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The ecology & phylogeography of the common lizard (*Zootoca vivipara*) in Ireland

By Linda Lyne (BSc)

Orchid ID 0000-0002-9068-1473

Head of School of BEES:

Prof. Astrid Wengler

Supervisors:

Dr. Fidelma Butler & Prof. Ruth Ramsay

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Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism and intellectual property.

Abstract

Ireland has only one native terrestrial reptile, the common lizard *Zootoca vivipara.* Many people are unaware of its presence in Ireland and little research has been conducted on the species here. However, understanding the ecology of the common lizard in Ireland could greatly help with the conservation of our only native lizard. Here we show that records of common lizards in Ireland are predominantly from coastal areas and that it occupies smaller microhabitats, such as banks or stone walls, which potentially have microclimates that offer advantages for thermoregulation. Using records of *Z. vivipara* sightings from the National Biodiversity Data Centre, this research identified data gaps within the distribution of *Z. vivipara* in Ireland, but it is uncertain if these gaps are explained by unsuitable habitat type or low sampling effort. In addition, distribution of records were found to be centred around coastal areas and sites popular with human outdoor recreation. Recorder bias, habitat suitability, and coastal sunshine hours were identified as potential factors influencing the distribution of records.

A focused study on the Iveragh Peninsula, in the south-west of Ireland, observed *Z. vivipara* from habitat types such as upland peatland/heath (23%), gardens (17%) and old stone walls/ruins (16%). Wind speed, air temperature, and relative humidity were environmental parameters examined in this research to investigate the influence of microclimates within the microhabitats which lizards occupy. Wind speed was found to be significantly lower at ground level ($P<0.05$) compared to 2m height, and thus, wind may have an influence on where lizards are found within habitats.

In addition, through genetic analysis, we confirm for the first time, that Irish *Z. vivipara* belong to the Western viviparous clade. This brings Irish phylogeographic research on the species up to date with similar research in other parts of the species' range. We also identify that unique haplotypes are present in Ireland and that unique lineages also exist within geographically disparate populations here. Additional genetic sampling is recommended to fully understand how *Z. vivipara* colonised Ireland post-glacially.

It is recommended that a long-term study is established to perform focused surveys for lizard presence/absence in areas where data gaps occur in sightings records of the species in Ireland. This focused study should also identify reasons for data gaps, such as habitat suitability or recorder effort. A population dynamics and behavioural study is needed to examine how

environmental parameters influence *Z. vivipara* presence/absence in certain habitats. Finally, additional samples for genetic sequencing would greatly benefit the research into the different haplotypes identified in this study. A more geographically widespread range of samples, including from off-shore islands, would aid in understanding how *Z. vivipara* arrived and dispersed in Ireland.

Introduction to this thesis

Chapter 1 of this thesis is a general introduction to the literature around the study species of this thesis – the common lizard (*Zootoca vivipara*). The chapter highlights research from across the whole range of the species in addition to what is known about it from studies in Ireland. Topics covered include habitat and distribution, hibernation, reproduction, colour variations, and predators of *Z. vivipara*.

Using both citizen science records and fieldwork studies, this research aimed to examine various aspects of this understudied native species. Chapter 2 focuses on the distribution of sightings of *Z. vivipara* in Ireland, using data from the National Biodiversity Data Centre. A finer scale study was also conducted, using data collected from the Iveragh Peninsula in the south-west of Ireland. It was predicted that the distribution records would be largely linked to areas easily accessible to the public and close to major outdoor recreation hubs.

Chapter 3 presents data from fieldwork and citizen science contributions which examined habitat occurrences of Irish common lizards. Environmental parameters such as wind, temperature, and relative humidity were analysed to investigate any potential microclimate thermoregulatory advantages within the habitats *Z. vivipara* occupies. Knowing habitat preferences and distribution of the species in Ireland will aid in better understanding the conservation requirements here.

Finally, Chapter 4 presents genetic analysis which was carried out in order to place the Irish populations of *Z. vivipara* within the phylogeography maps of studies on mainland Europe. Using mtDNA to compare with other research, results in Chapter 4 bring research in Ireland up to date with work elsewhere within the species range, especially important given that Ireland holds the western range edge for common lizards. This study also adds the genetic information of Ireland's only native terrestrial reptile to the growing catalogue of work on post-glacial species here (Sleeman *et al*., 2014).

<u>Chapter 1</u>

General introduction

to the common lizard (*Zootoca vivipara*)

An island on the Atlantic edge of continental Europe, Ireland has a limited number of native land animals when compared to the UK and mainland Europe (Sleeman, 2014). Island isolation, cool climate and high rainfall are some of the ecological reasons why certain animals are absent in Ireland while present in the UK or mainland Europe (Harrison, 2014). Carlsson *et al* (2014) reviewed Irish genetic studies on a variety of animals including mammals, invertebrates, and freshwater fish. The review found that a combination of genetic analysis, ecological studies and archaeological work was required to understand colonisation by animals here. Understanding how animals colonised Ireland aids in describing early post-glacial landscapes in here (Carlsson *et al*., 2014).

For some species, introduction for food, the fur trade, or hunting, are potential reasons for their presence in Ireland (Carden *et al*., 2012; O'Meara, *et al*., 2012). Introduction by humans, or indeed multiple introductions, can influence distribution, as can geographical barriers such as mountains or rivers (Fitzmaurice, 1984; Flaherty & Lawton, 2019). There is also much debate about how glaciation and icesheets have influenced the colonisation and distribution of many of Ireland's terrestrial animals. Glacial refugium and the expansion of post-glacial habitats played a role in how our faunal species persisted or colonised the island of Ireland (e.g.: Rowe *et al*., 2006; Teacher *et al*., 2009; Ó'Cofaigh *et al*., 2010; Montgomery *et al*., 2014).

