The suitability of habitat in Kent for Reintroduction of Pine Marten *(Martes martes)*

By

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ABSTRACT

This study used a combination of literature review and meta-analysis to analyse a variety of resources covering the Pine Marten's (*Martes martes*) habit needs and preferences and whether they were considered a habitat specialist or generalist. The literature was found using set phrases such as 'Pine Marten reintroduction' and 'habitat requirements *Martes martes*'. The literature review found the majority of researchers agreed that the Pine Marten is a habitat generalist and an opportunistic carnivore, altering their diet to fit the availability of food in the differing seasons. Furthermore, the literature review found that the Pine Marten's original decline in the UK was caused by persecution from gamekeepers and the impacts of human activity such as deforestation, agriculture, and urbanisation. However, many studies demonstrated that they found Pine Martens have become adaptive to habitat fragmentation and urban settings.

The literature review was followed by an *ad hoc* selection of forests from Wales, Scotland, and England, and specifically focusing on Kent, with and without Pine Marten populations to compare the habitat features of each forest. In total 34 forests were selected, and habitat data was mined from a selection of scientific journals, organisation produced documents, government publications and communicating with specialists in the field. The data was then used to create a multivariate model. This model further supported the findings of the literature review. It was found that Pine Marten are a habitat generalist with no preference towards a specific forest type. They did not require ancient woodland for survival. Additionally, it was found that woodlands in Kent did possess the habitat requirements for a reintroduction programme. This supports the need for further research into the field to establish a programme for reintroduction into Kent forests.

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CHAPTER 1:
INTRODUCTION

Figure 1.1 – Image of a Pine Marten (*Martes martes*) for appearance reference sourced from Williams, 2019.

Pine Martens (*Martes martes*) (Fig.1.1) were once widespread across the UK and considered the second most common carnivore in the country (Maroo and Yalden,2000; MacPherson et al., 2014; Montgomery et al., 2014; Sainsbury et al., 2018). They were thought to have evolved to be a habitat specialist, requiring mature, coniferous woodlands to survive (Birks et al., 2004; Brainerd and Rolstad, 2002; Caryl, 2008). However, it is argued that Pine Martens were habitat generalists, able to be flexible and adaptable to a combination of habitat features which they have various uses for such as, grassland for hunting and woodland to avoid predation (Porter et al., 2005; Virgós et al., 2012; MacPherson et al., 2014; Lombardini et al., 2015; McNicol et al., 2020).

During the 18th and 19th Centuries pressures from deforestation and persecution from the fur trade and gamekeepers (Lovegrove, 2007; Stringer et al., 2018) caused the Pine Marten populations to decline rapidly, with reports of the species becoming functionally extinct before the 1920s (Croose et al., 2016; Gazette, 2017; Sainsbury et al., 2018; Grabham et al., 2019). However, after the second World War populations began to recover (Langley and Yalden, 1977; Lovegrove, 2007; Sainsbury et al., 2018) through a combination of natural dispersal across Scotland into Kielder Forest, Northumberland, and translocation projects such as those carried out by the Vincent Wildlife Trust in 2015 and more recently in the Forest of Dean by the Gloucestershire Wildlife Trust in 2018 (MacPherson et al., 2014; Stringer et al., 2018; McNicol et al., 2020).

Due to being a widespread species, Pine Martens are thought to have been present in the southeast before the rapid decline occurred (Lockie, 1964; Sainsbury et al., 2018; Mellor, 2018). However, it was thought to be unlikely that Pine Martens were going to return to the Kent area through natural dispersion (MacPherson et al., 2014; Stringer et al., 2018). Therefore, Kent Wildlife Trust (2019) developed a project they named ‘A Wilder Future for Kent′ which included reintroducing Pine Martens as a control species for grey squirrels and aid the restoration of native biodiversity (Mayle, 2004; Mellor, 2018; Sheehy et al., 2018).

This study aimed to use previous research into Pine Martens to identify their habitat niche and key habitat requirements needed to be successfully reintroduced to a location. It used a similar approach as seen in MacPherson et al. (2020), UK Amphibian and Reptile Group (ARG) (Oldham et al., 2010) and Stringer et al. (2018) to create a list of habitat requirements that were ranked on a scale of importance, which was then reviewed. Forests in Kent, Wales, Scotland, and other areas in England were identified and data were mined from various studies on the habitats of each forest to compare for similarities in a resemblance matrix that was produced using Primer 6. This aimed to then highlight forests in Kent that had similar habitat features to those in Wales, Scotland, and other areas in England that had successfully established and maintained populations of Pine Marten.

The project aimed to answer the primary question of whether Kent forests had similar habitat features to forests in Wales, Scotland and other areas of England that were already supporting Pine Marten populations, as this would suggest that there was a possibility Pine Martens could thrive in Kent if reintroduced in the future. However, it also intended to answer whether ancient woodlands had an impact on Pine Martens success when reintroduced; are Pine Martens a true generalist species or do they have a required specialist niche such as needing mature, coniferous woodland (Birks et al., 2004; Brainerd and Rolstad, 2002; Caryl, 2008); and which habitat requirement does previous literature emphasis as being the most important to consider when planning a reintroduction programme for the species.

From these questions, it was hypothesised that habitat features in Kent would be significantly different to the habitat features that are present in Wales, Scotland, and other areas in England. However, it was also speculated that there would be no suitable habitat in Kent forests that would support a newly reintroduced Pine Marten population to the area.

CHAPTER 2:
LITERATURE REVIEW

The Pine Marten belongs to the family *Mustelidae*, the same family as the American mink (*Neovison vison*), European badger (*Meles meles*), weasels (*Mustela nivalis*), ferrets (*Mustela putorius furo*), polecats (*Mustela putorius*), and otters (*Lutra lutra*) (Yalden and Harris, 2008; Mellor, 2018). They are a small semi-arboreal, carnivorous predator native to Britain, with populations recovering throughout the UK but more specifically in Wales and the Forest of Dean (Zalewski et al., 2004; Jordan et al., 2012; Croose et al., 2014; Croose et al., 2016; O'Mahony et al., 2017; Twining et al., 2018; Twining et al., 2019). Pine Marten are a species that is considered to be a habitat specialist (Brainerd and Rolstad, 2002; Caryl, 2008; Lombardini et al., 2015; McNicol et al., 2020). However, it is now thought that they are a species that can adapt to their habitat and require a combination of various habitat features to be able to thrive (Caryl, 2008; Mergey et al., 2011; McNicol et al., 2020).

They were originally the second most found carnivore throughout the UK (Maroo and Yalden, 2000; MacPherson et al., 2014; Walter et al., 2017; Mellor, 2018). As a result of persecution by gamekeepers and the fur trade, and deforestation for urbanisation and resources, the Pine Martens' range was isolated in northern pockets of Scotland (Sainsbury et al., 2018; Twining et al., 2019). By the mid-20th Century, populations started to recover and expand in range within Scotland and by 2015 the Pine Marten populations were being translocated by the Vincent Wildlife Trust (VWT) with a license provided by Scottish Natural Heritage to re-establish their range in Wales (MacPherson et al., 2014; VWT, 2015a; Stringer et al., 2018). There are now other organisations and wildlife trusts seeking to identify suitable habitat for reintroductions in other areas of the UK, one being the Gloucestershire Wildlife Trust (GWT) who have already started to reintroduce the Pine Marten to the Forest of Dean and now the Kent Wildlife Trust (KWT) are looking to follow suit with their '*A Wilder future for Kent*' project (Stringer et al., 2018; KWT, 2019)

This study would be beneficial for the Kent Wildlife Trust as they are in the process of planning a release programme for Pine Marten into the area (KWT, 2019; Wildwood, 2020). Pine Martens have aided in the management and restoration of complex forestry sites around the UK, which in parallel has led to the reinstatement of native biodiversity and balanced ecosystems (Mayle, 2004; VWT, 2015a; Mellor, 2018; Sheehy et al., 2018; KWT, 2019). Kent Wildlife Trust (2019) also aims to reintroduce the Pine Marten to control the grey

squirrel (*Sciurus carolinensis*) population for future red squirrel (*Sciurus vulgaris*) reintroductions (Sheehy and Lawton, 2014; Sheehy et al., 2018), which would further help their *'A Wilder Future for Kent'* project. Therefore, this research was essential for assessing areas to ensure that a reintroduction programme for Pine Marten in Kent has every opportunity of success but will also be beneficial for future reintroductions of other species such as the red squirrel.

2.1 History of the Pine Marten

The Pine Marten is a native predator within Britain which arrived post-glaciation period (MacPherson et al., 2014; Montgomery et al., 2014; Sainsbury et al., 2018), and rose to be one of the most common and widespread predator species in the country during the Mesolithic period (c.15,000-5,000bp) (Maroo and Yalden, 2000; MacPherson et al., 2014). The species can also be found in Western Europe where it is considered an indigenous species (Jordan et al., 2012; Stringer et al., 2018). However, in Britain, most current populations that can be found are in small pockets in the northern parts of England and Wales and originated from populations that remained and became established in the Scottish Highlands (MacPherson et al., 2014; Stringer et al., 2018; Sainsbury et al., 2018). This was the result of translocation programmes (VWT, 2015a; Stringer et al., 2018) that have been required due to the persecution of the species which reportedly started as early as the Tudor period (c.1485-1603) (Wildwood, 2020), but most studies suggested the true decline began within the 18th and 19th Centuries (Lockie 1964; Langley and Yalden, 1977; MacPherson et al., 2014; Walter et al., 2017; Sainsbury et al., 2018) (Fig. 2.1).

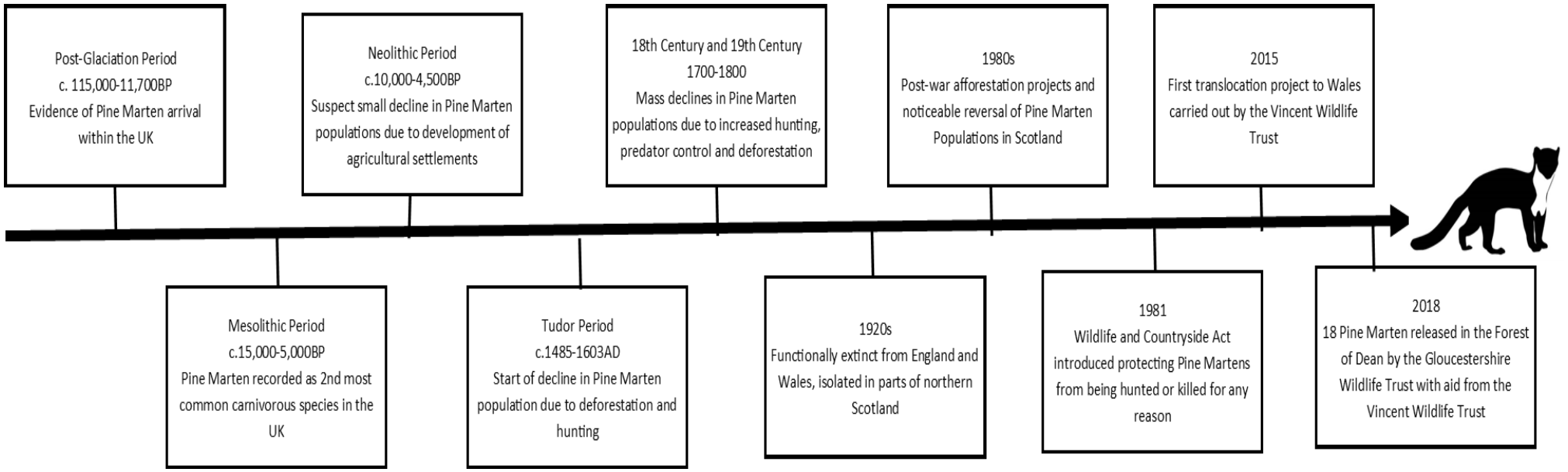

Figure 2.1 – A timeline created using the information provided in studies mentioned in the literature review to order the events Pine Martens have been through.

2.1.1 Persecution and Decline

The persecution and decline of Pine Martens began in the 18th and 19th Centuries and were close to functional extinction in England and Wales just before the 1920s (Lockie, 1964; Langley and Yalden, 1977; Croose et al., 2016; Gazette, 2017; Walter et al., 2017; Grabham et al., 2019). This emanated from direct and indirect human-wildlife conflicts (Bavin et al., 2020), which resulted in many human-caused factors impacting the Pine Marten populations alongside other carnivore species found in Britain such as the polecat (*Mustela putorius*) and wild cat (*Felis silvestris*) (Caryl, 2008; MacPherson et al., 2014; Sainsbury et al., 2018; Stringer et al., 2018). Factors that affected the abundance of Pine Martens were habitat loss and fragmentation, resource exploitation, predator control by Victorian gamekeepers, the fur industry, and vermin status (Bright, 2000; Jordan et al., 2012; MacPherson et al., 2014; Sainsbury et al., 2018; Stringer et al., 2018; Twining et al., 2019).

2.1.1.i Habitat Loss, Fragmentation and Resource Exploitation:

It is thought that woodland decline has been occurring since the Neolithic period 1200 years ago (c.10,000-4,500bp) when the agricultural settlements started to become widespread (Hunter and Ralston, 1999; Twining et al., 2019). There are also records of woodlands being reduced during the Tudor times (c.1485-1603) for timber to create the battleships required for invading countries such as France and Spain (Griffiths, 2011; Elton, 2018; Wildwood, 2020). By the Victorian period (c.1837-1901) land was being managed to maximise the abundance of game birds such as pheasants (*Phasianus colchicus*) and grouse (*Tetraoninae spp.*) (MacPherson et al., 2014; Stringer et al., 2018). These activities exploited natural resources which Pine Martens required for survival for things such as agriculture, commercial entertainment and profit, and urbanisation which continues even today with the development of new housing estates across the country (Robinson and Sutherland, 2002; Caryl, 2008; Balestrieri et al., 2009; Montgomery et al., 2014; Sainsbury et al., 2018; Stringer et al., 2018).

These few things are considered to now be the greatest threats to global biodiversity as well as national biodiversity (Twining et al., 2019). It is believed that by the start of the 20th Century that less than 5% of the UK had woodland cover and required the Forestry Commission (1992) to step in to begin afforestation conversions in Scotland and areas such as the New Forest, Thetford Forest, and Cannock Chase (Caryl, 2008; Bowen-Jones, 2020). It is likely that Kent has been highly impacted by the clearing of woodlands and therefore

before a reintroduction could take place, an afforestation project may be required (Forestry England, 2021).

2.1.1.ii Predator and Vermin Control:

Historically Pine Martens were trapped and controlled by Victorian gamekeepers (Stringer et al., 2018). They were seen to be pests that depleted the population of game birds, which were hunted for sport by humans (Lovegrove, 2007; MacPherson et al., 2014; Sainsbury et al., 2018). Methods such as trapping (Fig 2.2.) and bait poisoning using compounds such as strychnine were used regularly on the Pine Martens to reduce their abundance to aid in the increase in the gamebird populations (Lockie, 1964; Langley and Yalden, 1977; Stringer et al., 2018; Twining et al., 2019). However, by 1914 war broke out diminishing the level of sporting activities and a generation of gamekeepers were lost which led to a reduction in the intensity of predator control (Langley and Yalden, 1977; Caryl, 2008) which provided the Pine Martens with a respite to recover (Lovegrove, 2007; Sainsbury et al., 2018; Grabham et al., 2019). Although recovery was only noted in the northwest of the Scottish Highlands (Sainsbury et al., 2018).

Figure 2.2 – Pine Marten found in an illegally set spring trap on a Highland estate. Image sourced from Raptor Persecution UK (2017).

2.1.1.iii Fur Industry:

Pine Marten pelts were highly prized and so the species were hunted and harvested for furs (Langley and Yalden, 1977; Lovegrove, 2007; MacPherson et al., 2014). In the UK, it is illegal to hunt Pine Marten for the purpose of obtaining their fur for trade. However, this is not the case in every country. Annually, there are less than 1000 marten furs harvested from Latvia and Austria, whilst there are over 5000 in France, Germany, and Sweden (Proulx et al., 2005; Caryl, 2008; MacPherson et al., 2014). Overall, an average of 6000 Pine Martens are killed for their fur in mainland European countries every year.

2.2 Current Status of the Pine Marten

Anthropogenic processes are still a constant and increasing problem for the natural world. Countless countries still destroy habitats to exploit resources for many purposes such as agricultural activities and urbanisation, which is the greatest threat to global biodiversity (Maxwell et al., 2016; Twining et al., 2019). Pine Martens have previously declined due to land-use and persecution (Croose et al.,2014), but now a reversal of the decline is occurring, and the populations have persisted and expanded in range since the 1980s (O'Mahoney et al., 2017; Twining et al., 2019). In Scotland, Wales and now England, conservation measures are helping the Pine Marten to thrive and expand back to their former range in the UK (Walter et al., 2017).

This is assisted by the legal protection provided by the Wildlife and Countryside Act (1981) (2017) and the European Union's Habitats Directive (1992) (MacPherson et al., 2014; Sainsbury et al., 2018; Twining et al., 2019). In the Wildlife and Countryside Act (1981) (2017) the Pine Marten comes under protection from schedule 5, which lists animal species that are protected under section 9 (MacPherson et al., 2014; NatureScot, 2017). This prohibits people from intentionally killing, injuring, taking the species from their habitat, possessing, and trading the animal. Additionally, it protects them from disturbance by prohibiting actions that affect places they use for shelter (Wildlife and Countryside Act 1981, 2017; NatureScot, 2017).

There are many projects and organisations now that have been tracking the Pine Martens status in the UK and helping to encourage them to return to the original range, which use to cover the entire UK (MacPherson et al., 2014; Walter et al., 2017; Sainsbury et al., 2018). The Vincent Wildlife Trust (VWT) is one of the main organisations participating in the

reintroduction of Pine Marten to the UK. All studies carried out must have abided with the International Union for Conservation of Nature (IUCN) Guidelines (2013). The guideline's state that any translocation should be one that yields quantifiable conservation benefits for the translocated population or the ecosystem the species occupies. It is highlighted by VWT (2015) that IUCN (2013) emphasises that the animals' welfare and health, as well ass the ecological landscape, are assessed before reintroduction to reduce risk of failures or damage to the established ecosystem. Therefore, they have carried out feasibility studies to identify areas within Wales for reintroducing Pine Marten, which they successfully achieved by translocating 51 healthy Pine Martens from Scotland under licence from Scottish Natural Heritage and NatureScot, complying with the IUCN and the Wildlife and Countryside Act (1981) (MacPherson et al., 2014; VWT, 2015a; McNicol et al., 2020).

Recently in partnership with VWT, the Gloucestershire Wildlife Trust (GWT) along with Forestry England are working towards reintroducing Pine Marten to the Forest of Dean and the Lower Wye Valley (Stringer et al., 2018). Upon completion of Stringer et al. (2018)'s feasibility study as required under IUCN guidelines (2013), it was concluded that the Forest of Dean was suitable and 35 Pine Marten were released between 2019 and 2021. A follow-up study, has found that the females have started to breed, successfully carrying kits to full term (Gloucestershire Wildlife Trust, 2022). From this, The Kent Wildlife Trust (KWT) is also starting to work with the Wildwood Trust in Herne Bay to start working towards *'a wilder future'* for Kent and is looking into identifying areas for Pine Marten reintroductions across the county (KWT, 2019; Wildwood, 2020).

The current range of the species appears to be concentrated in Scotland, Wales, and Northern England, with a small range appearing in Southern England (Fig. 2.3) (Battersby, 2005; Joint Nature Conservation Committee (JNCC), 2019; VWT, 2015a; Mathew et al., 2018). However, looking at distribution map that had been generated by the JNCC (2019) and the NBN Atlas (2021), the Pine Martens distribution appears to have had a few recorded sightings in the Midlands, East Anglia and verging towards the Southeast (Fig 2.4). However, these sightings are very rare, and it is more accurate to use the range maps provided by the Mathew et al. (2018) (Fig 2.3) and the Vincent Wildlife Trust (2015a) due to the sightings and recordings being more consistent over time.

Unfortunately, JNCC (2019) have found that Pine Marten have low population density making it difficult to apply density estimation for different habitat types. Low population is

suggested a common occurrence for solitary carnivorous species like the Pine Marten due to their requirement for large territories and continuous travelling behaviour (Croose, 2021). Due to the low density of pine marten, it makes it challenging to compare distribution to density. However, there is approximately 3,700 adult pine marten (NatureScot, 2023) in Scotland. Studying the distribution map provided by JNCC (2019), this further enforces Croose (2021) and Iossa et al. (2009)'s theory that carnivore behaviour to continuously travel results in low density due to the population spreading out widely in a larger area, reducing the density of per 10km square. Therefore, this further supports the Pine Martens need for large habitat spaces.

