presence of footprints could suggest rabbits do sometimes use the area for foraging but when human disturbance opportunities were low.

4. Discussion

Trends in sightings of both common buzzards and red kites across the National Park correlated with trends in roadkill record data, suggesting that existing raptors within the National Park use roadside carrion as a supplementary food source. Both species selectively chose to feed within the 'improved grassland' habitat type, which represents agricultural land containing either livestock or monoculture hay crops. Feeding in these open agricultural environments could also suggest a reliance on carrion from fallen livestock, especially in spring where there are peaks in juvenile prey species and mortality rates are higher. Across the studied sites there was a significant lack of evidence to suggest the presence of European rabbits, there was very little anecdotal evidence of the species across the National Park since a local outbreak of Myxomatosis in 2016. The presence of livestock carrion was recorded mainly across the two upland sites studied, changes in EU regulations in 2003 required farmers to remove fallen livestock from not only their own land, but from 'shared common land'. This regulation poses many problems for farmers, especially for those that used upland 'shared common land' as often fallen livestock is inaccessible or is impossible to remove without heavy machinery that cannot access upland areas. Resident raptors within the National Park seem to benefit from farmers being unable to remove fallen livestock as they gain an additional food source which replaces the lack of European rabbit presence. Whereas it could be argued that farmers are aiding resident raptor species in the National Park by leaving fallen livestock in situ, gamekeepers could be viewed as hindering them. A lack of observed common buzzards and red kites around Glanusk Estate could suggest that resident raptor species have suffered from past alleged raptor poisoning incidents. This issue requires further study to determine whether game estates are having a negative effect on surrounding raptor populations and whether this would affect future release plans for golden and white-tailed eagles.

4.1. Road transect surveys:

As eagles are currently not present in the Welsh landscape, to make an assessment of prey availability it is important to look at similar species that share their dietary requirements. Within the Brecon Beacons National Park, the species that most closely share the dietary requirements of golden eagles are common buzzards and inland breeding peregrine falcons,

with white-tailed eagles sharing similarities with red kites and coastal breeding peregrine falcons (Lane, 2021). However, a comment could also be made of the raptor species that are not present within the region, ospreys (*Pandion haliaetus*) are another fish-eating raptor species similar to white-tailed eagles. They also suffered persecution but have begun to naturally re-colonise Wales since 2004 (Skujina et al., 2021). So far ospreys have failed to re-colonise in South Wales, this may just be because the population has not yet expanded its' range from North Wales, and could potentially be present in the future. However, it may be due to the lack of large water bodies in the region, reducing fishing opportunities for raptors. If this is the reason, then the National Park might not be able to support a fish eating raptor species, therefore, the region might not be suitable for white-tailed eagle reintroduction.

Both common buzzards and red kites are regularly seen flying within the National Park foraging for prey species and quite often can be viewed from the roadside. Planillo et al. (2015) suggested that red kites are more tolerant of human disturbance than some other raptor species like the common buzzard. As common buzzards are less resistant to disturbance, this implies that these raptors may only choose to feed on the roadsides if there is a high abundance of prey available on them, or there is little else to eat in the surrounding environments. Therefore, quantifying the number of raptors observed from the roads within the National Park can give an indication of potential prey species abundance in the local area. GPS locations of bird of prey sightings were recorded while driving along road transects through mid-Wales, and a land cover mapping database was then used to extract the habitat type data within 20 m of each GPS point, to determine what habitat type the individuals were foraging in. A higher number of red kites were observed throughout the study period than common buzzards (Fig. 6 and Fig. 7), which could either mean there is a larger red kite population or the species is more likely to be observed near the roadside. There was a peak in observations per journey (controlling statistically for journey length) in March for both species, which is similar to the main peak in roadkill biomass (Fig. 12). This suggests that a potential abundance of food in the spring months could encourage both species to forage nearer to roadsides where scavenging opportunities may be higher. Both red kites and common buzzards were observed flying over the same set of habitat types throughout the study, although the two species were distributed between habitats in strikingly different proportions. Overall, there was a greater number of red kites observed,

which were mainly recorded in suburban locations; the suburban habitat type made up 36% of the red kite data set (Fig. 9), whereas it only made up 11% of the common buzzard data set (Fig. 8), suggesting that red kites are more likely to use residential areas for foraging. However, part of the survey included a drive from Brecon to the Elan Valley and back again, this was carried out twice a week for two months, and included driving past the 'Red Kite Feeding Centre' located on the edge of the town of Rhayader. This route was driven a total of 24 times, between September 2021 and November 2021, each time the feeding centre was driven past the total number of red kites viewed was recorded as '30+'. The sightings from the feeding centre accounted for 230 of the 615 red kite records, this may have influenced the red kite data set, especially as the feeding centre is in a suburban residential area. When sightings at the feeding centre were removed from the data set, the most common habitat type was improved grassland accounting for 38% of the data and the suburban habitat type dropped from 36% of the data set to 26% (Fig. 10). In contrast, common buzzards only used the suburban habitat type 11% (Fig. 8) of the time, supporting the idea that red kites are more tolerant of human disturbance and therefore are more likely to be seen in urban environments. The feeding centre at Rhayader may have also accounted for the second peak of red kite observations within Fig. 7, where there was an average of 2.0 individuals seen per journey across all sites. Sightings from the feeding centre were not removed from the dataset, even though they may have skewed the results. One of the reasons for this was that the feeding centre is open all year round, and it was only due to the surveyor that it featured in the data set between the end of September and the beginning of November. Furthermore, speaking to local people within the National Park revealed some towns also supplementary feed red kites, resulting in higher numbers of individuals in one place. It is currently unknown the amount of supplementary feeding offered to birds of prey within the Brecon Beacons National Park. Therefore, if results from the feeding centre were to be removed from the dataset, all other instances where groups of red kites were observed would have to be removed too, as it cannot be proven that they also weren't at a supplementary feeding location.

The three most consistently driven transects over the whole study period were chosen to compare what habitat types raptors were using against what was available. Route 3 (Pencelli to Libanus) was the most surveyed, at 150 journeys, followed by route 1 (Pencelli

to Abergavenny) at 32 journeys, and route 2 (Pencelli to Elan Valley) at 24 journeys. Across all three routes it was clear that both common buzzards and red kites used improved grassland areas more often, and within five out of six models (Fig. 11) observed sightings within this habitat type were significantly higher than the expected value. Therefore, it could be suggested that both common buzzards and red kites within the National Park preferentially chose to hunt within the improved grassland environment that makes up a large proportion of the upland areas within the park. Route 3 (Pencelli to Libanus) was not only the most driven route within the transect survey, but was also the most consistently driven with a minimum frequency of four times a week across the whole study period. This meant that it gave a good idea as to how raptors use the habitat available to them across the seasons. Both red kites and common buzzards along this route had a significant affinity towards the improved grassland environment, while common buzzards also had a significant affinity towards coniferous woodland. Woodland areas are common roosting locations for common buzzards (Arraut et al., 2021) which could explain their affinity towards the habitat type, if they were not using it for hunting purposes but instead for rest and shelter. The second largest number of recorded sightings of both common buzzards and red kites along route 3 were within the broadleaf woodland habitat type. However, both species used this habitat type significantly less than expected, suggesting that even though the habitat type was abundant along the route, neither species selectively chose to spend a lot of time hunting there. This could be a consequence of the data collection method, all sightings were recorded from the roadside from a moving vehicle, meaning identification of flying raptors had to occur quickly before birds went out of sight. Driving through a woodland environment poses a greater amount of visual barriers than within an open environment, which could mean that some potential sightings were missed within broadleaf and coniferous woodland (Viñuela, 1997). Unlike common buzzards, red kites showed no significant affinity towards coniferous woodland but were significantly selective towards the urban habitat type. This could be further evidence to support the suggestion, made within the Planillo et al. (2015) study, that red kites are more resistant to human disturbance. It could be argued that red kites are choosing to hunt within the urban environment as they are relying on scavenging opportunities mainly from the roadside. Anecdotal evidence during the study period, saw three occasions along route 3 where a group of up to five red

kites were viewed feeding on roadkill, along the main A40 road; a busy route where disturbance is highly likely.