Extensive research has been conducted on a number of Ireland's mammal species, including complex predator-prey interactions (Sheehy & Lawton, 2014; Twining *et al*., 2020), multiple introductions of a single species (Carden *et al*. 2012) and the diets of a range of mammals from bats to badgers (McAney & Fairley, 1989; Cleary *et al*., 2009). A number of mammal species have also been identified as distinct in Ireland versus their UK or mainland Europe counterparts, including the Irish mountain hare *Lepus timidus hibernicus* and the Irish stoat *Mustela erminea hibernica* (Hamill *et al*., 2006; Martínková *et al*., 2007). Terrestrial invertebrates are understudied in Ireland, with the hairy wood ant (*Formica lugubris*) alone in being identified as distinctive in Ireland (Mäki-Petäys & Breen, 2007).

Ireland has only one native terrestrial reptile, the common lizard, *Zootoca vivipara*, formerly known as *Lacerta vivipara*. It is protected under the Wildlife Act, 1976, and a license, obtained from the National Parks and Wildlife Service, is required to handle the species. The slow-worm (*Anguis fragilis*) has a very restricted range in Ireland, being mostly confined to the Burren in County Clare, and it is believed to have been introduced in the 1970's (Parry, 2020). The native amphibian species the smooth newt (*Lissotriton vulgaris*), is the only animal that is likely to cause confusion with *Z. vivipara* identification in Ireland. Similar to reptiles, Ireland is also depauperate in native amphibian species. For example, Ireland has one native lizard and three native amphibians, while the UK has three native lizards and seven native amphibians (Inns, 2009). Climate, land connectivity, and habitat suitability at the time of colonisation are potential reasons for the lower numbers of species making the move across to Ireland (Sleeman *et al*., 2014).

Despite its status as Ireland's only native terrestrial reptile, the species is understudied here. This can also be said for the smooth newt in Ireland (Meehan, 2013). Long-term ecological studies are key in understanding how species interact with their environments, conspecifics, and other species (Lindenmayer *et al*., 2012). Understanding these interactions is also key in effective conservation management and public policy (Ludwig *et al*., 2001; Ribeiro *et al*., 2009). However, herpetofauna (reptiles and amphibians) are under-represented globally in conservation considerations and wildlife research journals when compared to other taxonomic groups (Gibbons *et al*., 2000; Christoffel & Lepczyk, 2012).

A potential reason for the lack of research on the common lizard in Ireland is that many people are unaware of their presence here. "I didn't know we had lizards here" or "I knew we had them, but I've never seen one" are two of the most common responses I have encountered during public outreach on the species. Known as '*laighairt choiteann*' (common lizard) in Irish, they are also known as '*earc*' or '*earc luachra*' meaning 'lizard' or 'lizard of the rushes'. The smooth newt is known as '*earc sléibhe*' meaning 'lizard of the mountains'. The use of '*earc*' for both lizard and newt in Irish would suggest that people did not distinguish between the two species in Ireland (MacCoitir, 2010). They are not seen as a pest, nor as a threat, and are not a source of food or another resource so, therefore, have gone under the radar for many people in Ireland.

The earliest written record for the species here is from the *Topographia Hibernica*, the 11th century account of life in Ireland written by Gerald of Wales (MacCoitir, 2010). While it is commonly said to have been in Ireland since the last ice-age (Marnell, 2002; Meehan, 2007), this is likely just inferred given its presence on some of Ireland's islands. The first written record of this assumption that this author could find was in the 1912 Clare Island survey by R.F. Scharff. Fossil records of *Z. vivipara* have been used to infer timelines in other parts of their range (Villa *et al*., 2018), however, no fossil evidence of the species has been found in Ireland (*pers. comm*. Dr Ruth Carden, UCD).

With little research being conducted here, there is potential for issues such as population decline, habitat loss, pressure from invasive species, effects of climate change, or an outbreak of disease, to go unnoticed. Mapping the distribution and habitat preferences of the species will aid in future conservation efforts in Ireland and identifying its genetic origin will elevate it in the ranks of other native Irish species which have their gateway origin to Ireland identified.