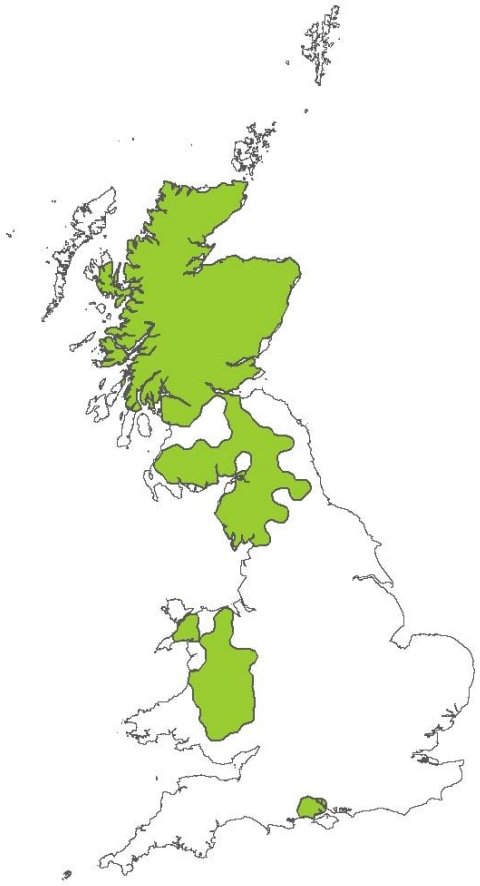

Figure 2.3 – Pine Marten range map across the UK according to findings by the Mammal Society (2018) and the Vincent Wildlife Trust (2015a). Image sourced from Mammal Society (2018).

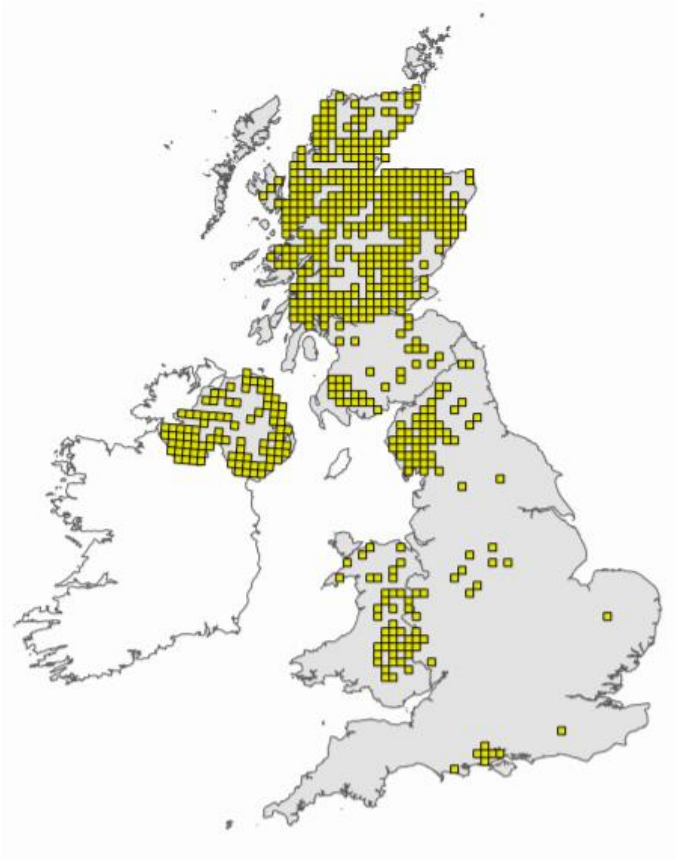

Figure 2.4 – Pine Marten distribution across the UK. Image sourced from JNCC (2019) and the NBN Atlas (2021).

These reintroductions have led to studies being carried out on Pine Marten and its impacts on the environment. Thus far, they have shown to support the administration and restoration of complex UK forestry sites, leading to the renovation of native biodiversity and balance to ecosystems (Mayle, 2004; VWT, 2015a). Pine Marten reintroductions have led to the discovery of their ability to be a native control species for the invasive grey squirrel (*Sciurus carolinensis*) (Sheehy et al., 2018; Ambrose-Oji et al., 2018), which came over from North America in 1876 (Mayle, 2004). This invasive species is considered a forestry pest and its introduction resulted in the decline of the native red squirrel (*Sciurus vulgaris*) due to exploitation competition and squirrel pox (Mayle, 2004; Sheehy and Lawton, 2014; Sheehy et al., 2018). This would be beneficial for later projects to reintroduce the red squirrel in southern areas of England and further the rewilding project being developed and carried out

in the southeast by the Kent Wildlife Trust (2019). Additionally, to grey squirrels, Pine Martens have been shown to assist in the capping of other overpopulated species, which allows other species that are feeling the pressure from overpopulated ones to thrive and repopulate (Sheehy and Lawton, 2014; Sheehy et al., 2018).

2.3 Pine Marten's Niche and Behavioural Traits

In preparation for projects such as this feasibility study with the outlook to develop into a reintroduction programme, it is essential to establish a clear knowledge and understanding of the species' required needs (Lombardini et al., 2015; Stringer et al., 2018; McNicol et al., 2020). It is important to study the target species' ecological niche to identify what the primary factors are and assess their quality (Chase and Leibold, 2003; Virgós et al., 2012; MacPherson et al., 2014; Twining et al., 2019). For instance, this study looked at the Pine Martens' habitat, behavioural and dietary requirements, which narrowed further into focusing on their home-ranges, social structures, seasonal diet and landscape structures that they sought out (Brainerd et al., 1994; Caryl, 2008; Stringer et al., 2018; McNicol et al., 2020).

Since the Pine Martens drastic decline between the 18th and 19th Centuries (Grabham et al., 2019) there have been dramatic changes to the habitat within the southeast regions of England (Sainsbury et al., 2018), which must be considered whilst studying forestry for feasible reintroduction zones. This is vital for the successful reintroduction and conservation of both the species and the land they could be introduced to (McNicol et al., 2020). Anthropogenic activity such as the exploitation of resources and agricultural uses have destroyed a high number of suitable habitat areas (Maxwell et al., 2016; Twining et al., 2019). This has been proven to be associated with mortality and resource reductions (Mergey et al., 2011). However, the Pine Martens have recovered in population numbers (O'Mahony et al., 2017; Twining et al., 2018). They have shifted from being considered a habitat, forest-dependent specialist species (Brainerd and Rolstad, 2002; Caryl, 2008; Mergey et al., 2011; Virgós et al., 2012) towards being a highly adaptive and flexible species in terms of habitat selection and use (Brainerd et al., 1994; Clevenger, 1994; Lombardini et al., 2015; McNicol et al., 2020).

Alongside being an adaptive habitat selector and user, Pine Martens are also food generalists and opportunists and consume a wide range of food items ranging from small mammals and birds to berries and insects, usually consumed in summer and autumn (Brainerd and Rolstad 2002; Yalden and Harris, 2008). Being able to adapt and alter their behaviour to fit a wide

range of habitat niches (Vázquez, 2005) and having dietary plasticity (Blackburn et al., 2009) are highly beneficial towards the Pine Martens abilities to recover in other areas and should, therefore be an advantage for them if reintroduce to the south-east of England (Twining et al., 2019).

2.3.1 Habitat Requirements

Habitats are the physical foundations used by individuals during their regular activities and are an important factor to consider when assessing an area before starting a reintroduction programme for any species (Morrison and Hall, 2002; Virgós et al., 2012; McNicol et al., 2020). In the case of the Pine Marten, it is a common belief that they require mature forests that are coniferous to survive (Gundersen, 1995 as cited in Brainerd and Rolstad, 2002; Caryl, 2008). This type of forest provided a pine marten with methods to avoid predators and access prey in addition to tree cavities that provided thermal insulation for denning and nesting (Caryl, 2008). It is also believed they will avoid open areas, as this puts them at risk of exposure to predation (Brainerd, 1990 as cited in Caryl, 2008; Lombardini et al., 2015).

However, studies have found that Pine Martens have a more flexible approach to habitat selection and usage (Virgós et al., 2012). In a translocation study carried out by McNicol et al. (2020), they found that first-year translocations did not display a habitat preference but did have a preference for felled areas, whilst in the second-year translocation there was a stronger habitat selection for forest areas, but they did not discriminate between forest types. They demonstrated that they could inhabit coniferous, deciduous, or mixed forestry habitats (Fig. 2.5) (Virgós et al., 2012). McNicol et al. (2020) along with other studies have found that the forest type and age is irrelevant in comparison to the structure (Brainerd and Rolstad, 2002; Caryl, 2008).

Further to this, young plantations have been found to be inhabited by Pine Marten (VWT, 2015; Croose et al., 2016; Twining, 2020). Plantations are areas where trees have been internationally placed (Woodland Trust, 2015), and have been found to be a habitat Pine Marten will inhabit (Forestry and Land, 2021). There are two types of plantations: commercial and restorative. Commercial plantations are solely created with the intention of creating a timber productions, whilst a restorative plantation creates new habitats and/or connects existing woodlands. The Vincent Wildlife Trust (2015) recommends that all forests should have areas that are managed with the primary aim of biodiversity with a secondary aim of timber production. With the correct management in place, Croose, Birks and Martin

(2016) found that commercial plantations in Galloway, Scotland posed no issues for Pine Marten. Croose et al. (2016) discovered that when humans introduced den boxes, female pine martens were able to successfully reproduce, and the risk of predation was significantly reduce. This has further been found the case in Northern Ireland, a country that only has 10.5% natural forest cover, of which 0.1% is identified as ancient woodland (Department of Agriculture, Food & the Marine, Ireland, 2018). Pine Marten located in Ireland were found to consistently select commercial plantations for denning and foraging due to borders to non-forested areas, which created access to resources typically limited in old-growth forests (Caryl et al., 2012; Twining, 2020).

Figure 2.5 – A comparison of coniferous, deciduous, and mixed woodlands. Images sourced from Eilbeck, 2006; Johnson, n.d.; The Wildlife Trusts, 2018a.

Figure 2.6 – Images of the predators of the Pine Marten: Lynx, Golden Eagle, Eagle Owl, Wolf and Red Fox. Sourced from Rafferty, 2008; Cairngorms Nature, 2019; Turbary Woods, n.d.; Guardian, 2019; National Wildlife Federation, 2017.

Additionally, a habitat factor that is important to note whilst assessing the suitability of a forestry area, such as a plantation, for reintroduction of a pine marten population is the structural complexity an element needed to fulfil their life requirements (Brainerd et al., 1994 as cited in Caryl, 2008; Virgós et al., 2012; McNicol et al., 2020). There are 3 forest management plans highlighted by the Vincent Wildlife Trust (2015) which they provide guidance on how to use these management strategies to create the structural complexity that Pine Marten thrive in. The VWT (2015) recommended that clear-felling should not exceed 20 hectares and should be long sinuous coupes in areas with Pine Marten presence, as these open areas are important for feeding and foraging behaviours. Long-term retention (LTR) is where trees are retained for longer than planned, which offers habitat continuity for the Pine Martens and has minimal human intervention. Continuous Cover Forest (CCF) is a method that provides the optimal environment for Pine Martens, as it enforces their need for a three-dimensional habitat (Croose et al., 2016). This management method avoids the need for clear-felling whilst still providing timber to the economy without impacting the Pine Marten population.

A more complex structure within a forest will provide the Pine Marten with increased cover from their native predators, which would be the red fox (*Vulpes vulpes*) in the southeast of England (Lomardini et al., 2015). In other areas, their predator range is far greater including species such as lynx (*Lynx lynx*), golden eagle (*Aquaila chrysaetos*), eagle owl (*Buboo bubo*) and wolf (*Canis lupus*) (Fig. 2.6) (Brainerd and Rolstad, 2002; Caryl, 2008). When there is a lack of complex structures in forested areas, Pine Marten will often resort to inhabiting ground-level sites which in turn increases their risk of predation from the species list above (Brainerd et al., 1995; Birks et al., 2005; Croose et al., 2016). Therefore, the consequences do not lie with the age or type of forest, but with how it is managed and whether those involved in management are provided with appropriate training to maintain the structural complexity for Pine Marten populations to reduce predation risks (VWT, 2015; Croose et al. 2016).

Landscape complementation enables Pine Martens to have greater flexibility and make use of various habitats than previously found for different functions and key resources (Porter et al., 2005; Caryl, 2008; Virgós et al., 2012; McNicol et al., 2020). Pine Martens can utilise many environmental structures. In Lombardini et al.'s (2015) study, they identified 8 environmental variables which Pine Martens seemed to utilise. These were: woodlands, shrublands, natural grasslands, open space with no vegetation, wetlands and water bodies, transitional woodland and shrubland, arable lands, and urban areas (Fig. 2.7). Within these areas, Lomardini et al.

(2015) managed to identify tree and plant species that were similar across all the areas that pine martens were located in. It was later found that Pine Martens preference for open areas was due to the abundance of one of their preferred dietary choices, field vole (*Microtus agrestis*). However, they still required areas such as shrubs and low canopy cover to avoid predators and to find safe denning areas (Lombardini et al., 2015; McNicol et al., 2020).

Figure 2.7 – Images of the habitats listed in Lombardini et al.'s (2015) study. Woodland, shrublands, natural grasslands, open space with no vegetation, wetlands and water bodies, transitional woodland-shrubs, arable lands, and urban areas. Images sourced from Woodland Trust (2019); Mucina et al. (2006); Kosztra (2017a); NALC (2016); WWF (2012); Kosztra (2017b); Fredenburgh (2015); and Mathiesen (2015).

In many areas where Pine Martens are currently located, anthropogenic processes have destroyed their habitats (Maxwell et al., 2016; Twining et al., 2019). This has resulted in certain habitats becoming fragmented, which was believed to be a challenge for the Pine Marten species populations (Caryl, 2008; Twining et al., 2019). Although this was disproven by Lombardini et al.'s study (2015) in Italy and by Mergey et al. (2011). Fragmented forests proved to be of better quality than originally believed. Pine Martens that were located and identified as establishing their home range within a fragmented area demonstrated stability for over 4 years (Mergey et al., 2011). Although, there is still little evidence to determine whether Pine Martens can reproduce successfully and develop a sustainable population from a fragmented habitat, thus further research would be required in this area to determine whether it is appropriate to reintroduce them into a fragmented area (Mergey et al., 2011). It is suggested that a suitable area for reintroduction would be areas of large forestry sectors surrounded by pasture, moorland, and farmland, which would provide structural diversity required for denning and foraging behaviours (McNicol et al., 2020).

Another essential requirement for the success of Pine Marten reintroductions is the availability of natural cavities for denning and nesting (Fig. 2.8) (Birks et al., 2005; Cameron, 2006). These cavities are usually created by other species such as insects, fungi and birds like the great spotted woodpecker (*Dendrocopos major*) and green woodpecker (*Picus viridis*) or through other methods such as forest fires (Fox et al., 2009; Twining et al., 2018). Pine Martens in Scotland have been found to use rock crevices (Fig. 2.9) when they cannot access arboreal cavities in trees. They are protected from terrestrial predators, but there is a trade-off for thermoregulation and insulation (Birks et al., 2005; Lombardini et al., 2015). However, in previous reintroduction projects, they have provided den boxes that eased the pressures of predation and the energetic cost of searching for a nesting area, which aided in the increase in populations (Fig.2.10) (Croose et al., 2016; Twining et al., 2019; McNicol et al., 2020).

Figure 2.8 – Pine Marten looking out from its den in a tree cavity. Image sourced from Clement (n.d.)

Figure 2.9 – Pine Marten looking out from a rock crevice den. Image sourced from The Red Squirrel Group (2012).

Figure 2.10 – Pine Marten den boxes as created by the Vincent Wildlife Trust (2015b).

2.3.2 Pine Marten Competition

In addition to intra-specifically competing with conspecifics, Pine Marten also must interspecifically compete with 6 other mustelid carnivores that live in the UK (McDonald, 2002). The other 6 mustelids are the weasel (*Mustela nivalis*), stoat (*Mustela erminea*), American mink (*Neovison vison*), polecat (*Mustela putorius*), badger (*Meles meles*), and otter (*Lutra lutra*). Unlike the Pine Marten, these species show a greater distribution and abundance throughout the nation, except for the Polecat which shows the contrary of the Pine Marten, as Polecats have a greater presence in England than Scotland (Mammal Society, 2018). All these species faced similar persecutions resulting in reduced population densities particular between 19th and 20th Centuries (Sainsbury et al., 2018). For example, the otter was seen as a pest due to the apparent competition with humans for food resulting in predator control (Jefferies, 1989; Lovegrove, 2007). The badger was also persecuted in the 1970s for being a reservoir for bovine tuberculosis (bTB), which resulted in widespread culling (Cassidy, 2017); however, badgers now have the Protection of Badgers Act (1992) to prevent unmanaged culling schemes.

These mustelid species are recognised as mesopredators, as they will adjust their behaviour to reduce any risk of competition with conspecific or other species and are often predated by larger predators (Garvey et al., 2021). They all have the potential to inhabit similar habitats; however, they all have their own unique niche which is how they avoid conflict for resources (St-Pierre et al., 2006; Mammal Society, 2018). For example, the badger as a terrestrial mustelid who does not have the ability to climb trees (Robertson et al., 2014), and the otter inhabits water source such as rivers something which has not been noted for other mustelids (Van Looy et al., 2014).

They all have similar habitat and dietary niches; however, they have demonstrated a sophisticated way of using resource partitioning to cohabit in the same areas. The UK mustelids are adapted to opt for prey which correlates to their size, for example, the Polecat has a preference for rabbits (*Oryctolagus* cuniculus) whilst stoats will go for smaller mammals such as water voles (*Arvicola amphibius*) (McDonald, 2002; King and Powell, 2007; Mammal Society, 2018). By practising resource partitioning, all the UK mustelids are able to inhabit an area together and are able to avoid intra-guild predation and competition. Therefore, competition is not a critical concern when constructing Pine Marten reintroduction projects.

2.3.3 Dietary Requirements

A variety of samples were taken from differing habitats to examine the impacts habitat had on the diet (Twining et al., 2019). Individuals who were studied in smaller home ranges within fragmented areas had access to a higher abundance of food resources, which fulfilled the energy requirements (Mergey et al., 2011). Therefore, this demonstrated Pine Martens can locate food in restrictive habitats. It was also found that Pine Martens used shrublands because there was high availability of food and a lack of predators, which reduced the probability of being predated whilst foraging (Clevenger, 1994 as cited in Virgós et al., 2012). It was also found there was regional variation in diet, but the Pine Marten still retained the same trophic niches breadth throughout (Twining et al., 2019).

It is key to identify suitable food resources for a reintroduction programme to be successful (Grabham et al., 2019). Pine Martens are opportunistic food generalists (Caryl, 2008; Grabham et al., 2019); they are highly adaptable to seasonal changes and varying prey availability (Lynch and McCann, 2007; Caryl, 2008; Twining et al., 2019). Pine Martens have a wide range of food items and will use them as they become more abundant and accessible (Zalewski, 2004; Caryl, 2008). They are a species that we can apply optimal foraging theory. As a generalist, they exploit resources that optimise net energy intake whilst reducing energetic costs, altering diet to focus on high-quality and abundant resources (Pyke et al., 1977 as cited in Twining et al., 2019). Pine Martens will also change their diet as a response to seasonal instability in resources (Popa-Lissenu et al., 2007; Twining et al., 2019).

As opportunistic generalists, they feed on whatever is available to them at the time. This could be small mammals, ungulate carrion, rabbits, hares, squirrels, birds (Lynch and McCann, 2007; Twining et al., 2019), eggs, insects, honey, fruit, nuts, fungi, frogs, toads, lizards and leftovers from bird tables and rubbish (Yalden and Harris, 2008; Mellor, 2018). The food items Pine Martens have access to are often influenced by both region and season. For example, large mammals and carrion are noticed more in winter and early spring, berries and insects are more frequent in scats during summer and autumn (Yalden and Harris, 2008).

However, studies have found that Pine Martens do have a strong preference for voles belonging to the genus *Microtus*, which also noted in their relative the American marten (*Martes americana*) (Balharry, 1993; Buskirk and MacDonald, 1984 as both cited in Caryl, 2008). This discovery is true for Pine Marten populations in Scotland, where field voles (*Microtus agrestis*) (Fig. 2.11) are the primary prey item occurring in approximately 80% of

scats (Balharry, 1993 as cited in Twining et al., 2018). Although this was not the case in Ireland. Ireland has a significantly lower small mammal biodiversity in comparison to Scotland; they have an absence of native voles, which demonstrates the regional variations in Pine Marten diets (Montgomery et al., 2014; Twining et al., 2018). A study by Twining et al. (2019) found that Ireland's Pine Marten population frequently consumed grey squirrels above most other small mammals available in the country. This discovery provided part of the foundation for reintroduction projects in the rest of the UK to manage grey squirrely populations (Sheehy et al., 2018). Lynch and McCann (2007) found that Pine Marten in Ireland favoured fruit items throughout the year, with minimal consumption of birds in spring and frogs through spring till autumn, then foraged earthworms were predominate in winter periods.

Figure 2.11 – Field vole, Microtus agrestis, pine marten's primary food source, but they are opportunists and will eat a wide range of prey and foraged items. Image sourced from The Wildlife Trusts (2018b).

Birds are another common find in both Pine Marten scats and caches. Twining et al. (2018) found that 66.62% of caches were made up of birds whilst only 33.11% contained small mammals. The most noted bird group was songbirds such as the robin (*Erithacus rubecula*), chaffinches (*Fringilla coelebs*), wrens (*Troglodytidae spp.*) and various tits (Lynch and McCann, 2007; Yalden and Harris, 2008; Twining et al., 2018). On close examination, it was found that the majority of the birds found were juveniles and fledgelings (Twining et al., 2018). It is argued that female Pine Martens alter their foraging behaviour and diet to target juveniles and fledgelings because it reduces the energetic cost and risk of predation whilst carrying and caring for kits (Grabham et al., 2019). Females that are carrying and caring for kits have also been studied and found to consume eggs to adhere to the energetic requirements that the gestation and lactation periods are accompanied by (Fig. 2.12) (Lewis and Kappeler, 2005; Grabham et al., 2019). For a population to be established during a reintroduction programme it is necessary to ensure that female Pine Martens will have access to eggs without having a significant impact on the bird populations. Furthermore, there was no immediate evidence that the Pine Marten populations are significantly impacting any red listed species in the UK (Mathews and Harrower, 2020; IUCN Red list, 2023) but are supporting the recovery of restricted species such as the red squirrel supporting the restoration of a native ecosystem (Sheehy et al., 2018; Twining et al., 2020; The Woodland Trust, 2020).