Anecdotal evidence also saw a significant number of red kite sightings along route 2 over the 'Red Kite Feeding Centre' in Rhayader, this was a large factor influencing Fig. 9 and Fig. 10 as there seemed to be a significantly skewed results towards the 'Suburban' habitat type due to the presence of the feeding centre. However, when the route is analysed with the habitat selection model both the 'Suburban' and 'Urban' showed no significant affinity. Therefore, even though it may look like red kites are being encouraged to scavenge in urban areas due to supplementary feeding, they are not selectively feeding in the habitat type. Along route 2, both common buzzards and red kites significantly avoided the 'Arable' habitat type. There could be a range of reasons for this, one of which being potential persecution or bird of prey deterrence from farmers. This is very unlikely, as 'Arable' land within the Landcover model is classified as crop growing or orchard land, both of which farmers would have no reason to deter raptors from. The most likely reason for the raptors' significant avoidance of the 'Arable' habitat type is seasonality. However, unlike routes 1 and 3, observations along route 2 only occurred between September and November, which for most crops and orchards in the UK is harvesting season. This season often uses large machinery to harvest crops, which may cause high levels of physical and audible disturbance to habitat inhabitants. It could be suggested that even though the raptors may not be affected by the disturbance themselves, the prey species that they are seeking such as rabbits and other smaller mammals might be. Therefore, the significant avoidance of the habitat type within the model may be due to prey species avoiding arable land within this time period instead of the raptors themselves not choosing to hunt within it.

Route 1 was the second most driven route at 32 journeys and was driven at least twice a week, mainly within the first four months of the study period. Despite being driven regularly it had the lowest number of raptor sightings per kilometre out of the three tested routes. One of the most obvious reasons for this is the time of day the route was driven, mainly in the evening or after dark, journeys that were discounted due to sightings not being possible and were statistically accounted for in the model. However, this would be a very unlikely occurrence as both red kites and common buzzards are diurnal raptors that roost at night in the woodland environment. Also, with the remaining journeys taking place in the evening,

sometimes close to sunset, this is a similar time as to when diurnal raptors are returning to roost locations, which could also explain a lack of sightings from the roadside. Even taking the time of day into account, there was a significantly large difference between raptor sightings on route 1 compared to routes 2 and 3. Over the course of the study period there was only a total of eight raptor sightings along the route and only two of these were of red kites. Red kites along this route were the only group that were not significantly selective towards the 'Improved Grassland' habitat type and instead were selective towards 'Acid Grassland' and 'Coniferous Woodland'.

This route, from Pencelli to Abergavenny, followed the main A40 road, through a mix of residential and agricultural areas, meaning that there should be no reason for red kites to avoid hunting in the vicinity, as shown by the habitat preference analysis described above. One of the suggested reasons is the presence of Glanusk Estate, a well-known game shooting location that borders the roadside between Blwch and Crickhowell, about half-way along the route. In 2013, Glanusk came into the raptor persecution spotlight, when the discovery of nine poisoned birds of prey were found, along with four poisoned baits. Raptor persecution within the UK is very hard to prove and is even harder to prosecute without solid evidence. With 104 cases of confirmed persecution in the UK in 2020 but with only one conviction (Wildlife and Countryside, 2021), it could be argued that there is still a serious issue of raptor persecution in Britain. This raises a collection of questions about the current lack of raptors within the vicinity of Glanusk estate, mainly the possibility that persecution is still ongoing but is unseen, or that the local population is still struggling to recover from the persecution event in 2013. How raptor populations in the UK respond in the years following larger persecution incidents is still an understudied topic, and it could be suggested that local raptor populations have not recovered since 2013. Unfortunately, due to the lack of evidence as to what the local population was before 2013, this question may remain unanswered without further study. Another factor that could have influenced the lack of raptor population surrounding the estate is the lack of game shooting during 2020 and 2021. Due to the Covid-19 pandemic and the range of restrictions put in place throughout the UK there was a significant lack of game bird releases for the 2020 season as shoot organisers were unsure if events could go ahead in the autumn months. Restrictions continued into 2021 meaning many game shoots may have forgone releasing a high number of game birds

to prevent income loss if the shoot season was stopped again. Anecdotally the roadside bordering Glanusk estate often has a high number of roadkill pheasants, but there was a distinct lack of them during the study period. Informal reports suggest that the estate may have given up its pheasant releases following the public outcry surrounding the poisoning incidents in 2013 and pressure from the Greenman Festival in 2016. Therefore, it could be suggested that the lack of game birds in the area consequently caused raptors to seek hunting opportunities elsewhere. The lack of game birds in the area could mean it is not a favourable landscape for potential a golden eagle population, in Scotland golden eagles rely on grouse species as well as lagomorphs to make up a large portion of their diet (Watson et al., 1993). The lack of game birds in the National Park since the reduction of game shoots could mean there is a smaller range of favourable prey species available to golden eagles, therefore, they would be required to have larger ranges to fulfil diet requirements (Brown and Watson, 1964).

Trends for the number of sightings for both red kites and common buzzards over the course of a year both followed the same pattern. Both species had a significant peak number of sightings in UK springtime, with the highest number of sightings for both being in March (Fig. 6). This peak coincided with the corresponding peak in roadkill biomass, with the largest amount of roadkill carrion available also being in March (Fig. 12). This could support the idea that both species use the roads as a reliable food source during the egg laying and chick rearing periods as a quick meal with requires little hunting effort. Furthermore, many prey species within the UK give birth to (or hatch) their young in the spring months of March and April, raising them over the summer months May – August when food is more plentiful. Predator species match this cycle as there is an abundance of vulnerable prey to feed their own young, the abundance of juvenile animals during this period also increases the likelihood of road collisions. Increased likelihood of road collisions results in higher amounts of carrion biomass available for scavenging species, therefore, birds of prey may rely on the roads to provide a stable food source during spring to successfully raise chicks. A second smaller peak of sightings for both species was also witnessed within the autumn months, namely October (Fig. 10). The association with roadkill availability continued here with a second smaller increase of total biomass in the autumn months of September and October. This second increase may be due to pressures from the shooting season on prey species.

Organised pheasant shoots often raise young birds through the summer months and release them for shoots in the autumn months. However, it is not always possible to keep birds within the shoot site and many escape into the surrounding countryside. A large proportion of these birds end up being fatally involved in road collisions and make up a significant amount of biomass available to birds of prey in autumn (Madden and Perkins, 2017).