Distribution and Habitats

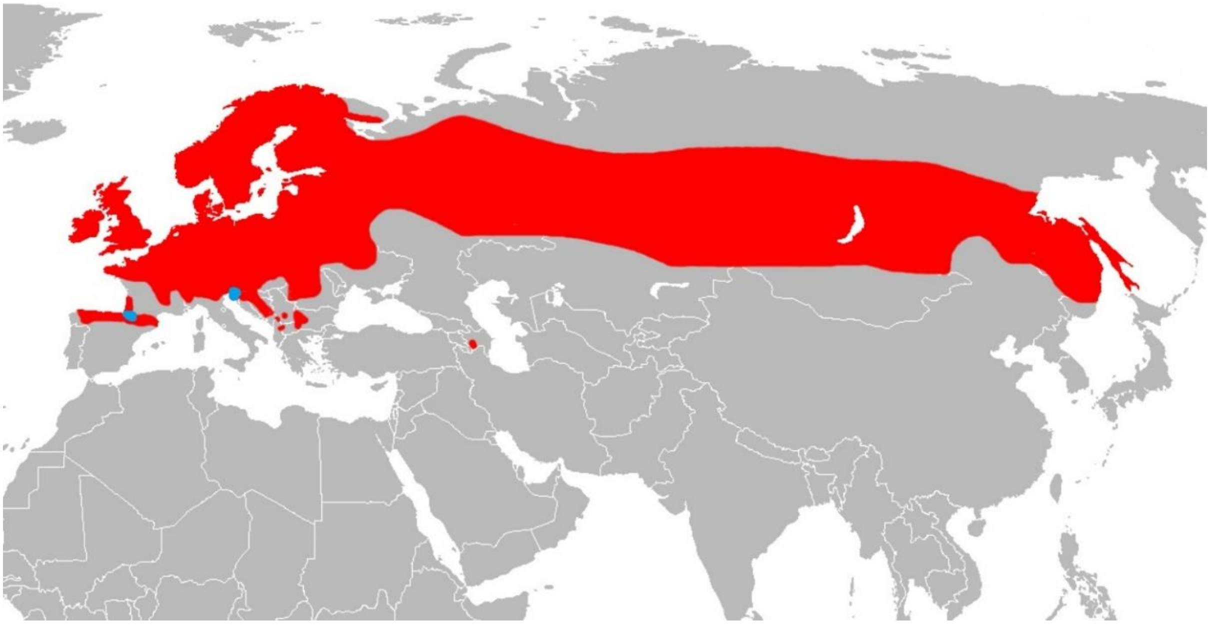


Figure 1.1 – Map of the global distribution range of *Zootoca vivipara.* The majority of the range consists of viviparous populations (shown in red). The blue areas represent the oviparous populations found in south-west France, north-east Spain, Slovenia and Croatia (modified from WWW1).

The common lizard has the distinction of being the terrestrial reptile with the largest known geographical range worldwide (Beebee & Griffiths, 2000) (see Figure 1.1). It has been recorded from the Japanese archipelago in the east, north into the Arctic circle, as far south as Greece, while Ireland holds the most westerly populations (Beebee & Griffiths, 2000; Strachinis *et al*., 2019). No literature focusing on the isolated population in Azerbaijan (seen in Figure 1.1) could be found. It is the only reptile present in large parts of its range, a status which according to a number of authors (Heulin, *et al*., 2000; Surget-Groba *et al*., 2006; Horreo *et al*.,

2021) is likely due to its dual reproductive strategy of both oviparity and viviparity, the latter suiting cold and damp climates. The species is capable of swimming short distances across pools (Beebee & Griffiths, 2000) and has been recorded in a range of habitats from dune systems, woodland verges, peatlands, and at altitudes of up to 3,000m in the European Alps (e.g., House *et al*., 1980; Stumpel & van der Werf, 2012; McInerny, 2016; Farren *et al*., 2010). Although they can occur in cold and damp climates, as an ectotherm, they need suitable basking sites which are exposed to the sun within their habitat in which to thermoregulate, while being close to vegetation cover to escape from predators (Bauwens & Thoen, 1981). They also require an adequate food source from their surrounding habitat along with specific hibernation requirements such as frost-free areas and cavities in which to secure themselves over winter (Hodges & Seabrook, 2022). They prey on a wide range of invertebrates such as arachnids, Diptera and Hemiptera (Beebee & Griffiths, 2000) and having such a non-specialist diet may aid in their large geographical range.

Little research has been done on tracking the dispersal range of individual *Z. vivipara*, with Beebee & Griffiths (2000) suggesting a home range of 100m while Strijbosch (1995) showed lizards made their way home from a distance of up to 250m following deliberate displacement. Such philopatry (returning to place of birth) has been recorded in studies of *Z. vivipara*, including age-specific dispersal patterns and oviparous females which returned to communal egg-laying sites (Cotto *et al*., 2015; Peñalver Alcázar *et al*., 2015). A survey of the literature review did not find any records of its accidental or intentional introduction to countries outside its range, such as that which has occurred with the slow-worm or common toad (*Bufo bufo*) in Ireland (Parry, 2020; WWW2). The literature suggests that *Z. vivipara*, first occurred in the late Pleistocene (>11,700 years ago) and colonised much of its global range by following retreating icesheets and persisting in glacial refugia (Milá *et al*., 2013; Horreo *et al*., 2018).

Little is known about its abundance or detailed distribution in Ireland, but there has been a handful of studies on common lizards here. Ní Lamhna (1979) suggested that the species is "*probably fairly widespread*" and noted it can be found in habitats such as hedgerows, heaths, waste land, open woods, gardens, bogs, and sand-dunes. Marnell (2002) combined survey work – by the Irish Wildlife Trust and the Ulster Wildlife Trust - and citizen science records to gather over 250 lizard sightings and form an estimate of their distribution in Ireland. Marnell (2002) also suggested peatland as one of the most important habitats for the species in Ireland, accounting for 22% of the records in their study.

Continuing from Marnell (2002), Meehan (2007) produced a report for the Irish Wildlife Trust which again combined survey work and citizen science sightings. The report received records of lizards from 29 counties, showing the species to be widespread, with sightings peaking in April and July. Peatlands were again identified as important habitats (15% of records) but rural gardens and inside homes accounted for 24%, suggesting that domestic dwellings may be encroaching on their habitats (Meehan, 2007).

Recent work on the species includes distribution modelling in Northern Ireland (Farren *et al.*, 2010) and an observation of a predation event by an invasive arachnid (Dunbar *et al.*, 2018). Conservation and awareness of the species is helped by public outreach through projects such as the 'Dragon Hills', based in Newry, Counties Armagh and Down (WWW3). The project has several collaborators including ARG UK (Amphibian and Reptile Group UK) and The HSI (Herpetological Society of Ireland, WWW4). The HSI is a charity based in County Dublin and is instrumental in habitat restoration for reptile and amphibians such as in Girly Bog, County Meath, and monitoring environmentally sensitive areas, such as Bull Island, County Dublin.