Figure 2.12 – Female pine marten caught on camera in a bird's nest searching for eggs. Sourced from Liznm, 2018.

2.3.4 Behavioural Needs

Behaviour is one way of assessing how an animal is settling into its new environment, thus it is essential to have a sound knowledge of the behavioural needs of a species being reintroduced into a new region (McNicol et al., 2020). Certain habitat types that provide the greatest opportunities for natural behaviours such as, breeding, resting, and denning, foraging, and predator evasion, should be maintained as much as is viably possible to ensure the Pine Martens can successfully become established (Brainerd and Rolstad, 2002; Lombardini et al., 2015).

2.3.4i Foraging

Pine Martens are defined as semi-arboreal predators (Croose et al., 2014; O'Mahony et al., 2017; Twining et al., 2018). This means they spend half their time in the trees. They are often found on the ground during periods of foraging with the occasional canopy hunt resulting in the capture of birds and squirrels (Yalden and Harris, 2008). On average they need to forage for approximately 140-160g of food, which equates to 10% of their body weight (Yalden and Harris, 2008). As previously established Pine Martens demonstrated they can locate food in restrictive habitats but often utilise shrublands because they have high availability of food and lack predators (Clevenger, 1994 as cited in Virgós et al., 2012).

However, there has been evidence to suggest they will create a food cache in scenarios where food becomes scarce. Food caching is defined as an act of storing food for later consumption (Henry et al., 1990). Although Twining et al. (2018) found that pine marten creates short-term caches for food storage to assist in an individual's survival during periods of high food demand such as raising young, the mating season and seasonal changes. One study carried out in Sweden found bird eggs in a winter scat collection survey, which supported the argument that Pine Martens will demonstrate caching behaviour alongside their normal foraging behaviour (Helldin, 2000; Twining et al., 2018). This would require further research to be proven for other regions (Yalden and Harris, 2008).

2.3.4ii Denning and Breeding

Being semi-arboreal means that Pine Martens generally use cavities that have developed in trees through the aid of other species such as insects, fungi and birds (Adkins, 2006; Fox et al., 2009; Twining et al., 2018). Felled trees are also found to be good for denning and foraging because Pine Martens do not have the ability to create cavities (McNicol et al.,

2020). If they are not able to access these denning opportunities this can limit the distribution, abundance and success of the species being able to demonstrate reproductive behaviours (Twining et al., 2018).

Females will often alter their behaviour to ensure the survival of their young from birth to become independent young adults (Grabham et al., 2019). She will choose to select prey that reduces the energetic costs of foraging such as birds' nests for eggs, which also aids in the lactation process (Yalden and Harris, 2008; Twining et al., 2018; Grabham et al., 2019).

She will choose a secure shelter during this period but if these dens are scarce it will impact the birthing and raising of the young, which could result in failure of a reintroduction programme if denning and breeding behaviour is not considered (Fig. 2.13) (Van Den berg and Gouwy, 2011; Lombardini et al., 2015). In Scotland, Pine Martens will not only use tree cavities but also rocky areas that are elevated and thus inaccessible to terrestrial predators (Webster, 2001). However, the cost of this is suboptimal for thermoregulation, insulation and energy costs, which can result in limitations to breeding success (Birks et al., 2005; Lombardini et al., 2015).

To ease this pressure on Pine Martens being able to successfully display denning and breeding behaviours during a reintroduction it has been suggested to identify suitable locations to place artificial den boxes (Fig 2.10; Fig. 2.13) (Twining et al., 2019; McNicol et al., 2020). This will help to reduce the pressures from predation and using energy to find suitable nesting places with thermoregulation (Twining et al., 2019).

Figure 2.13 Mother pine marten with her kits inside an artificial den box. Image sourced from Deadline News (2018).

2.3.4iii Establishing Territories

Pine Martens are a naturally dispersing species and establish large territories among individuals (Yalden and Harris, 2008). Therefore, it is important to consider this behaviour because there needs to be enough space for a population to be established without too much overlap (McNicol et al., 2020). Studies have found that the minimum home-range requirement for a male Pine Marten is 2.23km^2 and 1.49km^2 for female martens (Yalden and Harris, 2008). However, this can vary from region to region due to the differentiation between available woodland areas. For example, pine marten from Scotland can occupy territories 5-fold greater than the minimum requirement stated (Yalden and Harris, 2008).

Males will often disperse further to find an area with the most space available for them to live without encountering another conspecific (Yalden and Harris, 2008; McNicol et al., 2020). In contrast to this, females do not disperse far from their home range. Male and females' territories are seen to overlap often so that procreation can occur, but there is less overlap between male-male territories and female-female territories (Bartolommii et al., 2016; McNicol et al. 2020; Wildwood, 2020).

CHAPTER 3:
MATERIALS AND METHODS

The data gathered was put into a multivariate analysis creating a resemblance matrix, after being collated through a combination of Pine Marten specific literature, resources provided by NGOs (Appx. A1-A9), and the UK Government's MAGIC Maps GIS application (Natural England, 2011). The resemblance matrix generated a similarity in which forests with alike features will cluster more closely together in space whereas forests that differ in their characteristics will be further apart and dispersed from cluster trends. The matrix assisted in highlighting which forests in Kent had similar habitat features to forests in Wales, Scotland, and other areas in England which had existing Pine Marten populations established. This would help to identify Kentish forests that could be proposed for further research into suitability for Pine Marten reintroduction projects.

Initially, the variables were identified from the literature and MAGIC Maps where data was available. Where data was not available on the variables, NGOs with links to Pine Marten research were contacted (Appx. A1-A9) to gain access to data which could fill any gaps in the dataset. MacPherson (Appx. A1) provided the key piece of literature which highlighted the most essential habitat features for Pine Marten, which established a foundation for recognising the habitat variables which would be relevant to Pine Marten reintroduction success.

Upon establishing the habitat variables that would be essential for reintroduction success, the study progressed into gathering woodlands outside of Kent which were then categorized by the presence and absence of Pine Marten. By having forests that had both presence and absence of Pine Martens, this allowed for comparison between why Pine Marten would struggle to succeed in areas where they were absent, looking at what features were lacking compared to the areas where they had established a stable population. Further to this, the study could then look at whether forests in Kent, which are yet to have Pine Marten reintroduced, would be able to provide the right habitat features for success which would determine whether a project would be feasible.

3.1 Identify Habitat Requirements

Habitat requirements for Pine Marten were extracted from a variety of literature such as journals, articles, books, and other resources that were found using a set phrase list in conjunction with the species name (Table 3.1). Multiple databases and search engines were

used to locate key resources. Books were sourced using Canterbury Christ Church University's Library search to find any physical copies of relevant literature which may not have been available electronically. This search extended to using Google Scholar, CORE, Elsevier, Springer, and ScienceDirect, which brought up many papers focused on Pine Marten. A more specific search with these terms was carried out on the Vincent Wildlife Trust's website to find the key literature that aided this research. These resources were accessed between September 2020 and March 2021, then revisited in August 2021 to check for any updates before the study concluded.

Table 3.1 – Common phrases and keywords that were recorded in a notebook whilst looking for literature to be able to identify the habitat requirements for Pine Marten (Martes martes). These phrases were searched in conjunction with the species name.

Keywords and Phrases
Pine Marten
Martes martes
Reintroduction
Forestry
Woodlands
Habitat features
Essential habitat
Habitat requirements
Pine Marten habitat
Martes martes habitat
Pine Marten reintroduction
Martes martes reintroduction
Pine Marten woodlands
Pine Marten forestry
Martes martes woodlands
Martes martes forestry
Habitat requirements Pine Marten
Habitat requirement *Martes martes*
Successful Pine Marten reintroductions
Successful *Martes martes* reintroductions
Unsuccessful Pine Marten reintroductions
Unsuccessful *Martes martes* reintroductions
Scottish Pine Marten
Scottish *Martes martes*
Welsh Pine Marten
Welsh *Martes martes*
Denning
Pine Marten denning
Martes martes denning
Territories
Pine Marten territories

Martes martes territories
Behaviour
Pine Marten Behaviour
Martes martes behaviour
Diet
Dietary requirements
Pine Marten diet
Pine Marten dietary requirements
Martes martes diet
Martes martes dietary requirements
Habitat fragementation Pine Marten
Pine Marten *Martes martes* history
Pine Marten current status
Pine Marten declines
Persecution and decline Pine Marten
forest
Kent Wildlife Trust
Gloucestershire Wildlist Trust
Vincent Wildlife Trust

Habitat features that were mentioned frequently by the authors were recorded and then ranked in importance for successful Pine Marten reintroductions from 1-14 (1 = most important; 14 = least important) (Table 3.2). For this study, frequently is defined as the main habitat features that the researchers have identified as their primary focus within their work. For example, McNicol et al. (2020) and MacPherson et al. (2014) appeared multiple times in the table below, because their research focused on a variety of habitat features and habitat structure overall rather than having a singular focus feature. Therefore, they mentioned the features at least four or five times through the papers. Studies such as Brainerd and Rolstad (2002) and Caryl (2008) had a core focus on woodland type and concluded that coniferous woodland was preferable, despite more recent studies arguing otherwise.

Table 3.2 – Habitat Features identified from the literature with the citations of where the habitat was recorded. The features are ranked from 1-14 for importance for successful reintroductions of Pine Marten (Martes martes) (1=most important; 14 = least important)

Habitat Feature	**Reason**	**Level of Importance (1-14)**	**Citation**
Nesting Sites: **- Natural Tree Cavities** **- Rock Crevices** **- Den Box Locations**	For denning and nesting, provides protection from predator and thermoregulation; however, thermoregulation and insulation sacrificed when using rock crevices. Suitable site for den box	1	Birks et al., 2005 Cameron, 2006 Lombardini et al., 2015 MacPherson et al., 2014 McNicol et al., 2020 Twining et al., 2018 Twining et al., 2019

	placement will aid to ease pressures from predation and settlement during initial reintroductions		
Deciduous (Broadleaf) Woodland	Second-Year translocators demonstrated a preference for forestry but did not discriminate	2	MacPherson et al., 2014 McNicol et al., 2020 Virgós et al., 2012
Natural Grassland	Demonstrated a positive association with the occurrence of pine marten in already populated areas of the species	3	Lombardini et al., 2015 MacPherson et al., 2014
Coniferous Woodland	Second-Year translocators demonstrated a preference for forestry but did not discriminate	4	Brainerd and Rolstad, 2002 Caryl, 2008 MacPherson et al., 2014 McNicol et al., 2020 Virgós et al., 2012
Mixed Woodland	Second-Year translocators demonstrated a preference for forestry but did not discriminate	5	McNicol et al., 2020 Virgós et al., 2012
Moorland or Heathland	Provides structural diversity suitable for denning and foraging behaviours	6	MacPherson et al., 2014 McNicol et al., 2020
Shrublands (Scrublands)	Foraging benefits – higher food availability, increased cover from predators – lack of predators	7	Lombardini et al., 2015 McNicol et al., 2020
Fragmented forestry areas	Believed to possess equal sometimes better-quality benefits to foraging and home range spacing, proven to hold a stable population for over 4 years. Higher abundance of food resources, fulfilled energy requirements	8	Caryl, 2008 Lombardini et al., 2015 Mergey et al., 2011 Twining et al., 2019
Pasture	Provides structural diversity suitable for denning and foraging behaviours	9	MacPherson et al., 2014 McNicol et al., 2020

Low canopy	Avoid predation and provides denning areas	10	Lombardini et al., 2015 McNicol et al., 2020
Felled Areas	First-Year translocators demonstrated a preference; this also add to complexity of the landscape making hideaways and denning areas more accessible	11	McNicol et al., 2020
Wetlands and water bodies	Access to a water source for drinking and bathing	12	Lombardini et al., 2015
Arable lands	Area where field voles could be found	13	Lombardini et al., 2015 MacPherson et al., 2014
Open space with no vegetation	Foraging benefits and passages from one habitat to another	14	Lombardini et al., 2015

The ranking of importance was a challenging task and one that was not based off the quantity of papers that discussed the habitat features. However, it looked at whether the studies concluded that the feature(s) had major positive or negative impacts on Pine Marten success in reintroduction. It also considered any minor impacts that could have interrupted with Pine Martens reintroductions. Sarrazin (2007) highlighted for a reintroduction to be successful there are 3 key stages: establishment, growth, and regulation. This information was key to analyse the studies and assess whether the reintroductions being discussed fit the success criteria laid out by Sarrazin (2007) and supported by Seddon (2015) and the IUCN (2013). Therefore, upon reading the studies available, it suggested that nesting site should be the most important feature as they are essential for Pine Marten establishment, growth, and regulation. Whilst open spaces were found to have severe negative impacts on establishment, which would fail to lead to growth and regulation.

3.2 Complication of Method

This method helped to identify the ideal combination of habitats for a release site, which would be beneficial towards the success of a Pine Marten reintroduction programme. These sites would provide structural diversity in the environment, an essential characteristic required in forests for Pine Marten to successfully repopulate an area. However, the 14 features that had been identified were unavailable in the woodlands of interest without carrying out an element of ground-truthing, which was not viable due to the COVID-19 restrictions in place across the UK during the period of this study.

A new approach was taken to overcome the challenges posed by the worldwide pandemic. The features originally identified were reduced to 8 after reviewing MacPherson et al.'s (2014) study and communicating with the current research leads at the Vincent Wildlife Trust and other NGOs around the UK (See Appx. A1 – A9; Table 3.3). The features that were removed were: nesting sites, fragmented forestry areas, low canopy, felled areas, wetlands and water bodies, and open spaces with no vegetation.

Table 3.3 - Final Habitat features list used in study for collecting data from previous studies. Ranked in level of importance for successful Pine Marten (Martes martes) reintroduction (1= most important; 8=least important)

Habitat Feature	Reason	Level of Importance (1-8)	Citation
Deciduous (Broadleaf) Woodland	Second-Year translocators demonstrated a preference for forestry but did not discriminate	1	MacPherson et al., 2014 McNicol et al., 2020 Virgós et al., 2012
Natural Grasslands	Demonstrated a positive association with the occurrence of pine marten in already populated areas of the species	2	Lombardini et al., 2015 MacPherson et al., 2014
Coniferous Woodland	Second-Year translocators demonstrated a preference for forestry but did not discriminate.	3	Brainerd and Rolstad, 2002 Caryl, 2008 MacPherson et al., 2014 McNicol et al., 2020 Virgós et al., 2012
Mixed Woodland	Second-Year translocators demonstrated a preference for forestry but did not discriminate	4	McNicol et al., 2020 Virgós et al., 2012
Moorland and Heathland	Provides structural diversity suitable for denning and foraging behaviours	5	MacPherson et al., 2014 McNicol et al., 2020
Shrubland (scrubland)	Foraging benefits – higher food availability, increased cover from predators – lack of predators	6	Lombardini et al., 2015 McNicol et al., 2020
Pasture	Provides structural diversity suitable for	7	MacPherson et al., 2014 McNicol et al., 2020

	denning and foraging behaviours		
Arable lands	Second-Year translocators demonstrated a preference for forestry but did not discriminate	8	Lombardini et al., 2015 MacPherson et al., 2014

Nesting sites was identified as a key feature for Pine Marten success. However, due to Pine Martens elusive nature and restrictions set by the Countryside and Wildlife Act (1981) and Nature Conservation Act (2004), the data is unavailable on nesting sites to avoid breaching laws and the disruption of known and unknown dens. Fragmented Forestry areas sometimes provided better-quality for foraging and spacing, as it adds complex structures for Pine Marten. However, data was very limited for this habitat feature and was frequently discussed at a UK wide scale, rather than recorded within individual forestry sites. The data that was available was dated for the late 19th Century and early 20th Century; the environment would have drastically changed since then making the data unusable.

Low canopies are another feature that was left out of this study, as there was no available data without completing a GPS marking and measuring survey in each of the locations. This was not possible within the country restrictions and project time frame. Further to this, felled areas were also a challenge to gain access to data. Like fragmentation, this is a feature that was talked about on UK broad scale, making it difficult to get a clear measurement of areas that had felled trees. Felling was also followed by replantation of trees, which avoids classing the area as being felled. Therefore, making it challenging to gain accurate data for this feature.

Additionally, wetlands and water bodies were removed as they were negatively associated with Pine Marten according to Lomdarbini et al. (2015), therefore suggesting they would not be a priority feature to gather data around (Table 3.3). The final feature that was removed was open space with no vegetation, as they provided minimal benefits (MacPherson and Wright, 2021) for the Pine Martens in comparison to other features.

After the removal of the features discussed this left: Deciduous woodland, natural grasslands, coniferous woodland, mixed woodland, moorland and heathland, shrublands, pasture, and arable land. These 8 features were then used to search and extract data from studies around habitat features in forests.

3.3 Identifying Forests for Study

Initially, forests were identified *ad hoc* from searching terms such as 'Kent woodland', 'Kent forests', 'forests in Kent', 'woodland in Kent', 'Wales forests', 'Wales woodland', 'forests in Wales', 'woodland in Wales', 'Wales forests Pine Marten', 'Wales woodland Pine Marten', 'Scotland forests', 'Scotland woodland', 'forests in Scotland', 'woodland in Scotland', 'Scotland forests Pine Marten', and 'Scotland woodland Pine Marten'. During this search, Kent did not require a search with the species name as it is already established that a Pine Marten population is not yet present in Kent (Mammal Society, 2018).
This search generated approximately 116 forestry and woodland sites across the UK which are officially classified as such. However, not all these forests and woodlands would have completed habitat datasets.

Therefore, after the identification of the forests through an initial search, there needed to be data available for these forests, which reduced the number significantly. This would enable the justification for their inclusion within the study. To establish whether data was available, the study explored the designated management NGOs databases for publications and initiated communication where databases were not immediately accessible (Appx. A1-A9). In total the dataset resulted in 34 forests: 10 Welsh, 7 Scottish, 15 Kentish, and 2 English (Table 3.4).
The majority of the final 34 forests included in the dataset had data provided by Data Officers within the organisations. Scotland proved to be the most limited for data according to Forestry and Land Scotland (Appx. A8). This resulted in only 7 Scottish forests having complete data that could be used in this study.
Originally, the dataset aimed to include 14 forests representing Wales, however, this was reduced due to areas lacking complete data on the habitat features found within those areas. This was due to a recent restructuring of Natural Resources Wales database, which did not contain information regarding the 4 forests causing them to be omitted from the study (see Appx. A2).

Table 3.4 – List of forests used in the study with where they are located, the size of the forest and whether they have a pine population present or not.

Forest Name	Location	Pine Marten Present?	Size (Km^2)
Gwydir Forest Park	Wales	Yes	72.5
Clocaenog Forest	Wales	Yes	100
Coed y Brenin Forest Park	Wales	Yes	36.42
Dyfnant Forest	Wales	Yes	24.3
Dyfi Forest	Wales	Yes	75
Bwlch Nant Arian Forest	Wales	Yes	4.7
Hafren Forest	Wales	Yes	35.13
Brechfa Forest	Wales	Yes	65
Afan Forest Park	Wales	Yes	39.4
Wentwood	Wales	No	10
Caledonia Forest	Scotland	Yes	180
Glen Righ	Scotland	Yes	20.74
Rothimercus Forest	Scotland	Yes	74.25
Anagach Woods	Scotland	Yes	3.86
Strathmashie Forest	Scotland	Yes	14
Galloway Forest Park	Scotland	Yes	721.4
Lochaber Forest	Scotland	Yes	440
Kent Downs	Kent	No	889.6
Bedgebury Forest	Kent	No	10.15
Chattenden Wood and Lodge Hill	Kent	No	3.51
North Kent Plains (includes Blean)	Kent	No	868.9
Denge Wood	Kent	No	7.34
Low Weald	Kent	No	518.54
Ellenden Wood and Victory Wood	Kent	No	1.8
Ham Street Woods	Kent	No	1.72
Hoad's Wood	Kent	No	2.1
Joyden's Wood and Chalk Woods	Kent	No	1.35
Oaken Wood	Kent	No	2.9
Orlestone Forest	Kent	No	4.1
Shorne and Ashenbank Woods	Kent	No	1.47
High Weald	Kent	No	1461.87
West Blean and Thorden Woods	Kent	No	7.81
Kielder Forest	Northumberland	Yes	647.5
Forest of Dean	Gloucestershire	Yes	526.3

An additional criterion that was considered whilst selecting forests for this study, was whether there were already established and supported Pine Marten populations or not. It was known that Kent forests and woodlands did not have any present populations of Pine Marten from recent distributions studies by the Mammal Society (2018). This was considered to draw a comparison between habitat features present in Kent that were also present in outside areas where Pine Marten were present. This would have aided in justifying the feasibility of the areas in Kent being viable for a Pine Marten population if they possess similar characteristics to forests with established populations outside of Kent.