In an ideal situation, the information from all three routes would be used together to gain a good idea of what is happening across the National Park, instead of making comparisons between them. However, as previously stated, each route had some unique features that may have affected their datasets, with route 1 having an estate that was previously a game shoot location, and route 2 having a supplementary feeding centre. Instead, comparisons between the routes have been made to make some suggestions as to why different numbers of birds of prey were observed on them. To make a strong comparison between each route, data from each month should be extracted and compared between each route. However, not all routes were driven the same number of times each month, and especially in the case of route 2, were not driven at all during some months. This would make it hard to make a good month by month comparison, instead comparisons were made over the study period as a whole.

4.2. Rabbit presence survey:

The European rabbit has historically been a prominent part of British bird of prey diets (Lees and Bell, 2008); therefore, it was important to quantify the European rabbit population within the National Park to determine prey availability for a potential eagle population. A few different surveys were attempted within the four sites to estimate European rabbit population, a random stratified quadrat survey was trialled on each site. None of the sites showed evidence of European rabbit presence within the quadrat survey, so this option was removed in favour of attempting to map burrows. However, apart from two burrows that were identified on the fence line of site D (Fig. 5), no other evidence of burrows was discovered on any of the surveyed ‘shared common land’, indicating that population density is currently very low. Some evidence of European rabbit and European hare presence was found on site C (Fig. 4) during February, the site had previously received a small snowfall, leaving 1-2 inches of snow across the site. While carrying out the transect survey, footprints of both European rabbit and European hare were discovered in the snow, however,

following the footprints led across the base of Mynydd Illtyd and towards private farmed land that bordered the hill. The footprints themselves were indirect across the hill, looping several times before disappearing over a boundary wall and under a boundary field gate. The pattern of the footprints, combined with visual evidence found later in April suggests that the current rabbit and hare populations use the lowland 'shared common land' for foraging opportunities as opposed to burrowing. The current lack of evidence of rabbit presence could also be due to Myxomatosis, a disease that often occurs in cycles, it causes lesions to form on the skin of the animal, mainly around the eyes, nose, mouth, and genitals, which is often fatal (Rivers, 1930). Myxomatosis can rapidly and significantly reduce local rabbit populations and is an annual occurrence in many areas, with its impact each year depending on the prevalence of carrier rabbit fleas (Ross et al., 1986). It first arrived in the United Kingdom in the 1950s; there is still a debate as to whether it was introduced intentionally to reduce the rabbit overpopulation that were considered pests by farmers, or accidently from mainland Europe (Bartrip, 2007). The virus was initially fatal, and has had a well-documented impact on reducing wild rabbit populations (García-Bocanegra et al., 2019; Trout et al., 1992). However, whereas the original pandemic was estimated to have reduced wild rabbit populations by 99%, natural immunity developed from the few individuals that survived, has resulted in local populations that are now more resistant to the disease (Ross et al., 1989). Even though myxomatosis failed to eradicate wild rabbits from the UK, the disease acts as a control to local populations, often acting in waves in years following population spikes. Anecdotal evidence within the National Park especially on sites A (Fig. 2), C (Fig. 4) and D (Fig. 5) suggests that the European rabbits were once prevalent on upland 'shared common land', meaning that diseases such as myxomatosis probably had a recent significant effect on local populations. Discussions with local farmers and residents suggests that myxomatosis had a significant effect on local rabbit populations in 2016, which could be one of the reasons why evidence for rabbits on 'shared common land' in the Brecon Beacons National Park is currently sparse. If this is the case, existing birds of prey like the common buzzard that also rely on rabbit populations (Graham et al., 1995) might already be suffering from feeding pressures. Introducing a new species in an environment where similar species are already experiencing difficulty in finding food, will have a significant detrimental effect on both species. Especially in this case where common buzzards are smaller than both golden and white-tailed eagles, the buzzard might be outcompeted for

resources. Being smaller might actually mean the common buzzard benefits more than either eagle species in this situation, similar to other raptors, common buzzards require about 10% of their body weight in daily food. However, as they have an overall smaller body weight this means they require about 150 g of food (Walls and Kenward, 2020) compared to eagles that require 300 g-400 g. Therefore, buzzards are more likely to fill their dietary requirement than eagles, but eagles may have the capacity to chase buzzards from a kill, this is potential intra-guild competition that also needs to be considered in future studies.

However, the anecdotal evidence of foraging individuals combined with consistent records of rabbit and hare roadkill, could imply that populations are slowly starting to recover and could be considered a viable food source for future eagle populations. Evidence of rabbits was recorded within the 'Project Splatter' dataset, even though this data encompassed all of the United Kingdom the high frequency of rabbits recorded on the roads supports the idea that at this much larger scale there is still a large population of rabbits to provide a food source for resident birds of prey. Furthermore, rabbits are a prey species and tend to exhibit disturbance avoidance behaviours, especially during the daytime when they are at risk from aerial predators (Moreno et al., 1996). Video evidence from camera traps left on some of the sites at random points in the study period, as well as anecdotal evidence driving within the park at dawn, did show the presence of rabbits. On some occasions driving at dawn, the surveyor witnessed at least ten rabbits on the road, often adults with multiple kittens. This, along with evidence from 'Project Splatter' could indicate that the reason for the lack of rabbit records is surveyor avoidance, similar to rabbit predator avoidance response. Surveys occurred during the daytime, often on the open hillside which would be prime locations for hunting birds of prey to take exposed rabbits. Therefore, the actual number of rabbits within the National Park might be much higher than the data suggests, supporting the healthy population numbers of both common buzzards and red kites. Rabbits and hares are a key component of the golden eagle diet within Scotland (Watson et al., 1992). Therefore, calculating the actual lagomorph population within the Brecon Beacons is a vital part in understanding whether the species would survive in the region. A additional camera trap survey would have been useful within the study period to establish the presence of lagomorphs during times of the day when human disturbance was not influencing avoidance behaviours. A separate camera trap survey could be carried out across the whole National

Park, including on private farmland to quantify the actual extent of lagomorph populations within the Brecon Beacons, this would give a better assessment as to whether the region could support potential eagle populations alongside existing common buzzard and red kite populations.

4.3. Fallen livestock survey:

Carrion is an important supplementary part of the diet for both golden and white-tailed eagles, especially in the winter months when more preferable prey items like lagomorphs and fowl are less abundant, active and/or available (Watson and Whitfield, 2002). Studies using deer carrion were carried out in Scotland to determine what species chose to come and feed on a carcass. Deer carcasses from individuals culled during population management were carried to upland sites and camera traps placed overlooking the carrion to record what species arrive to feed (Fielding et al., 2013). An attempt was made to recreate these studies within the Brecon Beacons National Park at the four chosen sites, instead of choosing to set up a carrion feeding site, the study intended to place camera traps on carrion found along the site transects. Wales is a traditional agricultural landscape, with sheep farming making up most of the livestock raising sector, it is estimated that Wales had just under 9 million sheep in 2020 (Gov.Wales, 2021). The mountainous landscape of North Wales and the hilly landscape of South Wales meant that traditionally raising sheep was favoured over cattle or growing crops, as sheep are better adapted to sloping or unstable land, and have been selectively bred to be more weather resistant (Morris, 2017). Being a traditional agricultural country, Wales also has a high proportion of land known as ‘shared common land’. Following legislation changes in 2003 from the EU Animal Health and Local Authority, deceased livestock were required to be removed from 'shared common land' to prevent disease spread. There is also an argument that removing deceased livestock requirements could also be for aesthetic reasons, especially in tourist hotspots and SSSIs like the Central Beacons range (which encompasses the main peaks of the Brecon Beacons and their valleys, Appendix. 5). In theory, removing smaller deceased livestock such as sheep or pigs, should be simple with the use of off-road vehicles like quad bikes. Larger animals like adult cows and horses prove more difficult and would require the use of a lorry, which does not have the ability to access more remote locations (Bathurst, 2022). Removing dead livestock from upland areas poses more issues than removing them from a lowland field, the