There has also been some focused research on common lizards in the southern regions of Ireland. There have been three unpublished final year undergraduate projects on common lizards examining the habitat and behaviours of the population at Ballycotton, County Cork, where there is a large population along a coastal cliff walk (O'Reilly, 2013; O'Toole, 2015; Lyne, 2017). In addition, I have conducted 'walks and talks', to educate the public on the species, in Ballycotton, County Cork, via the charity organisation Cork Nature Networks.

(Distribution and habitats will be discussed in much more detail in Chapters 2 & 3 respectively)

Genetics

International research on the species is varied with much focus on the dual reproductive strategies, particularly in neighbouring populations on mainland Europe (Heulin *et al*., 2011; Milá *et al*., 2013), and on the evolution of oviparous and viviparous lineages (Surget-Groba *et al*., 2006; Recknagel *et al*., 2018). Hybridisation between viviparous and oviparous populations has been investigated through both captive programs and genetic studies, with results showing the two parity modes do not hybridise in the wild (Arrayago *et al*., 1996; Heulin *et al*., 2000). The diversification of the species into clades with common ancestors has been a major focus of genetic research, with many studies identifying a Pleistocene origin for the species, with glaciers and geographic barriers such as mountain ranges explaining multiple lineages (e.g., Heulin *et al*., 2011; Milá *et al*., 2013; Cornetti *et al*., 2014). In Japan, the eastern range edge for *Z. vivipara*, low genetic diversity and a single haplotype was found between three separate populations on the northern tip of Hokkaido (Takeuchi *et al*., 2013). The haplotype matched an eastern viviparous clade found in eastern-Europe and Asia, suggesting either a single founder event or a Pleistocene land-bridge colonisation >10,000 years ago (Surget-Groba *et al*., 2006; Takeuchi *et al*., 2013).

(Genetics will be discussed in much more detail in Chapters 4)

Reproduction and hibernation

Lizards and snakes can reproduce via oviparity (egg laying) or viviparity (live birth) (Shine, 2005). However, bimodal reproduction, where populations of both oviparous and viviparous occur within the species' range, is rare and only known in two species of Australian skinks (*Lerista bougainvillii* and *Saiphos equalis*) in addition to *Z. vivipara* (Smith *et al*., 2001). *Z. vivipara* is viviparous in the majority of its range (Figure 1.1), including Ireland, with oviparous populations occurring in isolated pockets in the Pyrenees, Alps, and eastern Europe (Surget-Groba *et al*., 2006). Oviparous *Z. vivipara* produce eggs which have thin parchment-like membranes and often lay eggs in communal 'nests', with gravid females showing philopatry to these sites (Arrayago *et al*., 1996; Peñalver Alcázar *et al*., 2015). In viviparous populations, gravid females tend to increase basking durations, to aid foetal growth, and the neonates are surrounded by a thin membrane which tears during, or soon after, birth (Arrayago *et al*., 1996; Beebee & Griffiths, 2000).

Both viviparous and oviparous populations of *Z. vivipara* hibernate during the colder winter months across the species range (Costanzo *et al*., 1995; Berman *et al*., 2016; Orlova *et al*., 2003). It can tolerate sub-zero temperatures (Berman *et al*, 2016), and may even construct its own hibernation 'cells' (Hodges & Seabrook, 2022). Grenot *et al*., (2000) showed that increased glucose levels were found in hibernating *Z. vivipara* and linked this with an ability to survive supercooling (very low body temperature but the body remains unfrozen) and even whole body freezing during sub-zero temperatures.

The end of July/beginning of August is the typical time of year for parturition in the species in Ireland and the UK (Inns, 2009). The extensive field enclosures and laboratories at the CEREEP (Centre de Recherche en Écologie Expérimentale et Prédictive) research facility south of Paris have long running projects on *Z. vivipara* (WWW5). The earliest birth recorded there was the 4th of June 2011 but was surpassed by the arrival of neonates on June 2nd 2022, following a mild spring (WWW6). How earlier spring mating or earlier birthing might affect common lizards is unclear, but it does show the potential of climate change to alter behaviour in the species.

The monitoring of phenological behaviours is a key method for studying the effects of climate change on reptiles and has been used in a range of studies (e.g., Rutschmann *et al*., 2016; Prodon *et al*., 2017; Jara *et al*., 2019). Phenological research on lizards is giving insight into how isolated populations can persist or how seasonal temperature changes may influence reproductive fitness (Chamaille-Jammes *et al.,* 2006; Ljungström *et al*., 2015). Stress levels from seasonal changes in temperatures or water availability driven by climate change has been shown to shorten telomeres, the end part of a chromosome which is linked to aging, in common lizards and thereby have the potential to drive local extinctions (Dupoué *et al*, 2017; Dupoué *et al*, 2020; Dupoué *et al*, 2022). Ireland, being the western range edge for the species, is in a unique position to monitor phenological changes in the species along with their effects. While there may be some benefits to the species, such as warmer spells allowing for higher levels of activity, it is uncertain if the extremes which come with climate change may outweigh any benefits in the long-term.