The single forest in Wales without a Pine Marten population was included as it was an interesting study point and would make for a thought-provoking comparison. Since Autumn 2015, when the Vincent Wildlife Trust reintroduced Pine Marten, the population has greatly dispersed across the country (VWT, 2015; JNCC, 2019). However, there are a few forests that have not been inhabited by Pine Marten within Wales, one of which had a dataset that could be included in this study. This could have helped in highlighting any habitat features that are similar in Kent forests and woodlands. Therefore, this study could then identify non-feasible sites, as well as feasible sites within Kent for any future projects.

3.4 Procedure and Data Analysis

After establishing the habitat features and forests that the study would focus on, data needed to be collected for all the variables in the study. A Microsoft Excel Spreadsheet was created to collate and organise the data. The data collected were that of forestry size, arable land, pastureland, deciduous forest, coniferous forest, mixed woodland, moorland/heathland, scrubland/shrubland, and grassland. These were all recorded in kilometres squared (km^2). The overall size of the forests and woodlands was the first thing to be recorded. This information was gathered from the respective management organisations' databases from the original communications (Appx. A1-A9) that were made at the start of the process (i.e. Natural Resources Wales, Kent Wildlife Trust, Cairngorm National Park Authority, etc.). This initial step also highlighted if the forests met the minimum territorial area size required for Pine Marten to thrive, which was approximately $1km^2$ (Rewilding Britain, 2022), ensuring Pine Martens had the space required to maintain stability.

6 out of the 8 variables data were being collected on were easily accessible through scientific journals, websites, the management organisations' databases, and government resources. These 6 were: deciduous woodland, natural grassland, coniferous woodland, mixed

woodland, moorland/heathland, and shrublands. These habitat features represented the provisions required to create a habitat that Pine Marten could establish, grow, and sustain their populations within the forest boundaries. Additionally, these habitat features have vast availability of data, as they are easily monitored by the NGOs that manage the forests and woodlands. These habitat features were also easier to access as they are usually present within the forest and woodland boundaries that have been established by the NGOs that manage the sites, which means that datasets are regularly updated.

Arable and pastureland were included in this study because it provides structural diversity which has been proven to aid in Pine Martens reintroduction success by MacPherson et al. (2014), Lombardini et al. (2015), and McNicol et al. (2020). Although, they were a challenge to gather data on, as it was more common to find them immediately adjacent to the forests and woodlands. Therefore, they were not often owned by the NGOs that were managing the sites, which meant there was restrictions on the data that could be gathered from pre-existing databases. However, MAGIC Maps (Natural England, 2011) was a useful application to gather this information for forests and woodlands in the UK. For Wales, an equivalent resource was available called Data Map Wales (Welsh Government, 2023), and Scotland provided Map: Scotland's Environment (Scottish Government, 2021). All three of these applications had data layers that highlighted arable and pasture areas, which could then be measured using the measurement tools within the application. The study measured areas that were immediately adjacent to the forest and woodlands, because these would be the areas primarily accessible for reintroduced Pine Martens.

Once data had been collected for all the habitat features within each of the selected forests in the Microsoft Excel Spreadsheet, it needed checking for any outliers that would decrease the statistical power of the outcome. Upon reading through the completed dataset, forests that were $1km^2$ or less were removed. According to MacPherson and Wright (2021) and NatureScot (2023), Pine Martens need at minimum a $1km^2$ area for being able to establish territories without imposing competition; therefore, forests that came under this category would have been considered as outliers.

Initially, the data needed to be normalised because it made the different forest and woodland sizes comparable, because the area sizes varied significantly, but the proportions would have been viable. The dataset was then analysed using a programme called PRIMER v.6 (Calke and Gorley, 2006). From this a multivariate comparison was completed which aided in the

creation of a resemblance matrix that was used to generate non-matrix multidimensional scaling (NMDS) plots. This resemblance matrix helped to identify the forests and woodlands with Pine Marten presence and absence, with the addition of where Kentish forests and woodlands would fit into the trend. It aided in the exploration of which habitat combinations correlated with Pine Marten presence. Furthermore, it depicted whether there was any correlation between Pine Marten presence and ancient woodland classification.

CHAPTER 4:
RESULTS

4.1 Results of Literature Review

The literature review found that there were varying findings on the topic of Pine Martens being habitat specialists or generalists. Originally believed to be a specialist species, 11 (34.37%) studies from the initial literature review found and presented the argument that Pine Martens are specialists regarding habitat requirements and were restricted to certain areas (Table 4.1). Although 2 of these studies (Brainerd and Rolstad, 2002; Caryl, 2008) contradicted their original statements and concluded that Pine Martens were habitat generalists. On the other hand, researchers have found in their studies that Pine Martens are habitat generalists, being adaptable to their environment. It was found that 21 (65.63%) studies from the preliminary literature review concluded that Pine Martens were not specialists and would be adaptable to the surroundings and were not restricted to specific areas (Table 4.1).

Table 4.1 – A list of the studies in date order from the initial literature review under the conclusions of pine marten being either a habitat specialist or a habitat generalist. The studies in italics first implied Pine Marten were habitat specialist but when concluding their studies changed their stance to generalist.

Habitat Specialist Studies	**Habitat Generalist Studies**
Brainerd, 1990	Lockie, 1964
De Marinis and Masseti, 1993	*Brainerd and Rolstad, 2002*
Clevenger, 1994	*Caryl, 2008*
Gunderson, 1995	Pereboom et al., 2008
Brainerd and Rolstad, 2002	Mortelliti et al., 2010
Caryl, 2008	Van Den Berge and Gouwy, 2011
Mergey et al., 2011	Virgós et al., 2012
Lombardini et al., 2015	Manzo et al., 2012
Walter et al., 2017	Caryl et al., 2012
Twining et al., 2018	Jordan et al., 2012
	MacPherson et al., 2014
	Croose et al., 2016
	Gazette, 2017
	Sainsbury et al., 2018
	Sheehy et al., 2018
	Stringer et al., 2018
	Mellor, 2018
	Grabham et al., 2019
	Twining et al., 2019
	McNicol et al., 2020
	Wildwood, 2020

There does not appear to be an immediate trend in the earlier research carried out; however, the arguments appeared to gradually become more supportive to the suggestion that Pine Martens are a generalist species as the studies progressed into the 21st Century. The research reveals that it is a debate that started as early as the 1960s and continues to be prevalent in more up to date research. The table suggested that there was more support for the species being generalist over specialist in 2012, as there were 4 studies (12.9%) found in this literature review for that year and none that argued for a specialist classification. Furthermore, there were significantly more studies that supported the argument for Pine Martens being generalists from 2018 onwards, suggesting that the argument is beginning to conclude that Pine Martens are a generalist species when considering habitat needs and it is gradually becoming widely accepted by all researchers in this field.

Brainerd (1990) was the most cited paper by the other authors listed in the table above. It was interesting to find that 4 out of 6 studies that referred to this piece of literature held the view that Pine Martens were generalists. Often these studies had utilised this paper to reflect on the previous history and theories that surround the Pine Marten as a species, which provided explanation as to why it was so heavily referenced by others. More recently, Caryl (2008) and Pereboom et al. (2008) have been key pieces of literature in this field. They have been referenced as supporting literature for the view that Pine Martens are generalists and continued to be very popular influencers on literature appearing in the 2020s.

Through this literature review, a habitat requirements list was created (refer to Table 3.2). 11 studies were identified that clearly talked about habitat features. Many of these studies had more than one habitat focus discussed. It was common for the studies talk about multiple habitat factors because they had a holistic approach. This holistic approach ensured that all the necessities required for a Pine Marten to be successful were readily available and accessible by a population.

Using figure 4.1 below, the study showed that 7 out of 11 studies (63.63%) reported that the provision of nesting sites either artificial nesting boxes or natural nesting areas are essential for a successful Pine Marten reintroduction programme and to ensure the development and maintenance of a stable population. 5 studies (45.45%) found that the provision of coniferous woodland was essential; however, 3 other studies (27.27%) claimed that deciduous woodland was equally as beneficial for pine marten success. Additionally, 4 studies (36.37%) discovered that Pine Martens were adaptable to fragmented forestry areas as it could be a

possible advantage and benefit to them for foraging and territorial reasons. Between 1-2 studies (9.09%-18.18%) suggested additional habitat features that had been found to be positively associated with pine marten presence and decided that they were an essential requirement for reintroduction projects (Fig 4.1).

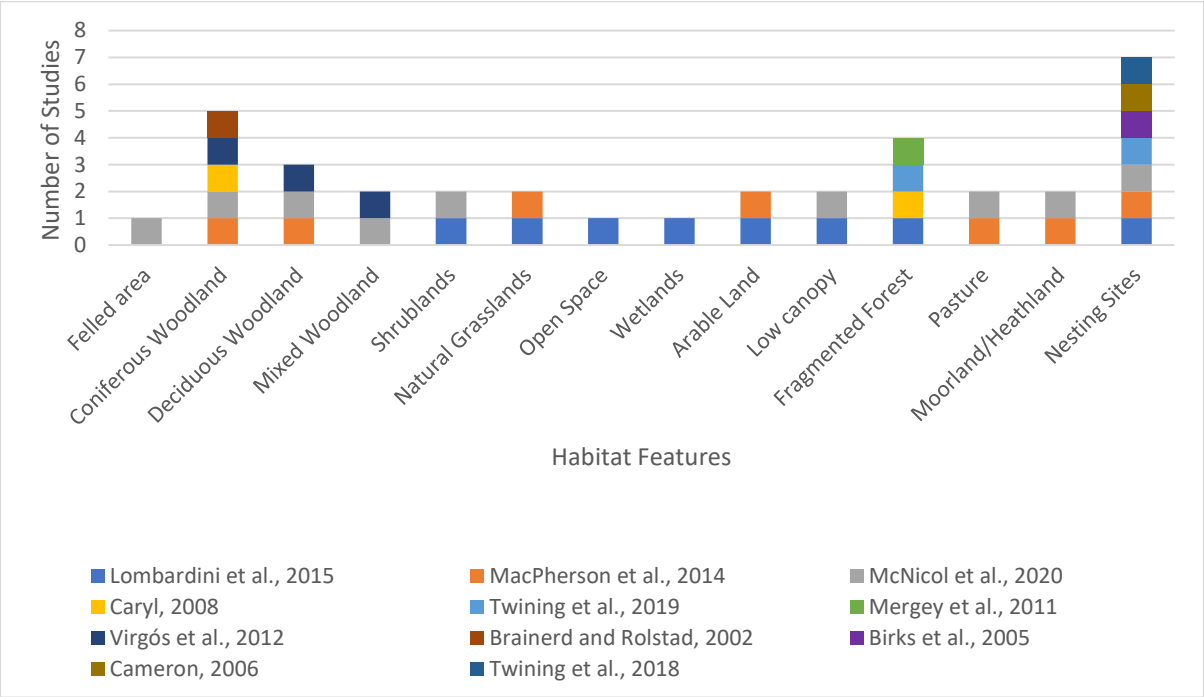

Figure 4.1 – A stacked bar chart to show which studies talked about the different types of habitats. A clear legend is provided to identify the studies within the stacks.

Information on plant species was collated from the studies that were analysed in the original literature review. These plants are in relation to those that have been recorded in areas that Pine Martens have been established and have a stable population. These plant species can be utilised by Pine Marten in various ways. Tree species are often used as nesting sites and for arboreal hunting. Shrubs and heathers are an excellent habitat feature for Pine Marten to forage for ground mammals and in some cases fruits and berries. Future research could be completed to identify if these species are present in Kent woodlands to further support possible Pine Marten success in the area. Therefore, a list was created containing information on plant species that were often associated with pine marten success, but this is not a limited list; they have been found to be successful with plant species that are not currently listed (Table 4.2).

Furthermore, the literature review provided a detailed list of predators and competitors to be aware of which could impact the success of a Pine Marten reintroduction programme. This list also included the prey and foraging items that the studies in the literature review provided (Table 4.3).

Table 4.2 – Plant species noted from the literature review studies and collated into a list. These are a plant species that have been found to be positively correlated with a Pine Martens success in inhabiting an area.

PLANT SPECIES (COMMON NAME)	SCIENTIFIC NAME	CITATION
SITKA SPRUCE	*Picea sitchensis*	McNicol et al., 2020
LODGEPOLE PINE	*Pinus contorta*	McNicol et al., 2020
SESSILE OAK	*Quercus petraea*	Lombardini et al., 2015 McNicol et al., 2020
DOUGLAS FIR	*Pseudotsuga menzieii*	McNicol et al., 2020
LARCH (*LARIX)*	*Larix spp.*	McNicol et al., 2020
BEECH	*Fagus spp.*	McNicol et al., 2020
ROWAN (*SORBUS SUBG.*)	*Sorbus subg. Sorbus*	McNicol et al., 2020
BIRCH	*Betula spp.*	McNicol et al., 2020
WILLOW	*Salix spp.*	McNicol et al., 2020
HEATHER	*Erica arborea*	Lomardini et al., 2015 McNicol et al., 2020 MacPherson et al., 2014

McNicol et al. (2020) was the key source for information regarding plant species and their relationship with Pine Marten. A variety of plant species were noted to be positively correlated with the success and stability of Pine Marten populations. The list was not extensive but highlighted the primary plant species that created habitats which Pine Marten often favoured. Heather was discussed in 3 studies, suggesting this was an important factor in Pine Marten studies. The studies reported that Heather was often used a place for foraging by Pine Marten and provided cover whilst they moved along the ground. This reduced the risk of predation from their predators that were present in the areas in which the studies took place.

Table 4.3 – A list of the predators, competitors, prey, and foraging items that were reported by the studies researched in the literature review.

SPECIES (COMMON NAME)	SCIENTIFIC NAME (IF APPLICABLE)	PREDATOR/PREY/COMPETITION	CITATION
RED FOX	*Vulpes vulpes*	Predator and Competition	Lomardini et al., 2015 MacPherson et al., 2014
LYNX	*Lynx lynx*	Predator	Brainerd and Rolstad, 2002 Caryl, 2008
GOLDEN EAGLE	*Aqualia chrysaetos*	Predator	Brainerd and Rolstad, 2002 Caryl, 2008
EAGLE OWL	*Bubo bubo*	Predator	Brainerd and Rolstad, 2012 Caryl, 2008
WOLF	*Canis lupus*	Predator	Brainerd and Rolstad, 2012 Caryl, 2008
GRASSLAND VOLE	*Microtus pennsylvanicus*	Prey	Lynch and McCann, 2007 Twining et al., 2019
FIELD VOLE	*Microtus agrestis*	Prey	Lynch and McCann, 2007 Twining et al., 2019 Balharry, 1993
VOLES	*Microtus*	Prey	Lynch and McCann, 2007 Twining et al., 2019 Mellor, 2018 Yalden and Harris, 2008
UNGULATE CARRION	-	Prey	Lynch and McCann, 2007 Twining et al., 2019
RABBIT	*Orycotolagus cuniculus*	Prey	Lynch and McCann, 2007 Twining et al., 2019 Mellor, 2018
EUROPEAN HARE	*Lepus europaeus*	Prey	Lynch and McCann, 2007 Twining et al., 2019
GREY SQUIRRELS	*Sciurus carolinensis*	Prey	Lynch and McCann, 2007

			Twining et al., 2019 Yalden and Harris, 2008 Mellor, 2018
RED SQUIRRELS	*Sciurus vulgaris*	Prey	Lynch and McCann, 2007 Twining et al., 2019 Yalden and Harris, 2008
EGGS	-	Prey	Yalden and Harris, 2008 Mellor, 2018 Lewis and Kappeler, 2006 Grabham et al., 2019
INSECTS	Insecta	Prey	Yalden and Harris, 2008 Mellor, 2018
HONEY	-	Prey	Yalden and Harris, 2008
FRUIT	-	Prey	Yalden and Harris, 2008 MacPherson et al., 2014
NUTS	-	Prey	Yalden and Harris, 2008 MacPherson et al., 2014
FUNGI	-	Prey	Yalden and Harris, 2008 Mellor, 2018
FROGS	Anura	Prey	Yalden and Harris, 2008
TOADS	*Bufonidae*	Prey	Yalden and Harris, 2008
LIZARDS	Lacertilia	Prey	Yalden and Harris, 2008
LEFTOVERS (BIRD TABLES + RUBBISH)	-	Prey	Yalden and Harris, 2008 MacPherson et al., 2014
BLAEBERRIES	*Vaccinium myrtillus*	Prey	MacPherson et al., 2014 Mellor, 2018 Yalden and Harris, 2008
ROWAN BERRIES	*Sorbus aucuparia*	Prey	MacPherson et al., 2014 Mellor, 2018 Harris and Yalden, 2008

SONGBIRDS: **- ROBIN** **- CHAFFINCHES** **- WRENS** **- VARIOUS TITS**	*Passeriformes:* *Erithacus rubecula* *Fringilla coelebs* *Troglodytidae spp.* *Paridae spp.*	Prey	Lynch and McCann, 2007 Yalden and Harris, 2008 Twining et al., 2018 Montgomery et al., 2014
WEASELS	*Mustela nivalis*	Competition	Powell and Zielinski, 1983 Rey, 2008 Caryl, 2008
STOATS	*Mustela erminea*	Competition	Powell and Zielinski, 1983 Rey, 2008 Caryl, 2008
AMERICAN MINK	*Neovison vison*	Competition	Powell and Zielinski, 1983 Rey, 2008 Caryl, 2008

The Pine Martens have 5 predators in their native areas; however, the only one that would need to be considered in England would be the Red Fox. The other challenge Pine Martens face with the Red Fox is competition. They both share a common prey item, which is voles. However, the data gathered showed that Pine Martens have a highly varied diet and would be able to perceptually switch their search image and would be able to target another prey item that has reduce competition and risk of predation. The Pine Martens have approximately 22 different potential prey, which made them adaptable to a diet that is readily available, easily accessible and reduces any potential risk factors for predation. Additionally, the species is behaviourally flexible. They demonstrated the ability to switch from hunting to foraging, and will gather things such as fruit, nuts, and fungi.

Amongst their predators and prey, the Pine Martens also have interspecific competitors. The main 3 competitors noted by the literature were weasels, stoats, and American mink. However, in areas where Pine Marten populations were already established and have been introduced, there have been no reports of this competition having any significant impact on the Pine Martens ability to develop and maintain stability in areas where they are already established or area becoming established. It has been demonstrated by McDonald (2002) and King and Powell (2007), that all mustelid competitors have adapted to implement resource partitioning.

4.2 Non-Metric Multi-Dimensional Scaling Plots

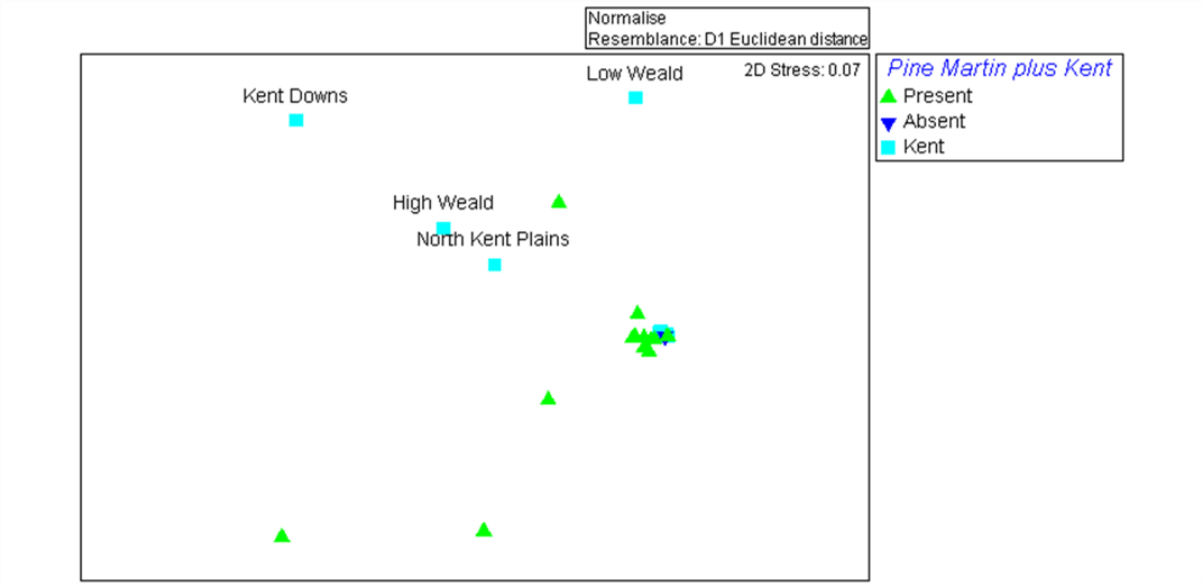

Figure 4.2 – A Non-metric multi-dimensional scaling plot produced from a resemblance matrix. Data plots represent the different forests and their habitat features as complete entities. Presence of Pine Marten is represented with the light green triangle. Absence of Pine Marten is represented with dark blue triangles. Kent forests are blue squares, they are presenting how they fit into the trend despite not having any recorded pine marten populations at present.