biggest one being accessibility. A short survey given out to farmers that used 'shared common land' had 18 respondents (Table. 1), 94% of respondents reported that the main reason they didn't remove livestock from 'shared common land' was due to the inaccessibility of the carcass. Upland ‘shared common land’ like sites A (Fig. 2) and B (Fig. 3) are often steep sided mountains or hills that are difficult for farm vehicles to navigate, they also often contain sharp drops into ravines that are completely inaccessible. Therefore, sometimes it is almost impossible to remove deceased livestock if the carcass has fallen into an inaccessible location or it is impossible to get a vehicle to the site. There is a strong suggestion that the laws requiring removal of fallen livestock from upland farmland starting in 2003, was a response to the BSE and Foot & Mouth outbreak that had a significant effect on Welsh farmers between 2000 and 2003. Reasons behind the law may have been to do with disease management following the outbreak and to prevent future epidemics.

In situations where deceased livestock cannot be removed, they become available carrion for birds of prey. Studies were carried out at all four sites to estimate the proportion of carrion available to birds of prey in the area, however, even though carrion was found, all the items were too rotten to be suitable food sources for birds of prey. Cameras were therefore unable to be placed to observe what species came to feed on carrion in each of the chosen sites and assumptions had to be made that resident bird of prey populations do feed on occasional sources of carrion, based on anecdotal evidence. However, the lack of suitable carcasses to place camera could suggest that carrion on the hills is being consumed quickly by scavenging species. As transects were checked weekly, it can be assumed that deceased livestock were being consumed by scavengers within a few days of animals dying. Therefore, suggesting that the current amount of livestock carrion on upland areas supports the number of birds of prey currently there, but might not support another species if it was to be introduced. This could mean that the current carrion population on upland areas within the Brecon Beacons cannot support the addition of another scavenging species, and therefore, goes against the potential release of golden or white-tailed eagles into the region.

Transects in sites A (Fig. 2) and B (Fig. 3) followed the hill boundary marker, in site A (Fig. 2) this followed the boundary wall between The Bryn and Talybont forest, whereas, in site B (Fig. 3) it followed the boundary fence line between Mynydd Llangorse and surrounding privately owned farmland. Observations carried out before the study was started discovered

that most sheep remains were found next to the boundary marker on both sites, resulting in transects being placed along the boundaries. In the case of site B (Fig. 3), livestock remains were more commonly discovered along the middle section of the transect which was located within a forested section, suggesting that ill livestock chose to move down the mountain slope, towards the forest boundary for protection against the weather. It could also be suggested in the case of site B on Mynydd Llangorse (Fig. 3), that the mountain is steep sided meaning deceased livestock could have perished further up the mountain and the carcass had fallen down the hillside post-mortem. Both sites C (Fig. 4) and D (Fig. 5) were classed as lowland shared common land, meaning the landscape was flatter and was more accessible to off road vehicles for removal of fallen stock. Therefore, the lack of remains on these sites compared to sites A (Fig. 2) and B (Fig. 3) could be down to the fact that farmers are more likely to find deceased livestock and are able to access them for removal. Furthermore, government rules on the disposal of fallen livestock discourage farmers from feeding deceased livestock to scavenging birds, and instead requires them to be disposed of by removal from the farm (Gov.UK, 2021). Abiding by this rule would mean that there is a lack of livestock carrion available to birds of prey from farms across Wales, and only inaccessible carcasses from upland 'shared common land' would provide a food source. However, all sites did have the presence of some bones that were identified as sheep, meaning at some point carcasses were available to scavengers. These carcasses might have been consumed quickly by current scavengers and might be considered a more random and unreliable food source, especially if an additional species was added to the landscape. Furthermore, livestock population numbers on common land areas can change on a weekly basis due to stocking limits, local markets, lamb rearing, and grazing rotations. Therefore, this data is unable to be used to extrapolate the amount of carrion available to scavenging birds of prey across the whole National Park.

4.4. Potential competition between eagles and other existing raptors:

Using red kite and common buzzard feeding habits to estimate the proportion of prey available for future eagle populations is extremely useful but also raises the question of competition. Golden and white-tailed eagles are both generalist predators, with golden eagles sharing a similar diet to common buzzards and inland breeding peregrines falcons, and white-tailed eagles sharing a similar diet to red kites and coastal breeding peregrine

falcons (Lane, 2021), with the addition of fish in their diet. This means that releasing a population of either or both species of eagle could increase prey competition between all five species. Both the red kite and common buzzard have dropped to least concern on the IUCN red list in recent years, and in some parts of Southern Britain red kites could be becoming a scavenging pest, swooping to search for food in school playgrounds and residential areas (Daily Mail, 2021; This Is Oxfordshire, 2022), especially after birds in the Chilterns introduction project were initially supported by supplementary feeding by the public (Oxford Mail, 2012). In the Brecon Beacons, red kites are not currently showing such behaviours; however they have been increasingly witnessed near urban areas where there are increased scavenging opportunities, as well as supplementary feeding areas.

There is an argument that introducing competing avian predators might help to balance the red kite and common buzzard populations within Britain. Golden and white-tailed eagles are both larger predators than red kites or common buzzards, which could mean that if a conflict occurs, the eagles are more likely to succeed than an existing smaller bird of prey species, meaning that in times like winter when prey is less available eagles could cause a negative effect on red kite and common buzzard winter foraging success. Furthermore, if prey availability is low, intra-guild predation may become a factor with larger eagles possibly predating on common buzzard or red kite nests (Kamarauskaitė et al., 2019) or potentially displacing these competitors (Virgós et al., 2020). However, if there is a large range of prey and carrion species available, it is believed that the potential risk for both these would be low. The factor of resistance to human disturbance also needs to be considered when debating competition between eagles and existing bird of prey populations. During the 19th and 20th Century era of intense persecution, red kite populations naturally occupied the remoter upland areas of the United Kingdom. Since the species has been reintroduced into the whole of the British landscape, however, they have adapted to be highly tolerant of human disturbance and have now become a common sight in the suburban environment. A large population of red kites now reside along the M4 motorway corridor, and it could be argued that they are now more frequently sighted in the Southeast England urban environment than in the uplands of the Welsh hills. There is currently no evidence to suggest that golden and white-tailed eagles share this tolerance to human disturbance, meaning that prey competition between red kites may not be an issue as they may not hunt

in the same locations. Golden eagles favour the upland landscape and may choose to stick to feeding on prey purely within the hill landscape of South Wales or the mountainous landscape of North Wales. Whereas red kites also favour these environments, their tolerance for human disturbance may result in the two species existing together with little prey competition. However, this also raises the question that red kites might be outcompeted by golden eagles in the upland environment, causing them to relocate into more urban areas which could have a negative knock-on effect by increasing human-wildlife conflict. Common buzzards are more abundant in the agricultural environment, especially over lowland crop fields and chose to avoid areas of higher human disturbance where possible. Therefore, common buzzards may be at more risk of being outcompeted by both golden and white-tailed eagles if the eagle species are equally intolerant of human disturbance.