Colour Variations

With adults averaging only 14cm in length and with cryptic colouration aiding the animal to blend into its surroundings, spotting common lizards in the wild is a difficult task. Traditional methods for reptile surveying include visual searches along transect routes or using artificial refugia, which reptiles use to bask upon or hibernate under (Stumpel & van der Werf, 2012; McInerny, 2016).

Arnold *et al*. (2007) described *Z. vivipara* colouration as "*Background colour brown, occasionally grey or olive, rarely greenish*". The species displays sexually dimorphic ventral colouration, with females showing a typically plain cream belly while the undersides of males are vibrant orange with dark spots. During courtship, the male flashes the underbelly to their potential mate, while remaining inconspicuous to aerial predators (San-Jose & Fitze, 2013). San-Jose *et al* (2013) identified that it was reflective iridophore cells, in the dermal layer of the skin, that were responsible for variation in this carotenoid-based pigment, rather than diet-based carotenoids. The snout to vent length is approximately 65mm, although humidity levels in habitat types is believed to have a negative influence on size (Lorenzon *et al*., 2001), with adult females slightly larger than males.

While no consistent dorsal colour categories have been designated for the species, reference books and other materials suggest common lizards are often found to be brown, a vibrant green, and olive green (which resembles a mix of brown and green), and the rarer melanistic individuals which result from a genetic mutation (San-Jose *et al*., 2008; Innes, 2009), see Figures 1.2 – 1.4 for examples. Some individuals appear pale in colour as they undergo skin sloughing as layers of keratin separate from the scales. The species is known to eat this sloughed skin as a source of protein (Vacheva & Naumov, 2020). The most recently published research on the common lizard in Ireland did not examine colour variations in Ireland specifically (Marnell, 2002; Meehan, 2007; Farren *et al*., 2010). Meehan (2007) produced work from data gathered via the Irish Wildlife Trust, and suggested colouration was directly linked to habitat type, however, no evidence for this could be found in a search of literature on the species.

There is no mention in the literature of melanistic individuals in Ireland, however, a search on social media suggests that they are present in small numbers (e.g. WWW7). Personally, I have only observed a single melanistic individual during years of studying the species which would suggest they occur sporadically and are not frequent in populations as seen in other regions (Lochhaas *et al.* 2021). This sporadic occurrence of melanistic individuals is not uncommon in the species (San-Jose *et al*., 2008).

In unpublished research from O'Reilly (2013), from a number of sites in County Cork including Ballycotton, brown and green colour morphs were noted. However, colour morphs were not the focus for that study and data on numbers of each type were not gathered. Another unpublished study by O'Toole in 2015, again divided lizards into two colour morphs, brown and green, and reported 46 brown adults and 33 green adults during his study. During my undergraduate research project (Lyne 2017), at the same site in Ballycotton, I found that the abundance of each colour type changed over time during the study (Figure 1.7) and while preliminary data showed no significant link between colour type and habitat type, a captive study was recommended to investigate colour variations further.

Predators

Common lizards play an important role in food chains. Predators include mammals such as foxes, stoats, and hedgehogs, along with several species of birds including kestrels and pheasants (Smiddy, 2017; Graitson & Taymans, 2022). Common lizards, amongst many other reptiles, can ‘drop’ or release a section of tail in a process called autotomy (Arnold, 1988). The tail continues to move following detachment to distract the predator while the lizard escapes. A review of caudal autotomy in lizards by Bateman & Fleming (2009), suggests that microhabitats can have influence on the occurrence of tail autotomy. Lizards occupying the edges of habitats may be more vulnerable to predation events and result in higher tail loss prevalence in these populations. Other research has examined the effects that tail autotomy can have on a range of traits, including increased risk of predation (due to extended foraging for the energy requirements to regrow the dropped tail), variation in reproductive rates, and impact on thermoregulatory abilities (Dial & Fitzpatrick, 1981; Herczeg *et al.*, 2004; Fox & McCoy, 2020).

The only predator mentioned by name in the National Biodiversity Data Centre (Ireland’s national repository for plant and animal records, henceforth referred to as NBDC) records for common lizards in Ireland is the domestic cat (*Felis catus*). However, Figure 1.5 shows a stonechat (*Saxicola rubicola*) with an adult female common lizard prey. The image was captured and sent to me from a member of the public who attended a common lizard citizen science event, which I guided, in Ballycotton, County Cork. It can be seen in the image that the bird has also retrieved a section of tail which the lizard dropped in a failed attempt to avoid capture. Figure 1.5 would suggest that stonechats, or at least individual birds, may be aware of this strategy and look to collect both lizard and tail.

Another image submitted by the same citizen scientist shows a grey heron (*Ardea cinerea*) predating a common lizard (Figure 1.6). Considered a ‘wading bird ally’ in I-WeBS counts (WWW8), Irish Wetland Bird Surveys, this interaction shows that common lizards varied habitat preferences can bring them into contact with a variety of predators.

Images such as Figure 1.5 and Figure 1.6 submitted by citizen scientists prove very valuable in recording rare or unusual behaviours. A search of literature and social media (Table 1.1) revealed some notable encounters. BBC Springwatch, a natural history series based in the UK, showed a selection of 'nest cam' activity. Cameras were set to observe nests of various species and a ring ouzel (*Turdus turquatus*) adult was seen returning to their brood with a common lizard prey item. Ring ouzel are a rare breeding bird in Ireland, restricted to a handful of sites in upland areas, and are at risk of extinction here (Mee, 2018). While the footage from the nest camera was from the UK, such activity shows that protecting prey species and their habitats may have a knock-on benefit to other species.