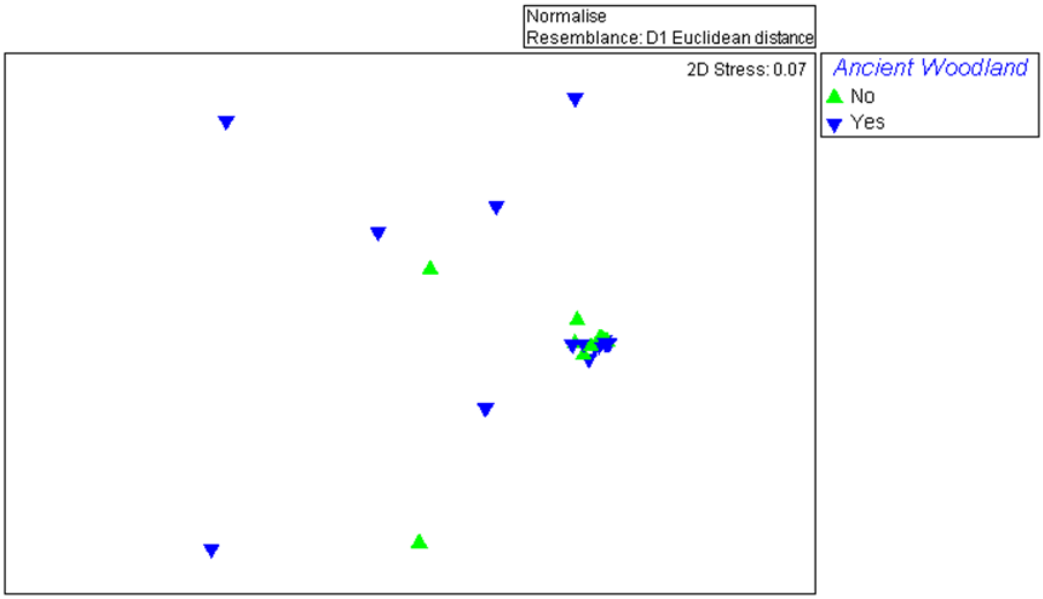

Figure 4.3 – A Non-metric multi-dimensional scaling plot depicting which forests had been categorised as ancient and non-ancient woodland. Data plots represent whether forests were either ancient (blue triangles) or non-ancient (green triangles).

The dataset created a resemblance matrix which generated non-metric multi-dimensional scaling plots (NMDS) (Fig. 4.2.; Fig .4.3). Both plots produced a stress score of 0.07, which indicated that there was fair ordination between the forests whilst looking at them as complete habitats instead of individual habitat features. However, there appears to be a weak to no correlation between the forests and whether Pine Martens are present, regardless of habitat. Additionally, there does not appear to be a correlation on whether Pine Martens were present when the forest was categorised as being ancient or non-ancient woodland.

Many of the data plots were far apart from each other, which showed dissimilarity in habitat features between the forests in this study that had Pine Marten presence and absence (Fig. 4.2.). Kent forests were presented as blue square markers, as they currently do not have Pine Marten present, but the study was looking to see where the county's forests fit into current trends of habitat and Pine Marten presence. Where Kent forests were clearly identified amongst the Pine Marten presence and absence NMDS, they appeared to have a greater distance from other data plots, which implied habitat dissimilarities from the other forests in the study that either had Pine Martens present or absent. Therefore, this suggested that they did not fit the habitat criteria needed for Pine Marten to be successful in these forests. However, a cluster formed in the NMDS which indicated a sub-population within the dataset. The cluster appeared to have smaller distances from a few data plots, which suggested there were similarities between these forests' habitats and the presence/absence of Pine Marten. Within this cluster of markers for presence and absence of Pine Martens, at least 2 markers for Kent forests were recorded. This suggested that these forests could have greater habitat similarities to the forests that already had Pine Martens present.

The NMDS was recreated to display which forests were categorised as ancient or non-ancient woodland (fig. 4.3). The data plots did not change positions, and remained the same as shown in figure 4.2, but the symbology now represented whether the forests had been identified as ancient (yes) or non-ancient (no) woodland. Upon comparison of figure 4.2. with figure 4.3, there does not appear to be a dominant trend of Pine Martens being present in one category. The cluster of forests identified previously when studying the presence and absence of Pine Marten, revealed that there was a combination of ancient and non-ancient woodlands amongst the cluster. Additionally, the data point that had shown dissimilarity to the cluster and other plots, exhibited variation in ancient status. Therefore, these findings implied that forests being categorised as ancient or non-ancient woodland had little impact on Pine Martens being present or absent from the areas.

CHAPTER 5:
DISCUSSION

5.1 Literature Review Discussed

5.1.1 Generalist not Specialist

At the begin of this project it was thought that Pine Marten were a habitat specialist species, requiring extremely rare and specific habitat features (Brainerd and Rolstad, 2002; Caryl, 2008; Lombardini et al., 2015; McNicol et al., 2020). Although, the literature review provided evidence that this species is capable of adapting to their surroundings and necessitate a variety of common and general habitat features, therefore implying they are a habitat generalist species, which the majority of studies agreed with (Caryl, 2008; Mergey et al., 2011; McNicol et al., 2020). Habitat generalist species have been found to be easier to reintroduce to an area than specialist species, as their requirements are easier to match and no drastic environmental changes would be needed in preparation for a reintroduction programme (Fisher and Owens, 2004; LaBar et al., 2014; Moy et al., 2021).

However, it was suggested that the south-east would benefit from an afforestation scheme in preparation for a Pine Marten reintroduction programme to reduce the fragmentation in Kent (Woodland Trust, 2013a; KWT, 2019; Forestry England, 2021). Approximately 300km^2 was recommended by the Environment, Food and Rural Affairs Committee (2022) and has been further supported by the Vincent Wildlife Trust (2011) as the optimal target for afforestation before reintroducing a Pine Marten population to any site within the UK. It has been suggested that Pine Martens can inhabit young woodland plantations that are between 10-13 years old; therefore, a reintroduction may only be plausible after a 10 year reforestation programme (Wilson et al., 2009; Croose et al., 2016; Twining, 2020). To further support Pine Martens in newer forests, Croose et al. (2016) recommended that den boxes be placed in afforested reintroduction sites to support breeding and provide resting sites for Pine Martens, due to the lack of tree crevices that often form over longer periods of time.

5.1.2 Persecution Cause for Restriction

The literature review did reveal that Pine Marten were restricted to certain areas, but this was not caused by the lack of specialist habitat requirements. Pine Martens were once one of the most common carnivores in the UK (Maroo and Yalden, 2000; MacPherson et al., 2014; Walter et al., 2017; Mellor, 2018), but populations are thought to have begun their decline in

the Tudor period (c.1485-1603) (Wildwood, 2020). However, the most notable declines occurred in the 18th Century and persisted into the 19th Century (Lockie, 1964; Lanlgey and Yalden, 1977; Croose et al., 2016; Gazette, 2017; Grabham et al., 2019). The majority of studies stated the cause to be anthropogenic (Robinson and Sutherland, 2002; Balestrieri et al., 2009; Sainsbury et al., 2018; Stringer et al., 2018). Sainsbury et al. (2018) highlighted many of the actions that caused Pine Marten to originally decline, and these were, persecution, habitat loss, habitat fragmentation, resource exploitation, predator and vermin control, and the fur trade. The literature review revealed that many studies agreed with Sainsbury et al.'s (2018) findings and furthermore how these problems continued to impact the species' current status (Croose et al., 2014; Maxwell et al., 2016; O'Mahoney et al., 2017; Twining et al., 2019).

Despite the findings of the literature review implying that anthropogenic processes were still a persisting problem for Pine Marten, it was also found that conservation measures were being taken in the UK (O'Mahoney et al., 2017; Walter et al., 2017; Twining et al., 2019). For example, the Vincent Wildlife Trust has successfully reintroduced through translocation of a Pine Marten population to majority of North Wales (MacPherson et al., 2014; McNicol et al., 2020).The Gloucestershire Wildlife Trust have begun their reintroduction project with 18 Pine Marten successfully released into the Forest of Dean (Stringer et al., 2018). Recently, a further 17 Pine Martens were released into the Forest of Dean in 2021 by the Gloucestershire Wildlife Trust to further enforce the success of their previous release in 2018 and to reduce risks of inbreeding. The Pine Martens have shown great success in Gloucestershire because the area provides excellent habitat requirements and connectivity. This was supported by a population viability analysis (PVA) carried out by MacPherson and Wright (2021), showing that the population size would steadily increase and stabilise due to the habitat provided and low density of road traffic.

Pine Martens have also shown to be naturally recolonising neighbouring areas to Scotland and Wales. In the 1990s, Pine Martens were recorded in Northumberland and Cumbria due to their close proximity to Scotland's border with England (Birks and Messenger, 2010; Scottish Natural Heritage, 2013). These recolonizations have been successful due to the close proximity to already established populations, but additionally, there has been availability of suitable habitat, low mortality, and minimal human conflicts.

Both these natural movements and human-led projects are showing great success and help to further demonstrate that Pine Marten are not restricted to certain areas but are a generalist species with the ability to adapt. Therefore, this will be beneficial for creating a reintroduction programme to fulfil one of the goals in *'A Wilder Future for Kent*' (KWT, 2019).

5.1.3 Prioritise Denning and Nesting Sites

It was discovered that many of the studies prioritised denning and nesting areas when planning a reintroduction programme for Pine Marten (Birks et al., 2005; Cameron, 2006; Lombardini et al., 2015; Twining et al., 2018; Twining et al., 2019; MacPherson et al., 2014; McNicol et al., 2020). This is because any reintroduction programme that involves the method of translocation can inflict stress on the animal and significantly reduce the success rate (Armstrong and Seddon, 2008; Dickens et al., 2010; Parker et al., 2012). Pine Marten have used tree cavities, felled trees, and rock crevices to establish denning and nesting areas. However, when they have been translocated, it would be essential to find a new denning and nesting site which can cause stress decreasing the success rate (Lindenmayer et al., 1995; Goldingay and Schiebe, 2000; Lindenmayer et al., 2011; Twining et al., 2018; McNicol et al., 2020). Therefore, the literature review noted that studies suggested using a soft release method, which would provide them with a denning and nesting area until they are able to establish their own (Bright, 2000; Lynch et al., 2006; McNicol et al., 2020). Twining et al. (2019) suggested creating artificial den boxes in their study, which found a reduction in the stresses of establishing a nesting place and pressures of predation. Therefore, this implies that it would be essential to identify suitable release site and provide den boxes in preparation for a reintroduction programme within Kent.

5.1.4 Forest Type Confliction

The woodland sizes in this study had some disparity as the size of woodlands are not consistent across the UK and it has been argued that it can impact on whether a Pine Marten will be successful in establishing itself in an area (Yalden and Harris, 2008; Mergey et al., 2011). However, the analysis demonstrated forest size does not appear to have a direct relation to Pine Martens being present or absent in an area. The 4 Kent forests identified in figure 4.2 had larger areas of forest than some of the areas observed in the cluster, which suggested that size does not necessarily impact Pine Martens presences. This finding concurred with Mergey et al. (2011), who found that the size of a forest does not have a

significant impact on Pine Martens establishing a territory. A minimum of 1km^2 is recommended by NatureScot (2023); this is the minimum space required for territories to be setup, but also because Pine Martens disperse from their initial introduction site, so a small woodland does not necessarily mean the species will remain within that area for the full duration of its life (Mergey et al., 2011; McNicol et al., 2020).

The studies that were reviewed demonstrated conflict in which forest type Pine Martens required for success in reintroduction projects. Many studies suggest that they required primarily mature, coniferous woodlands (Gundersen, 1995; Brainerd and Rolstad, 2002; Caryl, 2008; Lombardini et al., 2015). However, other studies disproved this and showed that Pine Marten do not display a preference for forestry types and can thrive in coniferous, deciduous, and mixed woodland (Brainerd and Rolstad, 2002; Caryl, 2008; Virgós et al., 2012; McNicol et al., 2020). Caryl (2008), Lombardini et al. (2015) and VWT (2015) presented that Pine Martens use forests for predator avoidance, prey access, and nesting. These features can be found in all 3 types of forests identified by the studies in the literature review, which suggested that Pine Martens utilise the different forests they can inhabit in similar ways (MacPherson et al., 2014; Lombardini et al., 2015). The plant species list that was created (Table 3.2) further supports the idea that Pine Marten have no preference to the tree species that are present, as long as there is cover from predators and access to prey (Porter et al. 2005; Lynch and McCann, 2007; MacPherson et al., 2014; Lombardini et al., 2015; McNicol et al., 2020). Therefore, this means woodlands in Kent that do not have coniferous trees present can be consider for Pine Marten reintroductions.

Forest types alone did not determine a Pine Marten population's success in a new area. McNicol et al (2020) and Virgós et al. (2012) determined that a combination of habitats was required for successful reintroduction, as this would create structural complexity that could have multiple uses (Brainerd and Rolstad, 2002; Caryl, 2008). Forested areas should be combined with open areas such as grassland and pastures, moorland/heathland, and shrublands to provide Pine Martens with the various habitats for different activities. MacPherson et al. (2014) and McNicol et al. (2020) identified that the forested areas were used as a base, where Pine Martens would den, nest and avoid predation. Lomdardini et al. (2015) and McNicol et al. (2020) further found that Pine Martens would explore beyond their base to use habitats such as shrubland, grasslands, and moorlands/heathlands to forage for food items.

Additionally, it was noted that fragmentation of habitat was a cause for Pine Marten decline (Caryl, 2008; Sainsbury et al., 2018; Twining et al., 2019), but studies have shown Pine Marten have become adapted to areas that are fragmented (Mergey et al., 2011; Lombardini et al., 2015). Mergey et al. (2011) discovered that fragmented forests provided greater quality and structural complexity of habitats, and Pine Marten populations demonstrated stability over 4 years in this study. Further research would be required to establish more detail around Pine Martens success in a fragmented habitat; however, this allows for areas within Kent that might not have originally been consider as a suitable area for reintroduction in this study to be inhabited in the future with further investigation.

Overall, Pine Martens will inhabit a wide range of differing habitats if they were in a reasonable distance from their forestry base site (McNicol et al., 2020). The forest type did not impact Pine Martens success in a reintroduction project and would thrive in coniferous, deciduous or mixed woodlands (Brainerd and Rolstad, 2002; Caryl, 2008; Virgós et al., 2012).

5.1.5 Predators/Competitors, Prey and Other Food

Previous studies also mentioned potential predators, competitors, prey, and other food items (see Table 4.3). The Golden Eagle, Eagle Owl and Wolf as cited in Brainerd and Rolstad (2002) and Caryl (2008), would not pose a problem in south-east of England. Although, there have been recordings of Eagle Owls being present in Kent, which could potentially pose a threat to a Pine Marten reintroduction to the area (Stewart, 2007; World Owl Trust, 2010). However, the most recent sighting was in 2019, but no sightings have been recorded int eh county since (Hunter, 2019). The data is limited on Eagle Owl distribution as they are not consistently sighted in the south-east of England and appear to be restricted to the northern parts of England and Scotland (Baker, 2004; Melling, Dudley and Doherty, 2008; Penteriani and Delgado, 2019).

The biggest predator and competitor that would bring the most challenges for a Pine Marten reintroduction project in the south-east would be the red fox (MacPherson et al., 2014; Lombardini et al., 2015). Unfortunately for the Pine Martens, the fox is highly distributed across the UK (fig. 5.1) (Croft et al., 2017; Mammal Society, 2018). Measuring the abundance of foxes is a difficult task; however, it is estimated that there are approximately 37 foxes per square metre in UK cities, which suggested they are high in abundance (Scott et al., 2014; Brand and Baldwin, 2020). However, these two species are capable of living amongst

one another, otherwise their distribution data would not overlap as shown when comparing figure 5.1 with figure 2.3 from the literature review. The two species able to do this by inhabiting different habitats. Foxes showed a greater abundance in urban areas than Pine Martens and demonstrated their ability to adapt their diet to human food scraps as well as small mammals (Lanszki et al., 2007; Brand and Baldwin, 2020). The Pine Martens also demonstrated that they would adapt their diet to plant, reptiles, amphibians and fish. This resource partitioning and habitat adaptability aided both species to live within the same areas in the UK.

There were also three other major competitors (Weasel, Stoats, and American Mink) that were mentioned in the literature, which can be located in the south-east of England and would need to be consider before a reintroduction can take place (Powell and Zielinski, 1983; Rey, 2008; Caryl, 2008). All 3 of the major competitors are widespread throughout with minimal areas that they have not been recorded across the nation (Fig 5.2; Fig 5.3; Fig 5.4). Despite being identified as competitors of the Pine Martens, previous projects did not discuss how these species would interact with each other and impact population numbers. The studies that did look at mustelid competition found that they all demonstrated resource partitioning to avoid intra-guild predation and costly competition (Powell and Zielinski, 1983). McDonald (2002) and King and Powell (2007) further supported this finding by noting that mustelids would prey on organisms that correlated with their own size. These studies suggested that other mustelids would not be a major concern when reintroducing the Pine Marten to the southeast, as they are well established in resource partitioning techniques. Despite this, it would still be advisable to take into consideration the predator and competitors when creating a reintroduction programme for the Pine Marten in Kent to be able to achieve the highest level of success.

The literature review helped to understand what the dietary requirements of a Pine Marten are and the types of prey items that would need to be accessible (see Table 4.3). Pine Marten are classified as an opportunistic food generalist and have demonstrated optimal foraging theory in their food choices through the year (Pyke et al., 1977; Zalewski, 2004; Popa-Lissenu et al., 2007; Lynch and McCann, 2007; Grabham et al., 2019). This list is not limited as Pine Marten have been reported to eat a great variety of items. Most of the prey and food items listed are recorded in Kent except for the grassland vole, which is commonly found in North America (Bond et al., 2005; Jackson and Cook, 2020). Field voles were found to be an important prey item for Pine Martens (Willebrand et al., 2017; Grabham et al., 2018). The

field vole is strongly distributed throughout the UK with some restriction seen in Scotland and Wales (Fig 5.5) (Mammal Society, 2018). There are approximately 75 million which would indicate the species has a high abundance (Kent Wildlife Trust, 2021). MacPherson et al. (2014) recommended that an area that had grassland would have high densities of field voles which enable Pine Martens to be successful. Kent is indicated as an area that homes field voles (Fig 5.5), so there is potential access to the prey and food items that Pine Martens require to thrive, which would decrease the pressure of foraging. Further study would be required to find the true abundance of field voles in Kent, as there is currently no data available.

5.2 Non-Metric Multi-Dimensional Scaling Plots

It was found that there were a group of 11 forests that had been identified in the study that had minimal Euclidean distance from one another and formed a cluster, displaying great similarity in habitat features. These findings are parallel to the results that Stringer et al. (2018) and MacPherson et al. (2014) found whilst carrying out their feasibility studies for forests in Wales and the Forest of Dean in Gloucestershire. Stringer et al. (2018) found similarities amongst the forests within Wales which already had Pine Marten populations and the Forest of Dean which had no Pine Martens established, suggesting a reintroduction was plausible in the area identified.

However, the study also found that there were 8 forests that displayed great Euclidean distances from the trending habitat cluster that was discovered. 4 of these forests were identified to possess Pine Marten populations. Therefore, this further supports the idea that Pine Marten are habitat generalists and can be reintroduced with ease into areas within Kent that possess generalist species needs, and that minimal specialist requirements must be met (Fisher and Owens, 2004; Virgós et al., 2012; LaBar et al., 2014; Sainsbury et al., 2018; McNicol et al., 2020; Moy et al., 2021). It also further disproved studies that still considered the Pine Marten as a habitat specialist species (DeMariuis and Masseti, 1993; Brainerd and Rolstad, 2002; Mergey et al. 2011; Twining et al., 2018).

5.2.1 Ancient Woodland

The study displayed which forests on the NMDS were forests that had been identified as ancient woodland and non-ancient woodland. The cluster that was highlighted when comparing the habitat features of the forestry areas was formed of a combination of both ancient woodland and non-ancient woodland, some of which were areas that in the dataset

were noted to inhabit Pine Marten populations. This supports the idea that Pine Marten do not discriminate between woodland types and that age is irrelevant whilst selecting a habitat to live in (Brainerd and Rolstad, 2002; Caryl, 2008; Virgós et al., 2012; McNicol et al., 2020). Similar to the studies identified as recognising Pine Martens are generalist, this further disproved the idea that Pine Marten are habitat specialists that require ancient, mature, coniferous woodlands to survive as previously proposed (Gundersen, 1995; Brainerd, 1990; Brainerd and Rolstad, 2002; Caryl, 2008).

Population data is vastly limited in the studies of Pine Marten in the UK due to their protection under the Wildlife and Countryside Act 1981 and elusive behaviour. Therefore, this made it challenging to fully understand the Pine Martens habitat requirements (Bright and Smithson, 2001; MacPherson et al., 2014). However, the studies that were analysed for this project provided a good insight into habitat preferences. In regards to woodland type, studies that focused on this aspect found that Pine Marten persisted in a variety of woodland types, but did appear to be more successful in mixed woodland (Bright and Smithson, 2001; Stringer et al., 2018; McNicol et al., 2020). Bright and Smithson (2001) found that mixed woodland was more beneficial due to the greater area of low tree canopy providing more shelter from predators, but also supporting a higher abundance of prey for the Pine Martens. More recently, Stringer et al. (2018) carried out studies in the Forest of Dean which is predominantly built up of mixed woodland, and has successfully been repopulated with 17 Pine Martens who successfully reproduced between February and March 2022 (Gloucestershire Wildlife Trust, 2022). Therefore, for future projects, the aim should be to evaluate the benefits of mixed woodlands over purely coniferous or deciduous on Pine Marten reintroduction success.