Another potential dietary overlap within the national park for future eagle populations is with resident peregrine falcons. Even though golden and white-tailed eagles mainly focus on hunting small mammals, scavenging carrion, or in the case of the white-tailed eagle also hunting fish, they have been known to take smaller birds (Sutton, 2015). Peregrine falcons, are mainly avian hunters, although they might take the occasional small mammal (Mearns, 1983; Dawson et al., 2011), they might not be a direct competitor of future eagle populations but help to give a wider understanding of what range of prey species are available within the National Park. When prey remains were collected from three sites in South Wales, a higher amount of remains were found in the late spring and early summer months of April to June, although there was no significant trend across the year (Fig. 13). Slightly higher amounts of prey remains found in the spring and summer months may be down to the peregrine falcon's breeding season, with chicks hatching in early May and fledging in mid June (Dixon and Gibbs, 2018). Both parents provide food to growing chicks and often cache prey items near the roost, all three sites studied are believed to be either roost sites or cache sites for resident pairs of peregrine falcons. Parent birds providing for chicks need to increase their prey catch rates to accommodate feeding growing chicks (Olsen et al., 1998). This could explain why more prey remains were found within early summer as chicks are larger and close to fledging at this point. Furthermore, smaller prey birds will also be fledging at this point of year, meaning there is a higher number of naive

adolescent birds that are easier to catch (Rosenfield et al., 1995) which could also explain higher catch rates. Feral pigeon seemed to make up a large proportion of peregrine falcon diets at the three study sites, being the most common confirmed prey remains in both the summer and winter months (Fig. 14 & Fig. 15). The consistency of feral pigeon remains found throughout the year could suggest that the species is abundant and may be a reliable food source for resident raptors. Both starling and blackbird remains were more commonly found in the summer months, juvenile starlings are a common food source for peregrines within the summer months. This could be because they are more naive than seasoned adults and are not an uncommon find at peregrine falcon roost and cache sites across Britain (Drewitt and Dixon, 2008). Even though there were higher number of remains found in late spring and early summer (Fig. 13) there was a greater range of species found within the winter months (Fig. 15), a reason for this may be that some smaller birds may have migrated or are not as abundant as in the summer months, meaning the peregrine falcons might have to travel further to find a more diverse range of larger prey. It is unclear what impact a released population of eagles would make on resident peregrine falcon populations within the Brecon Beacons National Park, as even though there is not large dietary overlap, eagles may take advantage of some abundant prey species that peregrine falcons rely on. White-tailed eagles especially can switch prey preference to waterfowl when fish numbers are low, and given that fish numbers across the National Park will be low due to lack of large freshwater areas, releasing white-tailed eagles could potentially add competition for resident peregrine falcons that also hunt waterfowl within the region. Golden eagles have also been known to predate on peregrine falcons in the past (Kamarauskaitė et al., 2019), so there is the also a potential risk of released eagles feeding on existing breeding birds in the region, which would have a detrimental effect on peregrine falcon populations. However, there is no evidence to suggest that releasing eagles would have a significant negative effect on resident peregrine falcons, as the species successfully co-exist together in other parts of British Isles (Mee, 2012) and both previously had stable populations across Britain (Newton, 2020).

4.5. Study limitations:

One of the main limitations of this study was the lack of evidence for rabbit population density estimates. The inability to quantify the European rabbit population within the Brecon Beacons National Park was detrimental to the overall results, as rabbits are considered a large part of resident common buzzard diets. There is a lack of data in mainland Wales quantifying rabbit populations, meaning that it was difficult to estimate total numbers purely by carrying out a literature search. Furthermore, although the roadkill data gained from 'Project Splatter' proved useful to give a good idea of the number of rabbits found on the roadside, the dataset was UK wide and did not give a proportional representation of the Brecon Beacons rabbit population. A lack of records concerning common species is a regular problem, records tend to focus on unusual or desirable species instead of reporting everything that is seen every day. One reason for the lack of rabbit records could just be that they are a common species in the UK, similar to hedgehogs and people are forgetting to record regular sightings of them. Anecdotal evidence was therefore relied upon to make assumptions as to the number of rabbits available for resident birds of prey, and estimates could not be made as to whether the rabbit population could also support a population of eagles. Anecdotal evidence of rabbits was mainly witnessed on privately farmed land that bordered the research sites. Whereas evidence for the presence of rabbits was seen, due to the private nature of the land studies could not be carried out to determine local rabbit populations. Cameras could not be placed, and quadrat studies could not be carried out on private land without landowner permission, which could not be gained before the study period started. However, some anecdotal evidence suggested that rabbits are avoiding human disturbance and therefore one of the reasons there is a lack of sightings is that they are using the landscape when people are not around. The focus of the rabbit survey should have instead been on placing more camera traps in more locations to potentially capture sightings of lagomorphs during nocturnal hours.

Another limitation of the study was the limited number of study sites; as only one researcher was available the study was limited to four research sites being checked once a week. The study sites also had to be within a reasonable driving distance of Pencelli, located at the base of the Central Beacons range and had to have parking areas available that were suitable for a car without four-wheel drive. The Brecon Beacons National Park covers an

area of 1,344 km² covering three mountain ranges, the Carmarthen Fans, the Central Beacons, and the Black Mountains. However, the four research sites only encompassed parts of the Central Beacons and the Black Mountains ranges, and the Carmarthen Fans were not considered (Appendix. 1). Therefore, there is a large proportion of land within the National Park where prey species populations were not surveyed, which limited the ability to properly estimate prey availability within the Brecon Beacons National Park. Furthermore, the research sites themselves were all within a 30-minute drive of the centre of the National Park and even though two sites were considered upland and two considered lowland, they all shared relatively similar habitat traits. Therefore, it could be argued that only a small range of habitat types within the National Park were included in the study and prey species availability was only recorded in a relatively small area. Even though the National Park has a large proportion of improved grassland and acid grassland which were included within the chosen study sites, some habitat types like bog, heather grassland and coniferous woodland also are well represented within the National Park and were not considered during this study (Appendix. 3).

Within the questionnaire that was given out to farmers, due to the nature of the survey, no location data was requested. This was mainly because the questions asked farmers to be honest as to whether they removed fallen livestock from 'shared common land' and the reasons behind their answers, this is something that farmers are required to do following the laws of common land rights. If farmers filling out the questionnaire were asked to locate where they were farming even without stating their names, online records show which farms have rights to which commons and it could be easily found out which farms were not abiding by the removal laws. To encourage farmers to be honest about their fallen livestock rates, the survey had to remain completely anonymous. This, combined with the fact that the version of 'Survey Monkey' used only allowed a maximum of ten questions, the only location data gathered was whether upland or lowland areas were used. Therefore, it was unclear as to whether all of the responses came from farmers in Wales or if some came from farms within England. Furthermore, the questionnaire was only released within the last month of the study period, meaning there wasn't a long period of time to gain responses and only a total of 18 were collected. However, this didn't have a big impact on the study as the information gained within the questionnaire was only used to support

points made within the discussion and to act as an explanation for some of the results gained.