Common lizards also appeared in another rare bird species study, this time on the hen harrier (*Circus cyaneus*). McCarthy *et al.* (2021) examined pellets from hen harrier sites in Ireland and found evidence of lizards in their diets. What was particularly interesting is that the study looked at winter foraging, with pellets being collected between November and March. Common lizards hibernate during the worst of the winter weather in Ireland, but NBDC records and sightings indicate that they can appear during milder winter weather throughout the year. Again, an important point when looking at whole ecosystem approaches to conservation.

The threat to common lizards, and other native Irish fauna, from invasive species is of major importance given that some have unknown population numbers in Ireland. The false widow, the non-native arachnid *Steatoba nobilis,* has a growing presence in Ireland since it was first recorded in 1998 in County Wicklow (Nolan, 1999). A predation event by the false widow on a common lizard in Killiney, County Dublin, was published by Dunbar *et al* (2018). The lizard was wrapped in a web and the spider was feeding on or guarding it. Whether this was a predation event where the spider actively hunted and caught the lizard, or if the hapless lizard fell into the web, is unclear. A social media search revealed another predation occurrence involving a spider on a common lizard, this time by the wasp spider *Argiope bruennichi* (Table 1.1). While the wasp spider is not present in Ireland, the spread of the false widow shows the potential for other arachnid predators to arrive and establish here.

The first record of the greater white-toothed shrew, *Crocidura russula*, in Ireland occurred from bird of prey pellets in 2007 and its subsequent expansion is well documented (Tosh *et al.*, 2008; McDevitt *et al*., 2014). A post on the Twitter social media platform in 2018, recorded images of a predation attempt by a greater white-toothed shrew on a common lizard (WWW9). Witnessed in Abbeyleix Bog, County Laois, the observer noted that the lizard dropped its tail and evaded the shrew. Given that *C. russula* is three times the size and more gregarious than Ireland's only native species, the pygmy shrew *Sorex minutus* (McDevitt *et al* 2014), there is potential for the continued spread of the larger shrew to result in more possible predation events on common lizards such as that recorded in Abbeyleix.

Accidental introductions such as the false widow and greater white-toothed shrew may be one potential risk to native species such as the common lizard but another threat may be the ease with which other potential predators can adapt to the Irish environment given climate change. The wall lizard, *Podarcis muralis*, is native to mainland Europe but has a growing population in the south of England (Michaelides *et al*., 2015). The larger wall lizards were both accidentally and intentionally introduced, and their expansion shows that they are coping with the cooler climate despite being oviparous (Michaelides *et al*., 2015). In May 2020, a wall lizard was observed hunting, killing, and ingesting a common lizard, in Dorset, England, as documented in Thomas *et al* (2020). A warming climate might allow similar predatory reptiles to gain hold in certain parts of Ireland and become a risk to the native species. Climate change is already predicted to be a concern regarding invasive species (Thuiller, 2007; Jarvie *et al*, 2022). It has also been shown that some prey species do not recognise predator threats if they have not evolved together (Twining *et al*, 2020) meaning that native Irish species, such as the common lizard, may not adapt to recognise the arrival of new predators. Social media and citizen science records may be a useful method to identify novel interactions between common lizards and non-native species in Ireland.

Coastal areas of Ireland are often good sites to look for exotic birds blown off course during storms. Unusual records often set the bird communities alight with avid birders travelling to see rare species. *Lanius* sp., commonly known as shrikes, are also referred to as butcher birds for their macabre behaviour of impaling their prey on the thorns of vegetation (Yosef & Pinshow, 2005). A study by Antczak *et al* (2019) looked at the great grey shrike *Lanius excubitor* and its predation of common lizards amongst other species. The shrikes studied showed a preference for male common lizards over females, possibly due to the male lizards taking more risks during the mating season including moving around territories. The NBDC has 325 records of shrike sightings in Ireland coming from 6 different *Lanius* species, including *L. excubitor*. While there are no reports of breeding shrikes in Ireland, climate change may cause some bird species (including new predators of *Z. vivipara*) to expand their range and breed here, as seen with the little egret *Egretta garzetta* and great spotted woodpecker *Dendrocopus major* (McDevitt *et al*, 2011; Fennelly & Cannon, 2015).

Figure 1.2 – Examples of the olive tones seen in some individuals (left) and the typical brown colouration seen in others (right). Image: Linda Lyne.

(a) (b)

Figure 1.3 – Some individuals, such as this male (a) from Ballycotton, County Cork, display very vibrant green colouration, while neonates have a dark bronze colouration (b). Images: Linda Lyne.

Figure 1.4 – Melanistic common lizards appear to be rare in the Irish populations. Image: Linda Lyne

Figure 1.5 – A stonechat (*Saxicola rubicola*) with a common lizard prey from a citizen scientist observation. Image: Gemma Kelliher.

Figure 1.6 – A grey heron (*Ardea cinerea*) with a common lizard prey from a citizen scientist observation. Image: Gemma Kelliher.

Table 1.1 - Examples of wild predator/scavenger events on *Zootoca vivipara* (table continues over page).