5.2.2 Pine Marten Presence and Kent Woodlands

The resemblance matrix created a NMDS to depict which forests had Pine Marten populations present or absent in the area. Amongst the symbols representing presence and absence of Pine Martens, the plot also included Kent forests as a separate marker (blue squares) to demonstrate how they would fit into the current trend despite not currently supporting populations of Pine Marten. A cluster of data points formed which suggested high similarity between these forests. This cluster had a combination of forests that were indicated to have Pine Martens present and absent, with most points represented as presence of the species. Within this group, a few Kent markers could be observed which suggested that these

Kent woodlands had significant similarity to Welsh and Scottish forests that supported Pine Martens. Therefore, Kentish forests within this cluster would have the habitat requirements to carry out a Pine Marten reintroduction project.

However, it was noted that forests with Pine Marten populations were also dispersed from the cluster that had formed. This suggested that despite having dissimilarities from forests in the cluster, these forests still met habitat requirements to support Pine Marten populations. Amongst these scattered plots, Kentish woodlands were noted. Although, these Kent markers have greater dissimilarity from the cluster, they were still within a fair proximity of forests with Pine Martens present. This suggested they had similarities to other Welsh and Scottish forests that supported Pine Martens. This indicated that these Kent woodlands could not be entirely ruled out from being considered for future reintroduction programmes within the Kent area (Bright and Harris, 1994).

Additionally, these findings further support Pine Martens as habitat generalists due to the varied dispersal across the forests that were studied (Caryl, 2008; Mergey et al., 2011; McNicol et al., 2020). Further to this, the findings support Sainsbury et al. (2018) and their conclusions that Pine Marten were a widespread species across the UK, as they have demonstrated an ability to occupy a variety of forests with differing habitat provisions after drastic environmental changes (Langley and Yalden, 1977; Virgós et al., 2012; Croose et al., 2016; Maxwell et al., 2016; Lombardini et al., 2015; Twining et al., 2019; McNicol et al., 2020).

5.3 Limitations

The study was carried out whilst COVID-19 restrictions were in place for the entirety of the UK, which made travelling to the areas of focus within the timeframe incompletable. Even when restrictions were being eased across England, Wales and Scotland still maintained a higher level of restrictions make forests inaccessible. This meant that any ground truthing that was originally going to be completed could not be carried out inside the remaining time that was available. However, this was overcome by mining data from previous studies to create a dataset that reflect what each forest provided.

Although not all the data extracted was an accurate reflection of the forests' habitat features in 2021. This was due to varying factors such as land being sold to another owner, land becoming privatized, and either not being studied regularly or studies being delayed by the pandemic. Another factor that was highlighted was Scotland and Wales also moved their

databases and renamed the companies that owned them which made it challenging to find the most recent datasets. Nevertheless, the dataset that was created was as accurate as possible without needing to carry out ground truthing and breaching the rules put in place to prevent the spread of COVID-19.

Another challenge that arose during the study was communications with authors and landowners for information regarding forestry sites that they had researched or owned. Electronic forms of communication were not always ideal and often went without any further response. Although responses were received from Dr. MacPherson from the Vincent Wildlife Trust and a few landowners of forests in Wales, Scotland, and Kent. In person meetings would have been preferred but with the restrictions this was not achievable, but the data that were provided within the responses was advantageous to the project and the dataset.

To expand on this research, now that COVID restriction are being eased, ground truthing could be employed to create a more accurate representation of each forest in current time. This could then be compared to the results found from this study to see how the forestry areas have changed, and whether they would be able to maintain Pine Marten populations. Alongside this, it would be beneficial to observe Pine Marten in areas where they are present to get an idea of how they utilise habitat features and, therefore, answer in greater detail why they are believed to be necessary through behavioural recordings. For example, why a Pine Marten can thrive in forests consisting of any tree species.

5.4 Summary and Conclusions

To summarise, Pine Marten were a habitat generalist species which used to inhabit all parts of the UK before their rapid decline in the 18th and 19th Centuries (Maroo and Yalden, 2000, MacPherson et al., 2014; Walter et al., 2017; Mellor, 2018; Sainsbury et al., 2018). Their decline was the combining result of persecution (fur trade and predator control) and deforestation, which restricted the species to the north-west of the Scottish Highlands (Langley and Yalden, 1977; Bright, 2000; Jordan et al., 2012; Sainsbury et al., 2018; Stringer et al., 2018; Twining et al., 2019). This was reinforced by reviewing the literature available and finding that areas in Wales, Scotland, and England, after afforestation projects had been carried out, for example in Galloway, Scotland (Davies, 1982; Purh et al., 2000; Croose et al., 2013), there was great success in reintroducing Pine Marten to the area. Additionally, it has been found that Pine Marten are adaptable to habitat fragmentation and have demonstrated stable populations in areas with fragmented forestry (Mergey et al., 2011; Lombardini et al.,

2015; De Groot et al., 2016), furthering the support that Pine Marten are an adaptable generalist, but additional research is needed before a conclusion can be made. Generalist species have been proven to be more successful in reintroduction programmes and need minimal alterations to the environments they are being introduced to (Fisher and Owens, 2004; LaBar et al., 2014; Moy et al., 2021).

Therefore, this aspect of the Pine Marten is beneficial in preparing for any future reintroduction programmes for the Kent area; however, it would be essential for afforestation to be carried out before the project began to increase the potential success rate, as previously mention at the beginning of this discussion (Croose et al., 2013; Forestry England, 2021).

It was also essential to prioritise identifying nesting and denning areas to aid increase the success rate of a Pine Marten reintroduction. Pine Marten use a variety of different habitat types for denning and nesting, with the three main choices being tree cavities, felled trees, and rock crevices (Webster, 2001; Adkins, 2008; Fox et al., 2009; Twining et al., 2018). However, the search for this denning and nesting areas were costly and increased pressure for predation from species such as the red fox. It was suggested and implemented by McNicol et al. (2020), Twining et al. (2019) and Croose et al. (2016) that artificial den boxes would be made available to reduce these pressures which in turn increased the species success rate in the reintroduction area. It was found that any reintroduction sites that were identified in Kent would need to be studied further to mark where ideal reintroduction zones might be and where den boxes could be placed.

After taking into consideration the alterations that would be required for Kent forests to become suitable for Pine Marten reintroductions, a protocol would need to be followed to ensure the species could eventually be self-sufficient and self-sustaining. MacPherson et al. (2014) and Stringer et al. (2018) used a soft release approach upon translocation of the Pine Martens from Scotland. Initially, both studies provided release pens which the Pine Martens were placed in for a few days to acclimatise to the new habitat and allow to observe for physical and emotional aliments (Birks and Messenger, 2010; Vincent Wildlife Trust, 2015).

MacPherson et al. (2014) successfully translocated 51 Pine Martens from Scotland to Mid-Wales under strict licencing from Scottish Natural Heritage. To ensure the cohort was being self-sufficient and self-sustaining, select individuals were allocated with tracking collars. 13 out of 20 collars were retrieved and health checks were taken to find that the Pine Martens were in good condition (MacPherson, 2016; McNicol et al.,2020). Stringer et al. (2018) and

the Gloucestershire Wildlife Trust (2022) released fewer specimens that had been translocated from a healthy population in Scotland with the assistance of the Vincent Wildlife Trust. This project initially released 17 individuals which increased to 35 by 2021. Currently, they are using camera traps and scat surveys to monitor the Pine Martens progress.

In both projects, the Pine Marten populations have proven to be self-sufficient as they have passed regular health checks when radio-collars are collected for battery replacement, suggesting they are able to gather enough food to be well-nourished (MacPherson, 2016; Hughes, 2019; Gloucestershire Wildlife Trust, 2022). Since the initial releases in both Wales and Gloucester, camera traps have caught that the females have successfully reproduced and been attentive to their kits (MacPherson and Wright, 2021; Gloucestershire Wildlife Trust, 2022). This showed that with this soft release approach and the provision of denning boxes has aided in the species becoming self-sustaining. For a reintroduction project in Kent, it would be recommended to follow similar protocols to reintroduce Pine Martens with high chances of success, as these methods have proven highly successful since 2015.

There are also concerns around the likelihood of inbreeding and lack of genetic diversity when working in conservation biology. These factors could potentially impact the individuals' fitness and the overall populations fitness (Hedrick and Kalinowski, 2000). However, the population of Pine Martens in Scotland consist of approximately 3,700 individuals (NatureScot, 2023) and so it is possible to select individuals who have low relatedness. A study by O'Reilly et al. (2020) found that the Irish population of Pine Martens had no evidence of inbreeding when studying DNA markers and that there was genetic diversity in the population. Currently, the Irish population has approximately 2,700 individuals, a significantly smaller population size to Scotland. It should be recommended that Pine Martens should be translocated from both Scotland and Ireland, because this could prevent the likelihood of inbreeding if all translocated Pine Marten were from Scotland. Furthermore, Irish Pine Martens maybe a better candidate for a reintroduction to Kent due to their requirement for significantly smaller territories, which could be more suitable for Kent's smaller woodland sizes (Caryl, 2008; Stringer et al., 2018).

Proximity to another region with an established population could also be an important factor in the success of a reintroduction project. However, MacPherson et al. (2014) successfully carried out the Welsh reintroduction with no proximity to any other regions with established Pine Martens. It has been considered to let the Scottish population to expand naturally to

reinforce the re-established Welsh population, but this would take 30 years or more to occur (Stringer et al., 2018). Initially, to avoid inbreeding, the project introduced Pine Martens gradually over a 3-year period from different areas of Scotland into Wales (MacPherson and Wright, 2021). However, Stringer et al. (2018) found that it was feasible to reintroduce Pine Martens to the Forest of Dean, a neighbouring English Forest. Upon completion of the Welsh reintroduction project in 2017, the Forest of Dean project began in 2019 creating a population that was in proximity to the Welsh population (MacPherson and Wright, 2021; Gloucestershire Wildlife Trust, 2022). Taking this into consideration, it would be recommended that whilst a Kent reintroduction is being worked through, a neighbouring county such as Surrey or Sussex should be assessed for habitat feasibility to reinforce a future south-east England population.

Pine Marten demonstrate no preference for a single forest type and age of the forest did not have any impact on their success. This was supported by the findings from this study, because Pine Marten were shown to be present in forests that had were not ancient woodland and were formed of a mixture of conifer, deciduous and mixed woodland. Therefore, this agreed with the findings of previous studies that found Pine Marten had a flexible style towards habitat selection and usage (Virgós et al., 2012). In McNicol et al. (2020) it was found first-year translocations had no habitat preference, whilst second-year translocations had a stronger preference towards forest areas; however, they did not discriminate between forest type or age but needed structural complexity (Brainerd and Rolstad, 2002; Caryl, 2008; Virgós et al., 2012). Furthermore, any reintroduction sites in Kent would not be required to have specific forest types nor ages but would need to be able to provide habitat structural complexity to ensure success. Similar, to the den boxes, this would be an area that would require further research in preparation for a project.

The study found that there are at least 11 potential forests within Kent that have similar habitat features to forests that already support Pine Marten populations in Wales, Scotland, and other parts of England. However, the 4 outliers that were identified from Kent should not be ruled out entirely, as they were within close Euclidean proximity to other forests that supported Pine Marten populations, which implies these areas could still have potential for Pine Marten success. It was originally believed Pine Marten could not thrive in fragmented areas, but this was disproven by Mergey et al. (2011) and Lombardini et al. (2015) suggesting they are a flexible species and could potentially adapt or even disperse (McNicol et al., 2020)

to the habitat provisions in the areas of Kent (Kent Downs, High Weald, North Kent Plains, and Low Weald) that did not fit the cluster trend (De Groot et al., 2016).

It should also be mentioned that since this study had been carried, a Pine Marten had been reported living in Broadstairs, Kent. If this study were to be repeated, it would be recommended that the area of Broadstairs be investigated to see where this individual has come from, how it is surviving, and potentially thriving (Chantler-Hicks, 2021).

Overall, it has been found that there is the potential for a Pine Marten reintroduction programme to be carried out in selected forests within the Kent area. The study found that for a Pine Marten reintroduction project to be successful it is important to note that they are a generalist species with the ability to adapt to their surroundings and they did not display any specific habitat preferences (Porter et al., 2005; Caryl, 2008; Virgós et al., 2012; Sainsbury et al., 2018; McNicol et al., 2020). It is also essential to have visited the targeted forest areas within Kent for a future project and mark out placement for den boxes (Twining et al., 2019) to aid in the reduction of predation pressures and energetic costs, therefore increasing potential in success rates (Brainerd and Rolstad, 2002; Caryl, 2008; Lombardini et al., 2015; Twining et al., 2019; McNicol et al., 2020).

In conclusion, the study found that Pine Marten are a habitat generalist with the ability to be flexible and adaptable towards their habitat selection choices and usages. It was discovered that there are areas within Kent that possess similar habitat features to areas that already support Pine Marten populations. Therefore, this implies that there are forests in Kent that have the potential for supporting a Pine Marten reintroduction programme and would be able to support and maintain a population of the species. Furthermore, the hypotheses that were set at the beginning of this study have been disproven. This means there are similarities between forests in Kent, Wales, Scotland and other areas of England, alongside the possibility that Kent forests would be able to support and maintain a reintroduced population of Pine Marten.

With COVID-19 restrictions now easing across the UK, further field research would now be possible; however, due to the limited timeframe available for this project it was not possible to complete the essential groundwork required. Therefore, it would be crucial to expand on this in the future by using ground truthing methods to identify specifically which Kent forests would be suitable to begin a reintroduction programme for Pine Marten in the future. Additionally, any ground truthing research that is carried out could then be compared to this

project to draw an overall conclusion to which Kent forests would be the most suitable for starting the reintroduction of Pine Marten to Kent.

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APPENDICES

Appendix – A

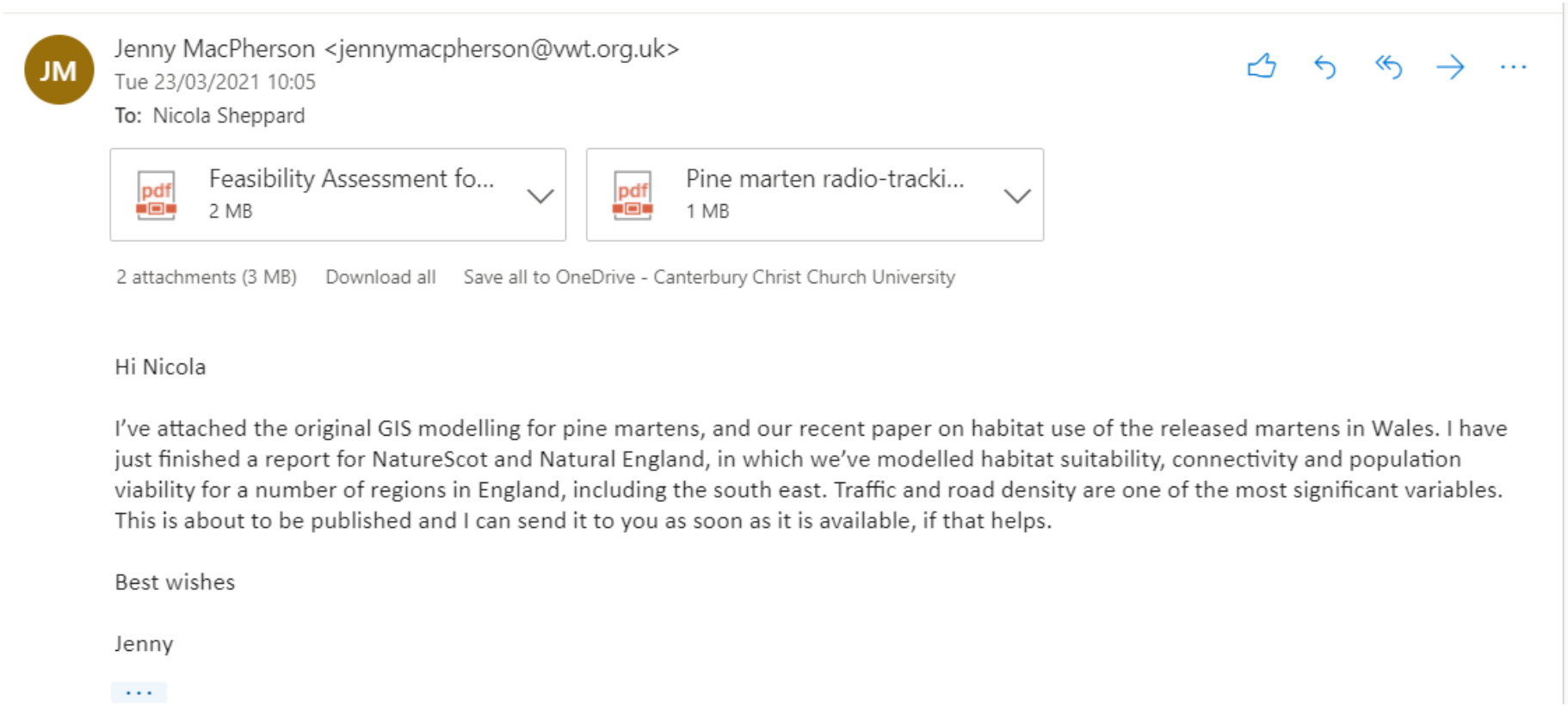
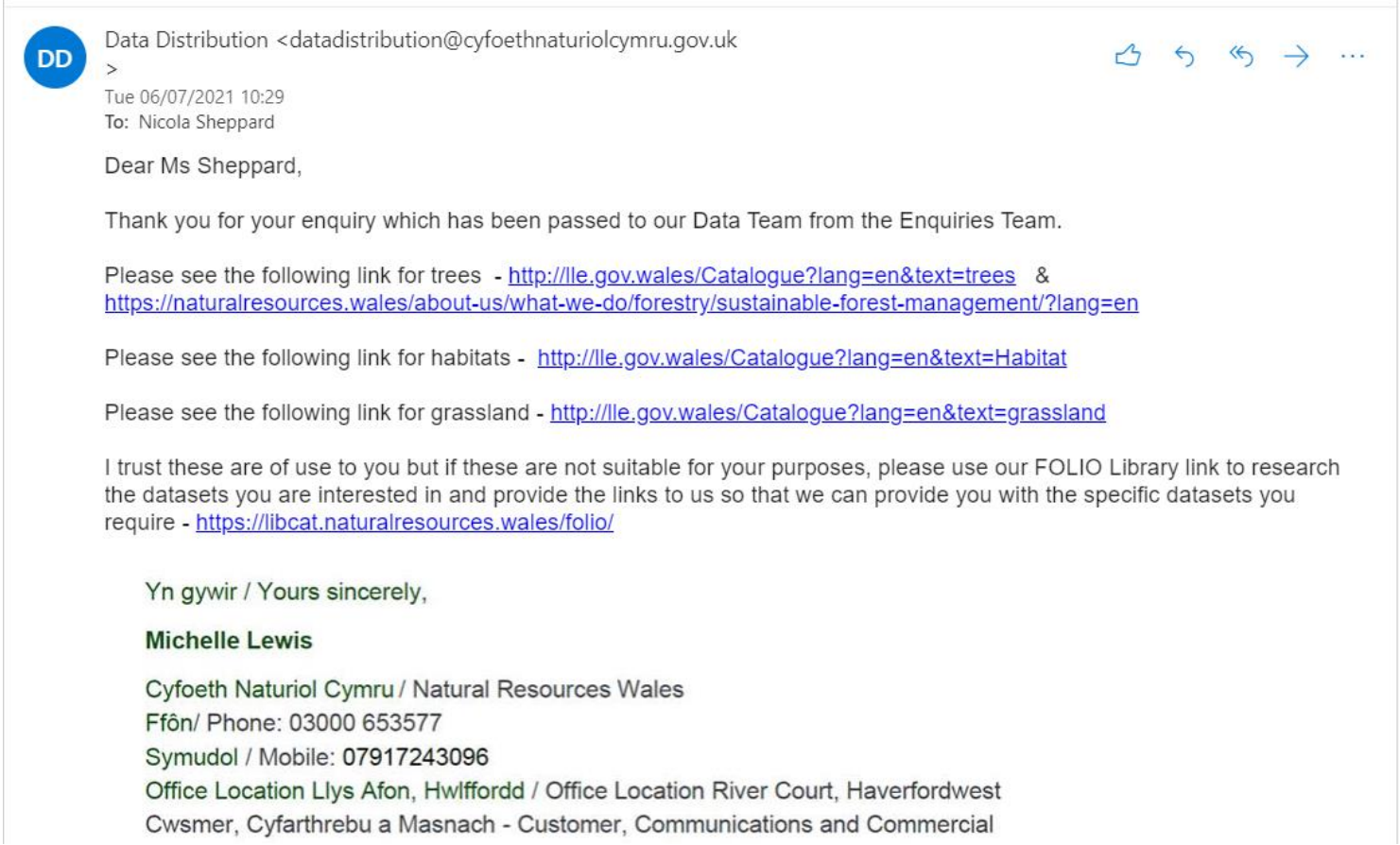


Figure A1 – Email communication from Dr. Jenny MacPherson, one of the lead researchers at the Vincent Wildlife Trust and carried out the original feasibility study for the reintroduction of Pine Marten in Wales.



DD

Data Distribution <datadistribution@cyfoethnaturiolcymru.gov.uk
>
Tue 06/07/2021 10:29
To: Nicola Sheppard

Dear Ms Sheppard,

Thank you for your enquiry which has been passed to our Data Team from the Enquiries Team.