4.6. Future studies:

Prey availability assessments need to be carried out in other potential release locations to create a greater understanding as to whether there is enough prey to support both species of eagle alongside existing bird of prey populations. In August 2020 the escaped falconer's golden eagle "Edwina" was found dead within the Abergwesyn valley of mid-Wales (around 20 miles north of the present study area) after surviving in the area for around 10 years. Her ability to survive in this region means it is a likely possible release location and prey availability assessments should also be carried out in this part of mid-Wales. Areas in North Wales such as Snowdonia National Park should also be considered for prey availability assessments as the habitat is favourable to golden eagles, and the coasts of Northwest Wales favourable to white-tailed eagles.

An extension of the original survey should be completed to gain a larger data set to be able to better quantify the amount of prey available within the National Park. Due to Covid-19 restrictions within the years 2020 and 2021, game bird hunting was limited which resulted in fewer birds being released to shoot. Game birds that have escaped shooting sites are a supplementary food source for birds of prey in the autumn months, the lack of game bird releases in the study period meant that there was very limited availability of these prey species. Repeating the study for at least another two years would give a stronger idea as to the level of food available to birds of prey within the National Park on a yearly basis.

One of the points raised by informal conversations with members of the local public during the process of this study, was the impact of supplementary feeding on bird of prey feeding habits within the National Park. Projects to re-establish red kite back in the 1980s resulted in the creation of 'Red Kite Feeding Centres' within Wales that both supported the local red kite populations and acted as tourist hotspots to enable visitors to view the birds without disturbing them. During the GPS study it was noted that a large proportion of 'suburban' sightings were due to regular sightings of large numbers of kites around the feeding centre in Rhayader, suggesting that the centre is an important food source for the local red kite population. Therefore, further studies should be carried out to determine what proportion

of red kite diets are supplemented by these feeding centres and whether that would have an impact on competition between potential released eagles and existing birds of prey. Even though feeding centres may just increase the amount of food given if eagles were introduced, eagles may exhibit food stealing or food dominance behaviours over red kites, therefore, forcing them out of the feeding centres altogether. It is unclear how feeding centres would change to adapt to this situation and more research needs to be done as to whether this issue has arisen in other feeding centres for birds of prey in other parts of the world. Supplementary feeding is not just carried out at designated feeding centres, but it is also believed some people supplementary feed birds of prey in their gardens, even though it is not advised to encourage birds of prey into the urban environment where they could potentially be harmed by, or cause harm to, the general public. Therefore, to gain a good understanding as to the level of supplementary feeding within the National Park, additional research should be done to find out how many people are feeding birds of prey on a regular basis and what the animals are consuming.

Peregrine falcon prey remains were looked at within this study but there was no study of common buzzard and red kite feeding remains. Future studies could be carried out on collecting raptor pellets from around the National Park to analysis what species they are consuming on a daily basis. This could also be combined with studies on both common buzzard and red kite nests, placing cameras on known raptor nests within the National Park could indicate what adult birds are feeding on by recording what is being brought to the nest to feed nestlings. These surveys fell outside the scope of this study, but are informative as to prey species population dynamics within a local area and therefore, would be useful information to be able to quantify the extent of prey populations within the National Park.

The GPS road transect survey proved useful in determining what habitat types birds of prey within the Brecon Beacons National Park. Despite there being a difference in how often the transect from Pencelli to Abergavenny was driven compared to the transect from Pencelli to Libanus, there was a notable difference in bird of prey sightings (Fig. 11). A lack of data along the Pencelli to Abergavenny route meant that strong conclusions could not be made as to the effect of bird of prey persecution incidents that occurred along the transect, notably at Glanusk estate. Bird of prey persecution by game bird estates within Wales is a well known problem, but there is a lack of data as to the effect on the wider bird of prey

population and their subsequent habitat use. Bird of prey persecution is a known factor in the historic decline of both golden and white-tailed eagle populations across the UK and their resulting local extinction in Wales, meaning it is important to understand what impact persecution is having on current populations. An extension of the GPS road transect survey across the whole of Wales would be beneficial to gain a greater understanding as to the dynamics of bird of prey habitat use and the influence of persecution. The most efficient way to expand the transect survey into a larger Wales wide project would be to create a citizen science project similar to 'Project Splatter' in conjunction with Natural Resources Wales (NRW). Having the general public record bird of prey sightings across the country would help to create a detailed map of the habitats that Welsh raptors are currently using when hunting. A citizen science project similar to 'Project Splatter' could ask members of the public to record the locations of raptor sightings, along with the species and time at which it was seen, on a website or a specifically designed mobile application.

The GPS transect survey was only carried out on roads within the National Park, but did not account for the expanse of open hillside that makes up the main mountain ranges within the Beacons (The Central Beacons, The Black Mountains, and The Carmarthen Fans). One of the point raised within literature searches within the study is that common buzzards avoid human disturbance more than red kites, therefore, avoiding roadsides. Common buzzard sightings within the study were lower than red kites and it is unclear whether this is because their population is smaller, or if they are less likely to be seen from the roadside transect. Therefore, the survey could be extended within the National Park itself to include walked transects within all three mountain ranges to determine the true number of common buzzards in the region. From the current study it could be suggested that the common buzzard population is struggling within the National Park, but they could be more abundant in the mountainous areas, further away from human disturbance. Similar to the road transect survey, regular GPS points along hill transect could be taken and associated to habitat types and the habitat preference analysis could be repeated. Habitat preference along the roadside could be compared to habitat preference on the hills to determine if resident raptors are being selective as to where they hunt, or if they are exploring the whole landscape. This could give an idea as to the home ranges of resident raptor species and could give an indication as to prey density, large home ranges of existing birds could mean

prey availability in the National Park is relatively low, and therefore might not be suitable for future release populations.

5. Conclusion

In conclusion, it is still unclear as to whether there is enough of a stable prey population within the Brecon Beacons National Park to support a population of eagles alongside existing raptors. Both golden and white-tailed eagles require between 5%-10% of their body weight in food daily, which is a common requirement with raptor species. However, with eagles being considerably larger birds than current raptors within the Brecon Beacons National Park, means their daily diet requirements are almost double the needs of red kites and common buzzards. A low density of rabbits and fresh carrion availability on the study sites raises the question as to where current raptor populations are obtaining a consistent food source within the National Park. Scavenging raptor species such as red kites and common buzzards are conspicuously abundant within the region, and large numbers of red kites were frequently viewed together. For many raptors to be present in the same location there must be an abundance of food available, some of which clearly comes from scavenging along the roadside, this is supported by similar trends in available roadkill biomass and roadside raptor sightings. The rest may be supported by supplementary feeding from a mix of 'feeding centres' and local communities, a factor that requires further study to determine how much existing raptors rely on supplementary feeding within the National Park. Regular sightings of raptors hunting over 'shared common land' sites despite a lack of evidence of rabbit presence suggests that fallen livestock scavenging is potentially a part of the diet of current raptors within the National Park, especially in upland 'shared common land' areas where fallen livestock carcasses are often impossible to remove. Trends in peregrine falcon prey remains show that there is potentially an abundance of food within the National Park within the spring months when juvenile prey species are more available, and adult peregrines are increasing catch rates to feed their own young. Introducing eagles into the Brecon Beacons National Park has the potential to negatively affect existing raptor species populations, even though existing raptors and the potential introduced eagle species co-evolved in similar regions there is a lack of data showing how abundant each species was in South Wales. Therefore, it is still unsure as to whether introducing eagles would balance raptor population dynamics, or negatively affect them. Future research is

also needed to determine how much existing raptors rely on supplementary feeing, as well as to what extent game estates impact population dynamics. Studies need to be continued to expand across not just a larger area of the National Park, but across the rest of Wales in other sites that have been identified as potential eagle release sites.