Species (Country of record) Conservation Status Ireland	Group	Source	Reference	Details	Image/video
Common Kestrel (IRL) (*Falco tinnunculus*) Red	Bird of prey	Scientific publication	Patrick Smiddy http://dx.doi.org/10.3318/bioe.2017.16	Evidence found in pellets.	No
Hen Harrier (IRL) (*Circus cyaneus*) Amber	Bird of prey	Scientific publication	Alan McCarthy doi.org/10.1080/00063657.2022.2103515	Evidence found in pellets.	No
Hen Harrier (UK) (*Circus cyaneus*) Amber	Bird of prey	Twitter	Alan Saunders https://twitter.com/Alansaunders007/status/1583448745425133568	Bird seen carrying lizard in flight.	Yes
Ring Ouzel (UK) (*Turdus torquatus*) Red	Passerine bird	Twitter	BBC Springwatch https://twitter.com/BBCSpringwatch/status/1138793073083727872	Video cam showed adult feeding lizard to young in nest.	Yes/ video
Stonechat (IRL) (*Saxicola rubicola*) Green	Passerine bird	Citizen science	Gemma Kelleher @BC_Gemma on Twitter	Bird seen perching on fencepost with lizard in mouth.	Yes
Grey Heron (IRL) (*Ardea cinerea*) Green	Wading bird	Citizen science	Gemma Kelleher @BC_Gemma on Twitter	Bird seen with lizard in mouth.	Yes
Common Pheasant (BE) (*Phasianus colchicus*) Green	Game bird	Scientific publication	Graitson & Taymans, 2022 doi : 10.48716/bullshf.180-2	Population surveys before and after pheasant releases/removals.	No
Greater White-toothed Shrew (IRL) (*Crocidura russula*) Medium Impact Invasive	Mammal	Twitter	Abbeyleix Bog https://twitter.com/abbeyleixbog/status/1022953542250885120	Shrew seen attacking lizard. Lost tail but survived.	Yes

False Widow Spider (IRL) (*Steatoda nobilis*) Invasive/Data Deficient	Arachnid	Scientific publication	Dunbar *et al*, 2018 doi.org/10.3318/bioe.2018.05	Spider found feeding on dead lizard in web. Unknown if spider caught lizard or opportunistic.	Yes
Wasp Spider (UK) (*Argiope bruennichi*) Not present in Ireland	Arachnid	Twitter	@PhilCorleyPhoto http://goldenorfephotography.blogspot.com/2015/02/dorset-holiday-pt2-castles-spiders-and.html	Spider found feeding on dead lizard in web. Unknown if spider caught lizard or opportunistic.	Yes
Common Wall Lizard (UK) (*Podarcis muralis*) Not present in Ireland	Reptile	Scientific publication	Thomas *et al*, 2020 https://doi.org/10.33256/152.44	Larger wall lizard seen hunting and ingesting the smaller juvenile common lizard.	Yes
European Praying Mantis (FR) (*Mantis religiosa*) Not present in Ireland	Insect	Twitter	Jean-François Le Galliard https://twitter.com/LeGalliard_Lab/status/1435363116951523328	Seen predating neonate lizards.	No