Please see the following link for trees - http://lle.gov.wales/Catalogue?lang=en&text=trees &
https://naturalresources.wales/about-us/what-we-do/forestry/sustainable-forest-management/?lang=en

Please see the following link for habitats - http://lle.gov.wales/Catalogue?lang=en&text=Habitat

Please see the following link for grassland - http://lle.gov.wales/Catalogue?lang=en&text=grassland

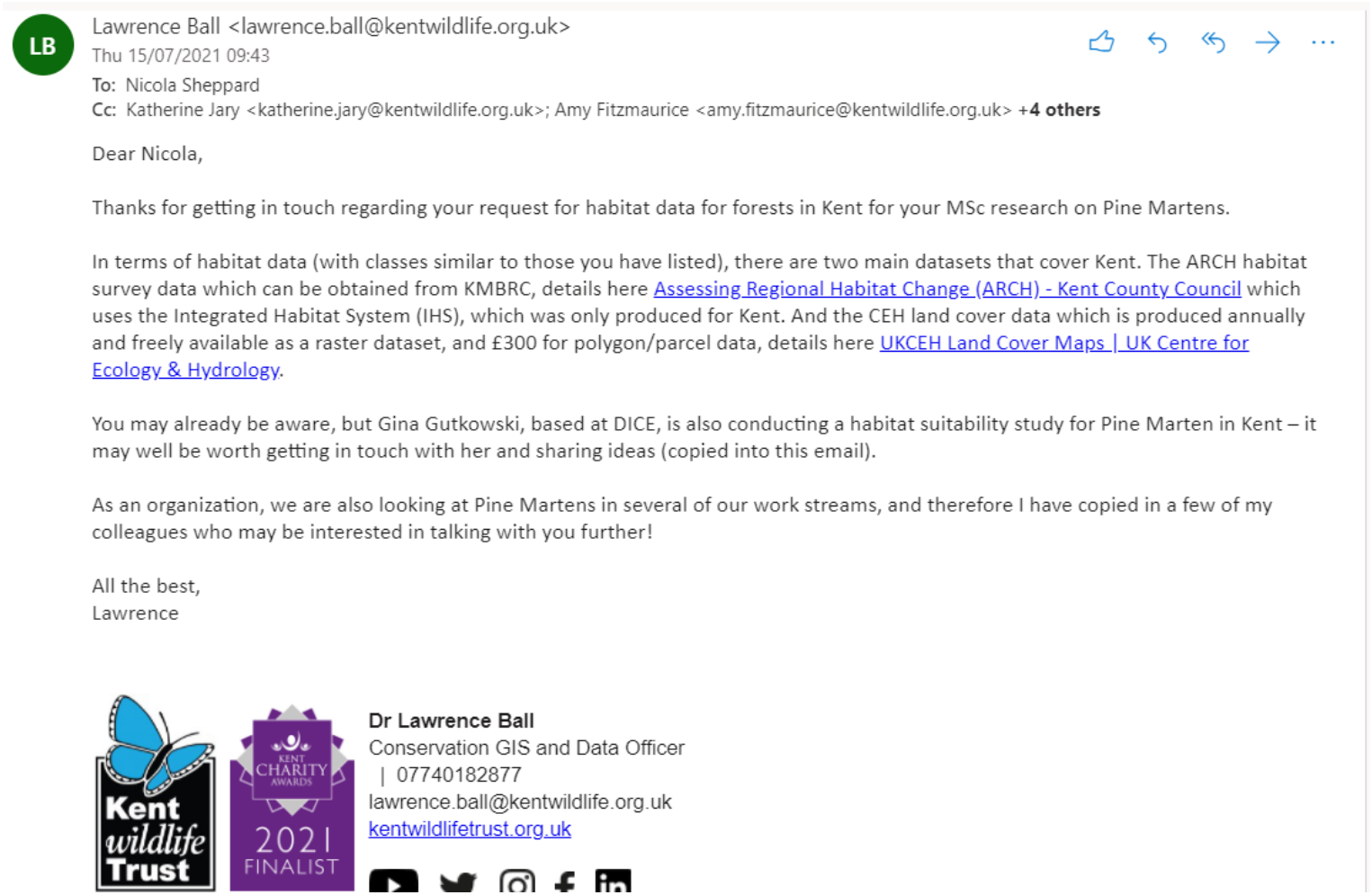
I trust these are of use to you but if these are not suitable for your purposes, please use our FOLIO Library link to research the datasets you are interested in and provide the links to us so that we can provide you with the specific datasets you require - https://libcat.naturalresources.wales/folio/

Yn gywir / Yours sincerely,

Michelle Lewis

Cyfoeth Naturiol Cymru / Natural Resources Wales
Ffôn/ Phone: 03000 653577
Symudol / Mobile: 07917243096
Office Location Llys Afon, Hwlffordd / Office Location River Court, Haverfordwest
Cwsmer, Cyfarthrebu a Masnach - Customer, Communications and Commercial

Figure A2 – Email communication from Michelle Lewis at Natural Resources Wales with guidance on where to mine data from Welsh forests.



LB

Lawrence Ball <lawrence.ball@kentwildlife.org.uk>
Thu 15/07/2021 09:43

To: Nicola Sheppard
Cc: Katherine Jary <katherine.jary@kentwildlife.org.uk>; Amy Fitzmaurice <amy.fitzmaurice@kentwildlife.org.uk> **+4 others**

Dear Nicola,

Thanks for getting in touch regarding your request for habitat data for forests in Kent for your MSc research on Pine Martens.

In terms of habitat data (with classes similar to those you have listed), there are two main datasets that cover Kent. The ARCH habitat survey data which can be obtained from KMBRC, details here Assessing Regional Habitat Change (ARCH) - Kent County Council which uses the Integrated Habitat System (IHS), which was only produced for Kent. And the CEH land cover data which is produced annually and freely available as a raster dataset, and £300 for polygon/parcel data, details here UKCEH Land Cover Maps | UK Centre for Ecology & Hydrology.

You may already be aware, but Gina Gutkowski, based at DICE, is also conducting a habitat suitability study for Pine Marten in Kent – it may well be worth getting in touch with her and sharing ideas (copied into this email).

As an organization, we are also looking at Pine Martens in several of our work streams, and therefore I have copied in a few of my colleagues who may be interested in talking with you further!

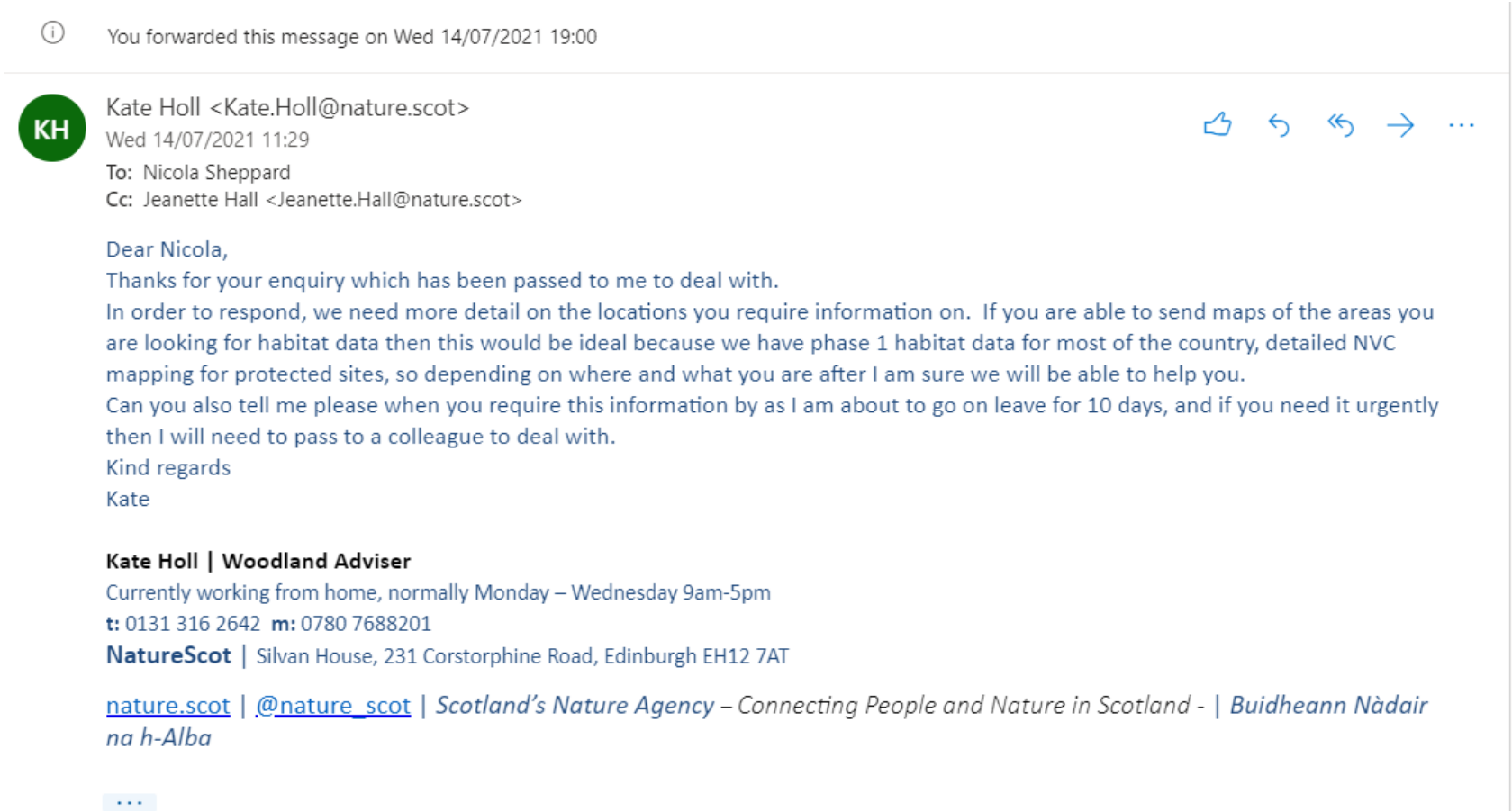
All the best,
Lawrence

Kent wildlife Trust

KENT CHARITY AWARDS 2021 FINALIST

Dr Lawrence Ball
Conservation GIS and Data Officer
| 07740182877
lawrence.ball@kentwildlife.org.uk
kentwildlifetrust.org.uk

Figure A3 – Email communication from Lawrence at the Kent Wildlife Trust providing links to get more information around the habitat features in the forests in Kent that study aimed to gather information from.



You forwarded this message on Wed 14/07/2021 19:00

KH

Kate Holl <Kate.Holl@nature.scot>
Wed 14/07/2021 11:29
To: Nicola Sheppard
Cc: Jeanette Hall <Jeanette.Hall@nature.scot>

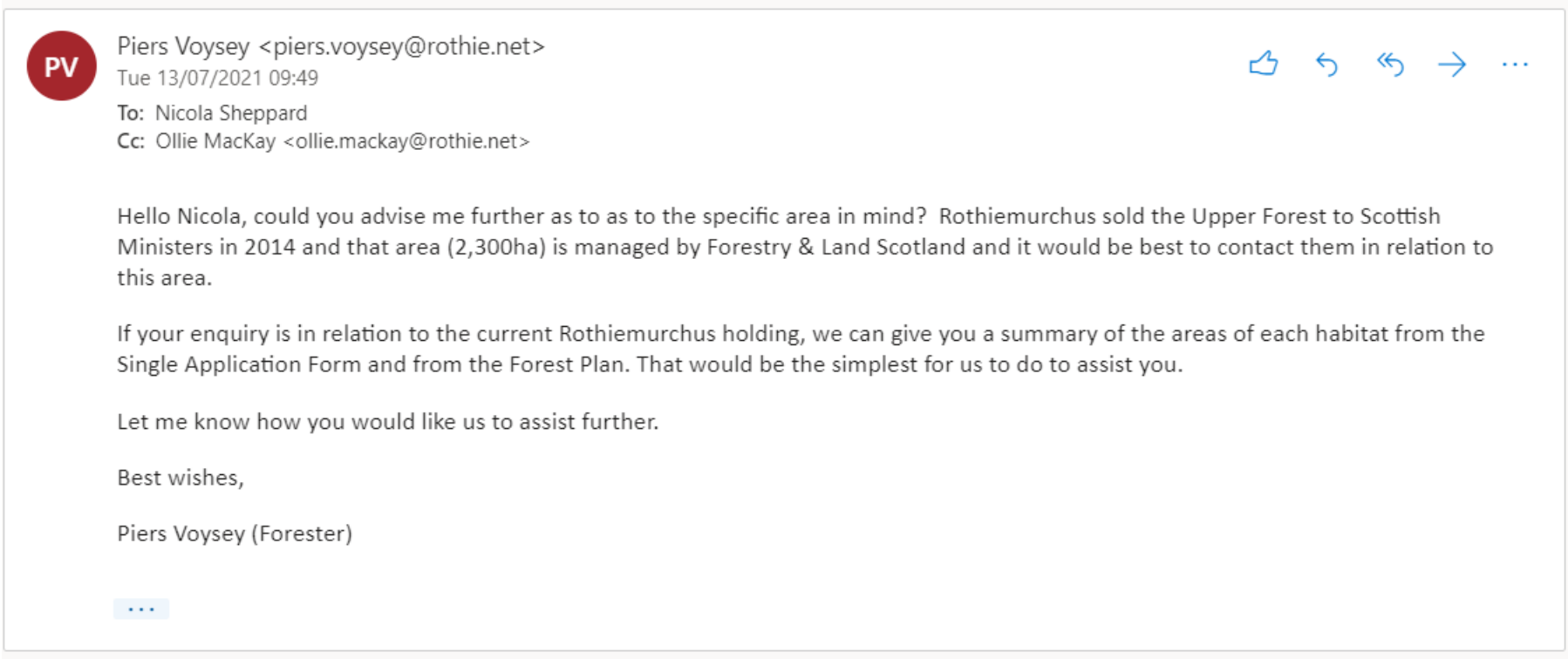
Dear Nicola,
Thanks for your enquiry which has been passed to me to deal with.
In order to respond, we need more detail on the locations you require information on. If you are able to send maps of the areas you are looking for habitat data then this would be ideal because we have phase 1 habitat data for most of the country, detailed NVC mapping for protected sites, so depending on where and what you are after I am sure we will be able to help you.
Can you also tell me please when you require this information by as I am about to go on leave for 10 days, and if you need it urgently then I will need to pass to a colleague to deal with.
Kind regards
Kate

Kate Holl | Woodland Adviser
Currently working from home, normally Monday – Wednesday 9am-5pm
t: 0131 316 2642 **m:** 0780 7688201
NatureScot | Silvan House, 231 Corstorphine Road, Edinburgh EH12 7AT

nature.scot | @nature_scot | *Scotland's Nature Agency* – Connecting People and Nature in Scotland - | *Buidheann Nàdair na h-Alba*

...

Figure A4 – An email response from Kate, a woodland adviser at NatureScot, providing guidance on areas to search for information regarding forests in Scotland.



PV

Piers Voysey <piers.voysey@rothie.net>
Tue 13/07/2021 09:49

To: Nicola Sheppard
Cc: Ollie MacKay <ollie.mackay@rothie.net>

Hello Nicola, could you advise me further as to as to the specific area in mind? Rothiemurchus sold the Upper Forest to Scottish Ministers in 2014 and that area (2,300ha) is managed by Forestry & Land Scotland and it would be best to contact them in relation to this area.

If your enquiry is in relation to the current Rothiemurchus holding, we can give you a summary of the areas of each habitat from the Single Application Form and from the Forest Plan. That would be the simplest for us to do to assist you.

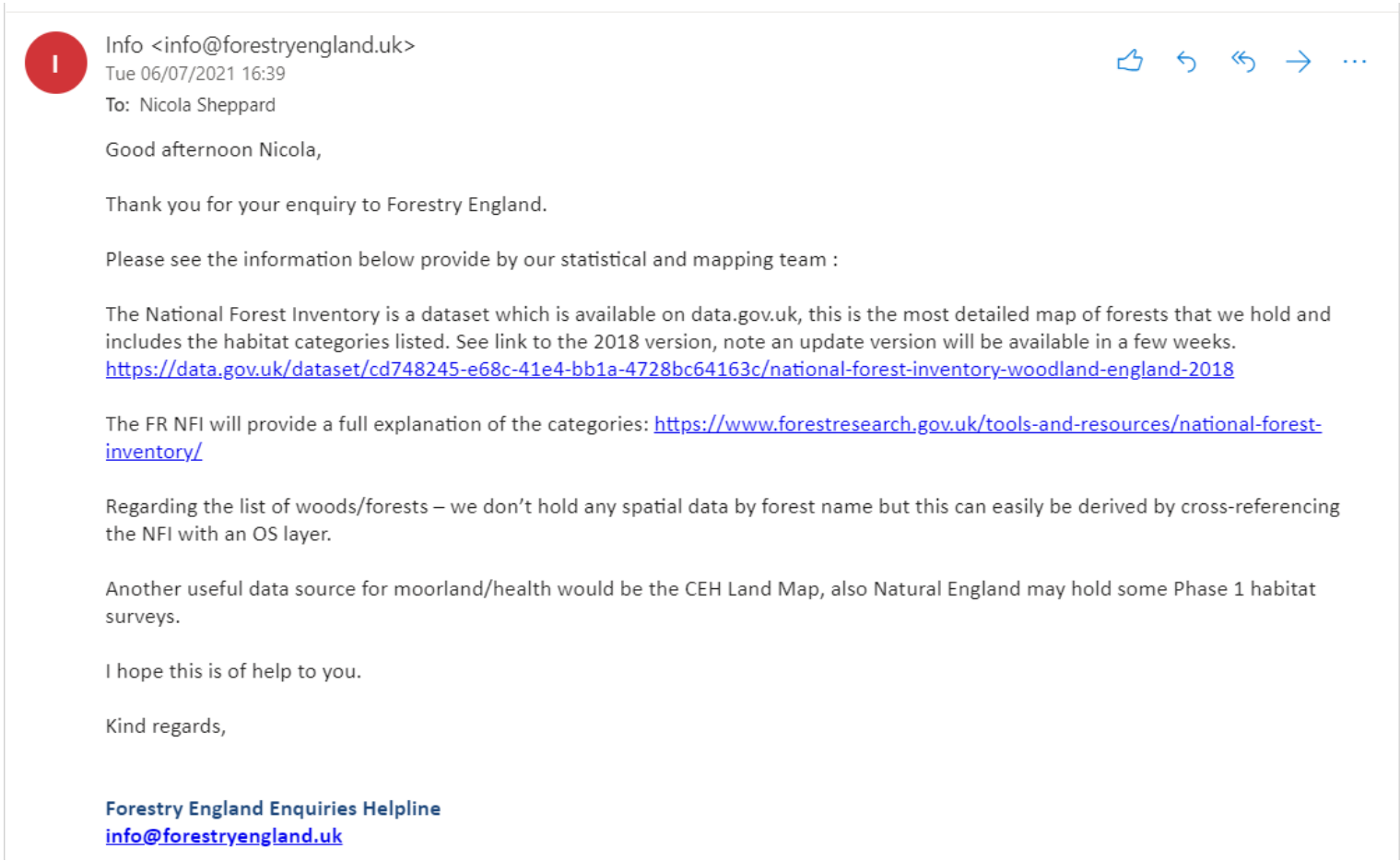
Let me know how you would like us to assist further.

Best wishes,

Piers Voysey (Forester)

...

Figure A5 – Email response from Piers at the Rothiemurchus estates providing information on the forest and an information sheet as a word document.



Info <info@forestryengland.uk>
Tue 06/07/2021 16:39
To: Nicola Sheppard

Good afternoon Nicola,

Thank you for your enquiry to Forestry England.

Please see the information below provide by our statistical and mapping team :

The National Forest Inventory is a dataset which is available on data.gov.uk, this is the most detailed map of forests that we hold and includes the habitat categories listed. See link to the 2018 version, note an update version will be available in a few weeks.
https://data.gov.uk/dataset/cd748245-e68c-41e4-bb1a-4728bc64163c/national-forest-inventory-woodland-england-2018

The FR NFI will provide a full explanation of the categories: https://www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory/

Regarding the list of woods/forests – we don't hold any spatial data by forest name but this can easily be derived by cross-referencing the NFI with an OS layer.