5.1. Should eagles be reintroduced?:

It is clear within this study that there is too much information missing as to prey species abundance within the Brecon Beacons National Park to be able to currently support the reintroduction of eagles into the landscape. Therefore, at this time the reintroduction of eagles into the region is not recommended with the outcomes of this study. However, habitat assessments carried out by Lane (2021) determined the Black Mountains region within the Brecon Beacons National Park was a preferable release location for a new population of golden eagles. Prey species found within the National Park suited diet preferences of the golden eagle more than the white-tailed eagle, but the landscape might not be mountainous enough to meet their completely habitat requirements. Golden eagles preferentially consume lagomorphs, even though these species are present within the National Park, lack of evidence within the study meant that an assessment as to the abundance of lagomorph populations was unable to be made. The lack of large water bodies within the region means white-tailed eagles may struggle to find suitable prey, namely a lack of large water bodies means a lack of fish (their preferred prey). White-tailed eagles therefore are unlikely to be suitable for release in the National Park, but nearby coastal regions around Swansea might provide a better environment.

With the amount of carrion and supplementary feeding within the region, it might to possible to support one additional raptor species within the National Park, but it is unlikely it will be able to support the reintroduction of both white-tailed and golden eagles. The Brecon Beacons National Park as a whole may be more suited to golden eagles that white-tailed eagles, especially with the prey species explored within this study. A considerable amount of work is still needed to determine the true population dynamics of raptor prey species within the region, especially in the case of lagomorphs that, from the data from this study, seem to lacking in the area, but are a key part of potential future golden eagle diets. White-tailed eagles might be less likely to be suitable for release in the National Park due to lack of their main food source (fish). However, white-tailed eagles in Scotland have been

known to switch prey preference when fish abundance is low, therefore, further study is needed to determine if there is no fish available, is there actually enough of another food source (waterfowl or livestock carrion) to support a population.

Not only is prey species data not conclusive enough within this study to support the reintroduction of eagles, it is still unclear as to whether their release would have a detrimental effect on existing raptor species. Red kites are more abundant within the region than common buzzards, suggesting that common buzzard populations might actually already be struggling in the National Park. Therefore, the release of another raptor that is not only bigger, but might predate on common buzzard nests could cause a significant negative effect on their population, a species that is still also recovering from persecution.

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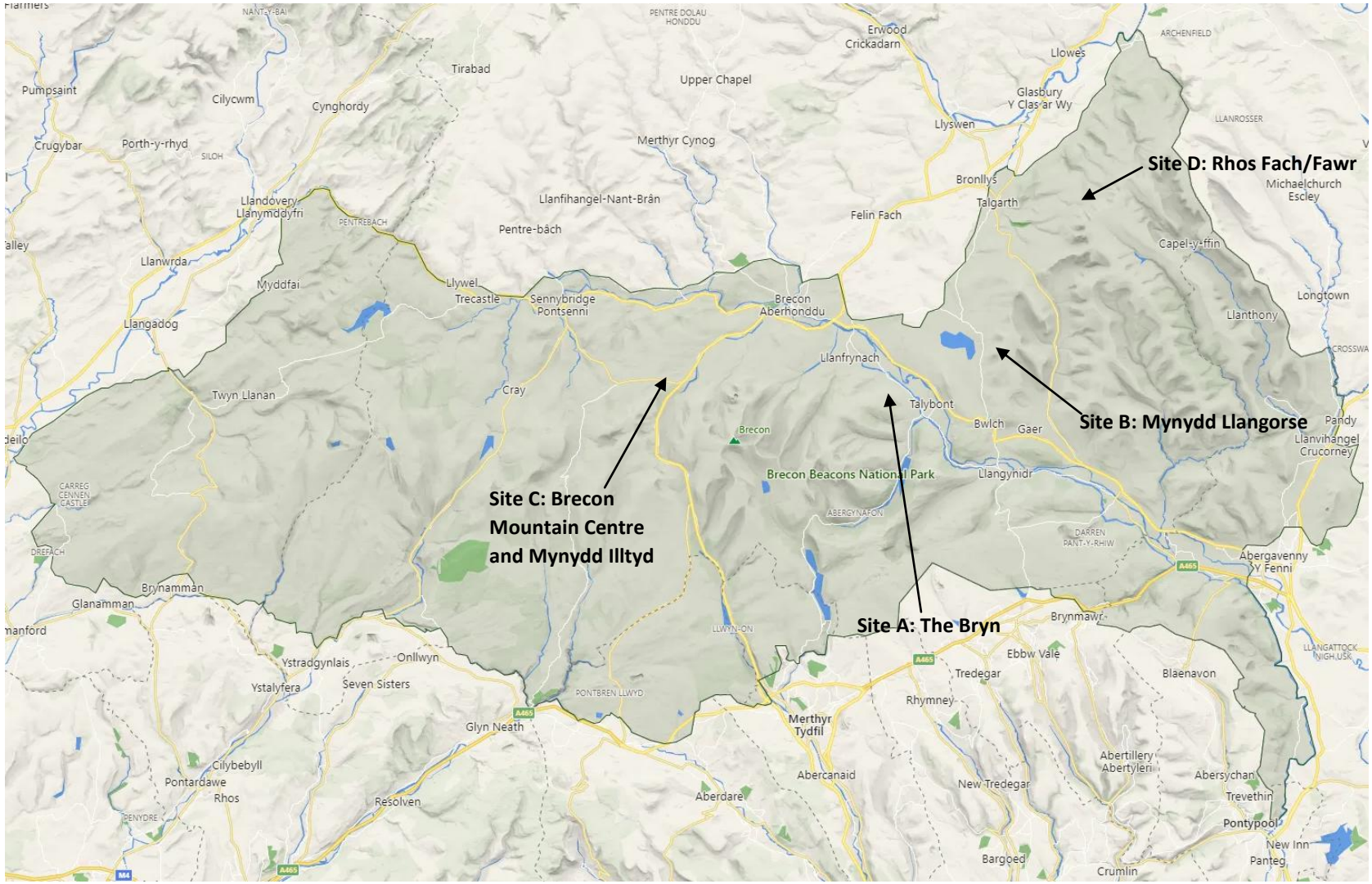
7. Appendices

7.1. Appendix 1: Map of the Brecon Beacons National Park, locations of sites A,B,C & D are identified. Source: Bing Maps.