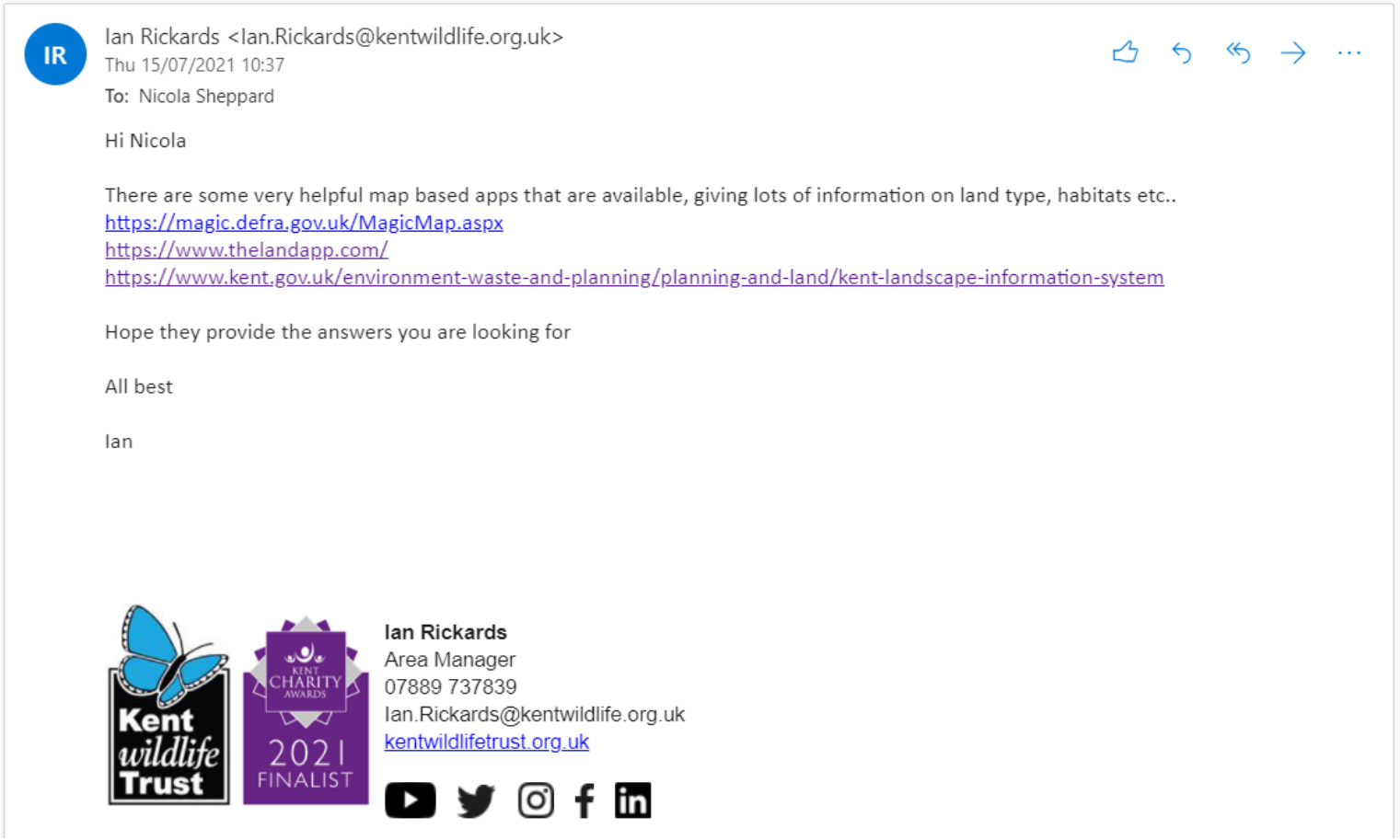
Another useful data source for moorland/health would be the CEH Land Map, also Natural England may hold some Phase 1 habitat surveys.

I hope this is of help to you.

Kind regards,

Forestry England Enquiries Helpline
info@forestryengland.uk

Figure A6 – Email response from the Forestry England Helpline with links to webpage that helped to provided data for this study.



IR

Ian Rickards <Ian.Rickards@kentwildlife.org.uk>
Thu 15/07/2021 10:37
To: Nicola Sheppard

Hi Nicola

There are some very helpful map based apps that are available, giving lots of information on land type, habitats etc..
https://magic.defra.gov.uk/MagicMap.aspx
https://www.thelandapp.com/
https://www.kent.gov.uk/environment-waste-and-planning/planning-and-land/kent-landscape-information-system

Hope they provide the answers you are looking for

All best

Ian

Kent wildlife Trust

KENT CHARITY AWARDS 2021 FINALIST

Ian Rickards
Area Manager
07889 737839
Ian.Rickards@kentwildlife.org.uk
kentwildlifetrust.org.uk

Figure A7 – Email communication from Ian at the Kent Wildlife Trust with links to useful apps that aided in the collection of data for this study.

H

Hebe.Carus@forestryandland.gov.scot
Thu 08/07/2021 14:40
To: Nicola Sheppard
Cc: enquiries.west@forestryandland.gov.scot

Hi Nicola

Basics publicly available for whole of Scotland on Map | Scotland's environment web. We have very little habitat data within FLS except maybe designated sites (Nature Scot will be best port of call for these though) or where we are considering peatland restoration. Neither of these is the case with Leanachan or Glenrigh. Try mapping from aerial photos for conifer vs BL.

Hebe Carus | Environment Forester

(Working day are Monday – Thursday)

Forestry and Land Scotland, Torlundy, Fort William
m: 07990 405 488 **e:** hebe.carus@forestryandland.gov.scot

Forestry and Land Scotland | Coilltearachd agus Fearann Alba

Figure A8 – Email communication from Hebe at Forestry and Land Scotland with links to helpful resources for gathering data around forests in Scotland.

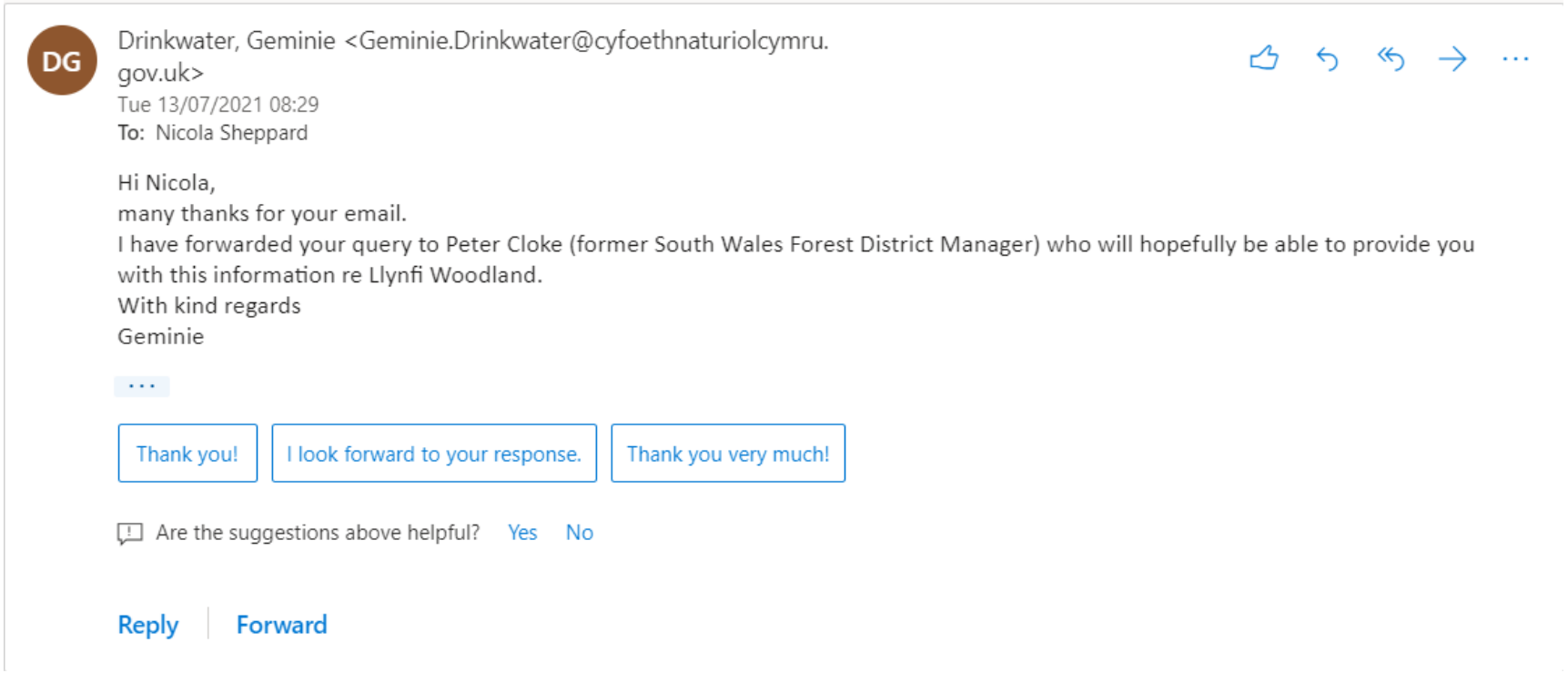


Figure A9 – Communication from Geminie informing that she has forwarded the enquiry for information around Llynfi Woodland in Wales to the former South Wales Forest District Manager.

APPENDIX – B

Table B1 – The complete dataset that was used in this study. Data was mined from several scientific journals, books, government documents, publicly accessible sites such the Vincent Wildlife Trust, Kent Wildlife Trust etc. and sometimes data were provided by owners of the land themselves. Where the data came from is provided in the Citation Source column in this table.

Forest/Area Name		Area (km^2)	Arable (km^2)	Pasture (km^2)	Deciduous (km^2)	Conifer (km^2)	Mixed Woodland (km^2)	Moor and Heathland (km^2)	Shrubs (km^2)	Grassland (km^2)	Citation Source
Gwydir Forest	W	72.50	18.93	4.78	18.24	49.11	4.18	9.2	16.59	9.01	MacPherson et al., 2014; Willis, 2008
Clocaenog Forest	W	100.00	1.15	11.62	4.29	65.59	0.17	13.81	4.36	15.52	Pommering, 2006; James et al., 2010; Bryce et al., 2005
Forest of Dean	E	526.30	148.78	2.34	78.36	43.20	12.75	0.24	13.12	2.35	MacPherson et al., 2014; Natural England, 2014a; Stringer et al., 2018
High Weald	E	1451.87	292.37	3.93k	78.18	10.98	6.93	17.68	19.11	192.7	Natural England, 2014b; High Weald, 2014; Kent Habitat Survey, 2012
Kielder Forest	E	647.50	242.67	0.60	18.84	365.61	1.55	74.32	74.98	0.60	Natural England, 2014c
Caledonian Forest/Cairngorm National Park	S	4528.00	90.56	378.54	147	455.39	30.00	2689	505.56	919.00	Green, 2008; Cairngorm National Park, 2017
Galloway Forest	S	1708.48	197.94	674.42	146.46	683.23	39.64	48.43	8.99	830.16	Forestry Commission, 1995; Forestry Commission Scotland, 2013; Sellars and Roberts, 2020
North Kent Downs	E	889.60	730.38	0.38	160.29	8.48	3.47	0.35	4.79	349.12	Natural England, 2014d; Kent Downs,

											2018; Kent Downs AONB, 2008; Kent Habitat Survey, 2012
Anagach Woods	S	3.86	0.01	0.01	0.42	3.66	0.15	0.01	0.03	0.54	Woodland Trust, 2014a; Oosthoek, 2013; Anagach Woods Trust, 2012; JNCC, 2015; Cairngorms National Park, 2017
Strathmashie Forest	S	14	6.46	1.54	1.4	9.1	3.4	5.32	2.66	1.96	Oosthoek, 2013; Anagach Woods Trust, 2012; Laggan Forest Trust, 2015; Forestry Commission, 1972
Rothiemurchus	S	74.35	0.51	3.17	0.45	11.05	2.09	5.77	0.21	5.6	Voysey, 2016 Information provided by Rothimercus through email communication (See Appx. C)
Glen Righ	S	20.74	2.44	10.4	0.61	9.42	0.41	1.49	1.8	10.4	Forestry and Land Scotland, 2013
Lochabar	S	440	27.18	149.6	61.6	347.6	8.8	31.76	330	144.3	Forestry Commission Scotland, 2009; Dargie and Scottish Natural Heritage, 1998; Jackson, 2016; MacEchern, 2016; Highland Council, n.d.
Coed y Brenin Forest	W	36.42	4.43	16.62	15.16	13.02	8.24	9.11	5.46	2.18	Coed y Brenin, 2020; Welsh Government, 2018a; Vincent Wildlife Trust, 2015;

											Forestry Commission, 2017
Dyfnant Forest	W	24.3	8.26	10.45	9.23	10.45	0.97	2.3	3.65	0.09	Grosvenor, 2021; Welsh Government, 2018a; Vincent Wildlife Trust, 2015; Montgomeryshire Wildlife Trust, 2021; Geographical Association, 2007
Dyfi Forest	W	75	1.05	51.45	18.75	56.25	3	5.78	11.25	11.25	Owens, 2009; Natural Resources Wales, 2016; Welsh Government, 2018c
Bwlch Nant Arian Forest	W	4.7	0	0	1.79	2.46	0.19	0	0.71	1.06	Forestry Commission, 2002; Welsh Government, 2018a; Vincent Wildlife Trust, 2015
Hafren Forest	W	35.13	22	22	13.35	15.11	1.41	18.04	5.27	13.35	Grosvenor, 2021; Welsh Government, 2018a; Vincent Wildlife Trust, 2015; Natural Resources Wales, 2021b; Natural Resources Wales 2021c; DEIMS-SDR, 2021; Kirby et al., 1991
Brechfa Forest	W	65	12.8	5.2	24.7	27.95	2.6	7.31	9.75	14.7	Natural Resources Wales, 2015; Welsh Government, 2018b; Vincent Wildlife Trust,

											2015; Anthony Jellard Associates, 2013; LUC et al., 2012
Afan Forest Park	W	120	7.08	48.72	76.78	169.93	3.50	40.47	0.39	9.27	Natural Resources Wales, 2014; Natural Resources Wales, 2021a; MacPherson et al., 2014; Welsh Government, 2018a; Welsh Government, 2020; Vincent Wildlife Trust, 2015; Blake 2015
Wentwood	W	10	0.66	0.99	7.15	7.95	1.05	0.51	4.5	4.5	Woodland Trust, 2016; Stringer et al., 2018; Brown, 2009; Grichards, n.d.
Bedgebury Forest	E	8.5	0	0	2.47	5.95	0.08	0.1	1.27	3.26	Forestry Commission England, 2009; Forestry Commission, 2018; Forestry England, n.d.
Chattenden Wood and Lodge Hill	E	3.51	1.87	1.14	1.64	0	1.10	0	0.53	0.27	Natural England, 2013b; Medway Council
Denge Wood	E	7.34	3.91	2.38	4.7	0.53	2.11	0	6.24	0.8	Woodland Trust, 2019a; Forestry Commission England 2012
Ellenden Wood and Victory Wood	E	1.8	1.33	0.31	0.07	0	1.21	0	0.36	0.18	Woodland Trust, 2013b; Kent County Council, n.d.
Ham Street Woods	E	1.72	0.92	0.56	0.53	0.65	0.11	0	0.29	0.04	Woodland Trust, 2019b

Hoad's Wood	E	2.1	1.12	0.68	1.68	0	2.1	0	0.32	0.56	Ashford Borough Council, 2005a
Joyden's Wood and Chalk Woods	E	1.35	0.71	0.44	0.98	0.27	0.71	0.01	0.47	0.02	Woodland Trust, 2021
Oaken Wood	E	2.9	1.54	0.94	1.89	0.55	0.35	0	0.07	0.12	Forestry Commission England, 2016; Woodland Trust, 2019b
Orlestone Forest	E	4.1	2.18	1.33	1.27	1.56	0.26	0	0.69	0.1	Woodland Trust, 2019b
Shorne and Ashenbank Woods	E	1.47	0.78	0.59	0.68	0	0.44	0	0.22	0.29	Woodland Trust, 2014b; Kent Country Council, 2015
West Blean and Thorden Woods	E	7.81	1.35	2.54	3.12	3.12	1.56	0	1.17	2.1	Kent Wildlife Trust, 2014; Kent Biodiversity Action Plan Group, 1997; Kent Nature Partnership, 2020; Swale Borough Council, 2011
North Kent Plains (including blean)	E	869.9	297.73	31.99	75.99	7.50	0.51	16.22	0.49	237.87	Kent Habitat Survey, 2012; Ashford Borough Council, 2005b; Natural England, 2015
Low Weald	E	518.54	169.89	384.51	53.79	3.23	4.35	0	0.03	252.99	Kent Habitat Survey, 2012; Natural England, 2013a; East Sussex County Council, 2012

APPENDIX – C

Rothiemurchus Factfile

24 reasons why Rothiemurchus is different:

Total extent: 7,435 hectares (in 2014 2,300ha (Upper Rothiemurchus Forest) was sold to Forestry Commission Scotland and is managed as part of the Forest Enterprise Glenmore/Inshriach forests)

'High ground' area covers 5,007 hectares that reaches the summit of Braeriach at 1296m;

'Low ground' area covers 2,428 hectares from 210m above mean sea level on the River Spey to 450m on Pityoulish hill and 500m on Kennapole hill.

EU Habitats and Species Directive Natura 2000 sites cover 6,121 hectares (Cairngorms SAC & SPA & River Spey SAC, also Cairngorms Massif SPA)

Sites of Special Scientific Interest (SSSI) cover 6,135 hectares (82% of the total area) (Cairngorms, Northern Corries, North Rothiemurchus Pinewoods and River Spey)

100% within the Cairngorms National Park

100% within the Cairngorms National Scenic Area

Loch Einich & Loch Coire an Lochan within the Cairngorm Lochs Ramsar site (A Ramsar Site is a wetland site designated of international importance under the 1971 UNESCO Convention on Wetlands, known as the Ramsar Convention.)

The only estate with an operational Concordat; recognising the multi-agency role in caring for Rothiemurchus

Recorded archaeological sites total 158; 4 of which are Scheduled Ancient Monuments

Doune Designed Landscape covers 522 hectares

Naturally regenerating native woodland (native pine/birch/juniper) covers 1063 hectares, including 3.9 hectares of montane woodland / montane scrub, 58 hectares of bog woodland (muskeg) with an additional 577 hectares of open ground for gradual, long-term regeneration to forest

Conifer plantation covers 209 hectares

Designated core paths extend to 20.5 kilometres with additional 2.3km of waymarked path and 1.2km of promoted hill path

Scotland's first Ranger Service established on a private estate in 1976

Recorded bird species total 173

Recorded mammal species total 27

Approximately 150 wild red deer and perhaps 100 roe deer; a population level that enables woodland regeneration targets to be met.

Farmland covers 400 hectares

Tenant farms now coming back in hand as farmers retire will increase this total.

Pedigree herd of Highland Cows (70) and a heard (50) of Highland cross or other cross-breed cows. Breeding herd of farm red deer (75).

An estimated 300,000 to 380,000 day visits per year by members of the public

Visitor activities (guided tours to 4x4 driving) and retail outlets

Employed staff (full-time equivalent) number 30 to 40 supported by 10 to 20 seasonal staff and other staff employed by partner visitor activity businesses

Over 450 years in the stewardship of the Grant family.

Long-term Forest Plan:

Introduced in 2006; based on the "Framework for Management of Rothiemurchus Pinewoods" and the "Rothiemurchus Biodiversity Action Plan" prepared by Dr Phil Ratcliffe.

Historically managed for timber, woodland grazing, der stalking, nature conservation and amenity; some areas have been consistently wooded since the last ice-age 8,000 years ago; without modification by drainage or ploughing and with one generation of trees succeeding another by natural regeneration.

The forest plan covers 1901ha, within which the woodland area currently covers some 1300 ha, of which 1004 ha is within a 2021-2025 Forestry Grant Scheme native woodland management contract.:

Figure C1 – Page 1 of the fact file provided by Piers from the Rothiemurchus Estate.

Rothiemurchus Factfile Continued...

881 ha Scots pine, birch, juniper
209 ha conifer plantation
72 ha bog woodland
43 ha riparian woodland
35 ha lowland broadleaf
29 ha policy woodland
16 ha scrub (juniper & some whins)
10 ha acid oak/birch
4 ha montane woodland

The remaining forest plan area (601 ha) include open water, clearings and land tending to regenerate to woodland. Significance as habitat for capercaillie, wood ants, narrow headed ant, Scottish cross bill, crested tit, intermediate winter green, twinflower, black grouse, osprey, otter, badger, fungi, lichens, bryophytes.

Forest Plan Aims & Objectives:

At least 60% will be managed as native woodland & that this area is regenerating, has high structural & age-class diversity & is delivering ecological functions appropriate for biodiversity action plan targets and maintaining designated areas in favourable condition.

Whole forest will be enjoyed by thousands of visitors, support sustainable livelihoods, compliant with UK Forestry Standard and will be independently certified under UKWAS.

Habitat Management categories:

Core Old Growth: 113ha (non-intervention) 263ha by 2025
Extension old growth: 316ha (minimal intervention, minimal extraction) 165ha by 2025
Extended rotation area: 477ha (extraction over long rotations) 526ha by 2025
Timber Production: 354ha (normal rotation forest management) 314ha by 2025
Felled to regenerate: 21ha - 61ha by 2025
Policy: 28ha – no change
Bog: 132ha – no change
Woodland expansion: 320ha – 271ha by 2025
Montane scrub: 4ha - 6ha by 2025
Woodland grazing: 11ha – no change
Un-stocked: 104ha – no change

Timber production on average 1,500 to 2,000 tonnes/yr

Wild Deer management

Culls over the last three years, increasing: 180 (61 red, 119 roe) in 2015, 218 (95 red, 123 roe), to 257 (116 red, 141 roe) in 2017. Principle aim is to secure woodland regeneration whilst delivering income from venison sales and client stalking.

Farm Plan

Farm area covers some 650 ha of which 51 ha is arable, including 43 ha Spring barley.
Grassland for grazing and silage production covers 243 ha, rough grazing 250 ha, woodland grazing 67 ha.
153 breeding cows of which 70 are Highland pedigree herd, with 135 associated calves, heifers, bulls. Some fields rented out and grazed by 230 sheep. 64 breeding herd of red deer.

Farm areas useful for wintering birds and farm waders (lapwing, curlew & snipe)

Figure C2 – Page 2 of the fact file provided by Piers at the Rothiemurchus Estate.