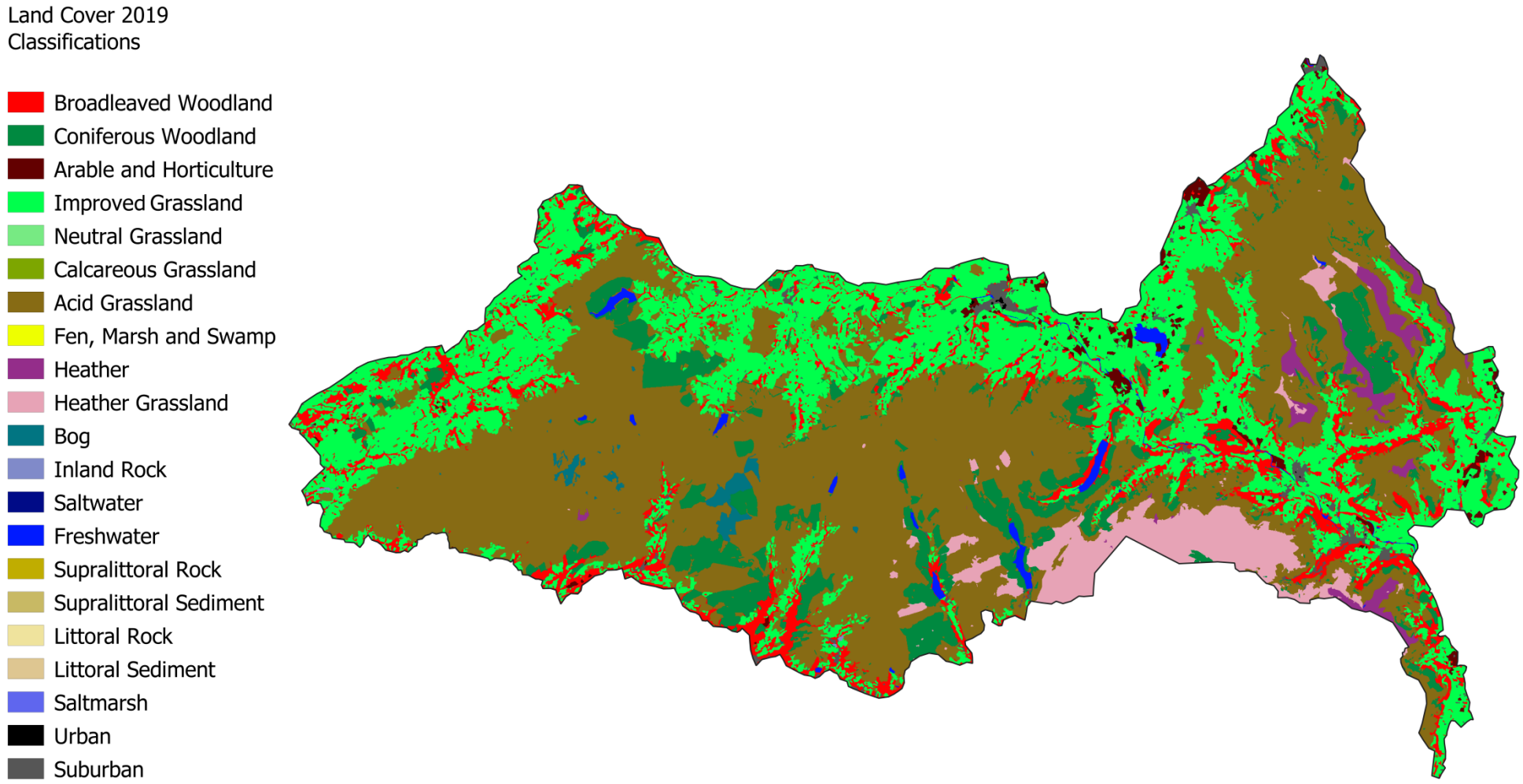
7.2. Appendix 2: UKCEH Land Cover Map 2019 Habitat Types.

Taken from the supporting documentation associated with UKCEH Land Cover Maps 2017,2018 and 2019. "Land Cover Class" refers to the habitat type assigned to each 20m square, and "Land Cover Class number" to its associated numerical value (Morton et al., 2022).

UKCEH Land Cover Class	UKCEH Land Cover Class number	Red	Green	Blue
Broadleaved woodland	1	255	0	0
Coniferous Woodland	2	0	102	0
Arable and Horticulture	3	115	38	0
Improved Grassland	4	0	255	0
Neutral Grassland	5	127	229	127
Calcareous Grassland	6	112	168	0
Acid grassland	7	153	129	0
Fen, Marsh and Swamp	8	255	255	0
Heather	9	128	26	128
Heather grassland	10	230	140	166
Bog	11	0	128	115
Inland Rock	12	210	210	255
Saltwater	13	0	0	128
Freshwater	14	0	0	255
Supralittoral Rock	15	204	179	0
Supralittoral Sediment	16	204	179	0
Littoral Rock	17	255	255	128
Littoral sediment	18	255	255	128
Saltmarsh	19	128	128	255
Urban	20	0	0	0
Suburban	21	128	128	128

7.3. Appendix 3: Habitat map of the Brecon Beacons National Park.

A habitat map created on QGIS showing the Brecon Beacons National Park using UKCEH Land Cover 2019 habitat classifications (Morton et al., 2022).



7.4. Appendix 4: Questionnaire to Farmers.

Questionnaire uploaded to 'Survey Monkey' and dispersed via social media to the local farming community.

This questionnaire is part of a Masters research project at Cardiff University. The purpose of this survey is to assist in estimating the amount of carrion available to scavenging birds of prey. Carrion is an important food source for many birds of prey including Red Kites and Common Buzzards, especially during the winter period. Estimating the amount of carrion available helps us to understand how these birds are using the Welsh landscape..

The answers to this survey will remain completely anonymous even to the researchers. For this reason specific location information is not required to be able to answer any of the questions below. The information collected within this survey will purely be used for the purpose of research and will not be shared with any outside parties or the public domain.

1. What type of livestock do you farm?
   Sheep
   Cattle
   Poultry
   Goats

2. Do you use shared common land to graze your livestock annually?
   Yes
   No

3. If yes, do you use shared common land within the Brecon Beacons National Park?
   Yes
   No

4. What do you class the shared common land you use as?:
   Upland (relatively mountainous landscape)
   Lowland (relatively flat, more grassland landscape)

5. At what time of year do you graze your livestock on shared common land?
   Tick all that apply:
   Spring(March-June)
   Summer(July-September)
   Autumn(October-November)
   Winter(December-February)

6. On average, how many animals do you graze on shared common land annually? (Answer to the nearest 10)

7. On average how many fallen livestock do you experience on shared common land per year?

8. What was the likely/suspected cause of death?
   Tick all that apply:

Bad weather
Illness
Animal attack
Old age
Unable to tell

9. On average how long does it take to discover fallen livestock on shared common land?

10. What is your motivation for removing fallen livestock?
    Tick all that apply:
    I am required to
    To stop wildlife feeding on it
    To prevent disease spread
    To discourage dogs feeding on it
    Aesthetic reasons
    To prevent public complaints

11. If fallen livestock cannot be removed, what is the main reason?
    Tick all that apply:
    Carcass is inaccessible
    To provide food for wildlife
    Time constraints
    Removal and disposal fees are too high

7.5. Appendix 5: Map of the Central Beacons SSSI range, SSSI is shown within the black outline.

https://naturalresources.wales/guidance-and-advice/environmental-topics/wildlife-and-biodiversity/protected-areas-of-land-and-seas/find-protected-areas-of-land-and-sea/?lang=en