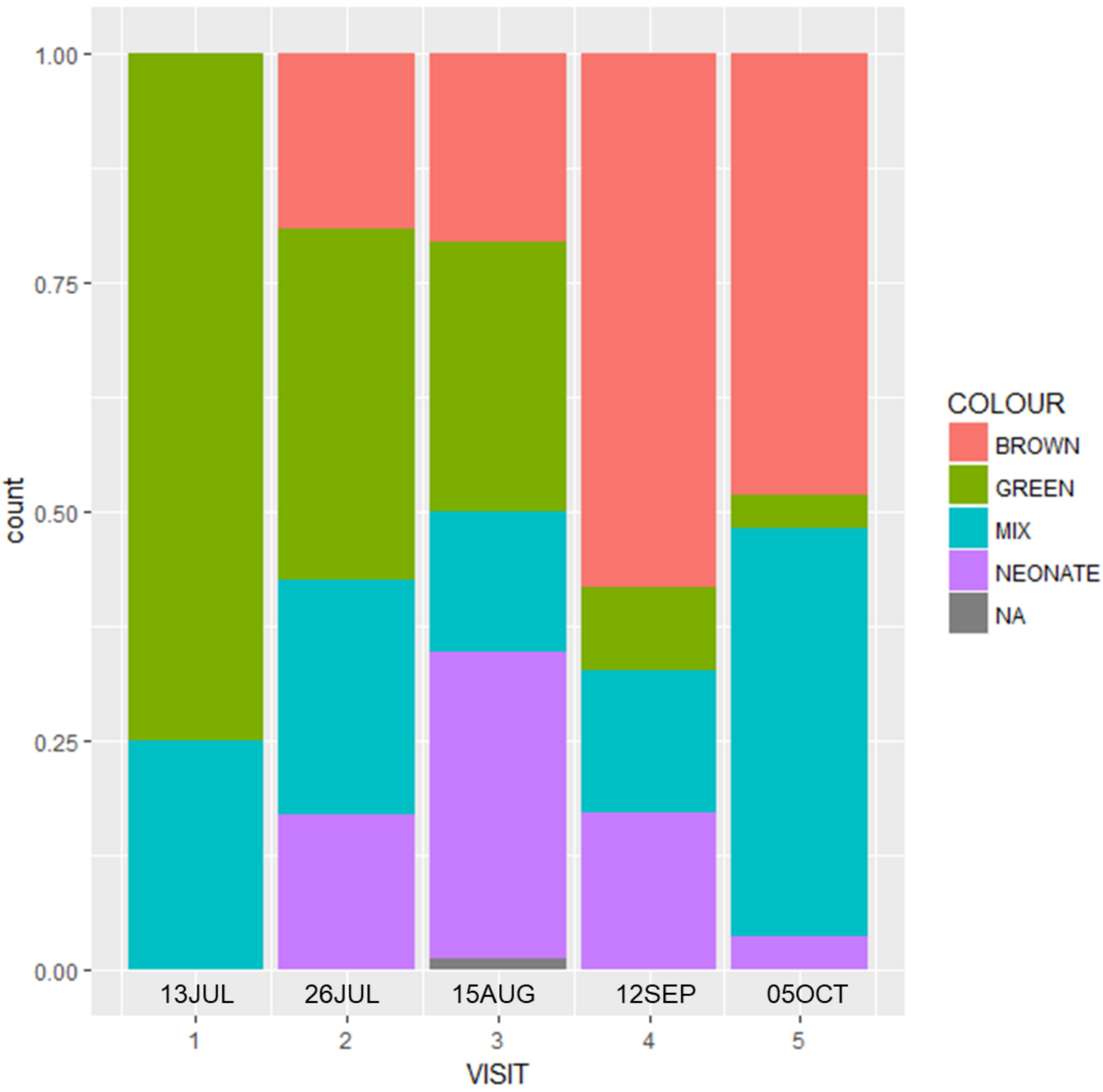


Figure 1.7 – The change in abundance of each colour type in the Ballycotton population, across five visits between July and October 2017, is seen to change over time (Lyne, 2017).

Chapter 2

Distribution of sightings records for the common lizard in Ireland

Abstract

Knowing the geographical distribution of a species can help inform certain aspects of its conservation. Understanding habitat requirements where it might be present or absent can help identify which areas need to be prioritised for protection. Records from the National Biodiversity Data Centre were examined to create a picture of the national distribution of the common lizard, *Zootoca vivipara*, in Ireland. These records showed a largely coastal distribution with clusters around areas popular with human recreation. In addition, citizen science records and fieldwork on the Iveragh Peninsula, County Kerry, were used for a more focused regional comparison. Similar patterns were identified from both datasets, where records were clustered in areas popular with human recreation and largely skewed to show a recorded distribution that reflects where humans live. In addition, records occur from peak holiday periods when people are more likely to be outdoors. Land use is also a factor in the distribution of records, with data for lizard sightings lacking in areas of intensive agriculture. However, it is unclear if land use is the main reason or if data gaps occur due to lack of sampling effort. A recommendation of this research is that focused sampling for *Z. vivipara* is undertaken in areas where there are gaps in the distribution of records and reasons for their absence to be established.

Introduction

The common lizard, *Zootoca vivipara*, has the largest geographical distribution of any species of lizard (Beebee & Griffiths, 2000). Its range extends from the Japanese Archipelago in the east to Ireland in the west. Much work conducted on the distribution of the species in mainland Europe has looked at how geographical barriers, such as mountain ranges or glaciation events, have altered its spread, including the variation of distribution between oviparous and viviparous populations (Milá *et al.*, 2013; Horreo *et al.*, 2018).

Distribution studies have used a range of techniques. Many use pitfall traps or artificial refugia to gain data on common lizards when looking at local ranges (e.g., McInerny, 2016; Lochhaas *et al.*, 2021). For large scale distribution maps, partnerships between research studies, literature reviews, or inference via species distribution modelling are alternatives. Another method is to utilise national data repositories for species, which often combine records from scientific surveys along with records submitted by members of the public.

Some countries have repositories which are specific to certain taxa, such as birds or cetaceans. In the UK, Record Pool (WWW10) is a collaboration between the Amphibian and Reptile Conservation Trust (ARC Trust) and the Amphibian and Reptile Group UK (ARGUK) which focuses on collecting herpetofauna data. The portal is for both public and research project records of all of the UK's herpetofauna, including the common lizard. Records can be accessed by the general public and scientific community for analysis, apart from vulnerable species such as sand lizards (*Lacerta agilis*) and adders (*Vipera berus*). In Ireland, the National Biodiversity Data Centre (NBDC) collates records on all species, including herpetofauna.

Only a handful of surveys have been conducted on the distribution of common lizards in Ireland despite its status as Ireland's only native terrestrial reptile. Crichton (1974) and Ní Lamhna (1979) were two early studies, while Marnell (2002) examined >250 records submitted to the Irish Wildlife Trust (IWT) and Ulster Wildlife Trust between 1990 and 2002. These early studies showed that the species is widespread, but clusters of records were around areas such as the Wicklow mountains and the south-east, suggesting a bias in records towards areas popular with recreational activities (Figure 2.11). Marnell (2002) also commented on the presence of lizards on a number of islands including Clare Island, Cape Clear, Sherkin and Dursey.

In 2007, the IWT published a report (Meehan, 2007) which examined 219 sightings from 2006 and 2007, largely submitted by the public. Potential for recorder bias was again seen in this report with 90% of sightings occurring in coastal counties. A more recent study, Farren *et al*. (2010), looked at the distribution of the species in Northern Ireland and found populations to be very isolated due to the unfavorability of landscape which only had fragmented habitat pockets which were suitable for *Z. vivipara*.

The present study used a combination of survey fieldwork methods, records submitted to the NBDC as well as citizen science records submitted to me. The term 'citizen science' was coined in 1979 in a paper published in New Scientist (Oberg, 1979) and can be defined as the participation and engagement of non-scientists in the gathering or analysis of data. The method is now becoming a frequent element in research projects, for example, ranging from monitoring of plastic waste (WWW11), identifying celestial bodies (Kuchner *et al.*, 2017) to the conservation of our flora and fauna (Ballard *et al*., 2017).

Ireland has a long history of citizen science. From early monastic record collections to the great scientific era following the establishment of the first Irish university at Trinity College, and to present day organisations such as the National Biodiversity Data Centre (Roche *et al*., 2021). Citizen science records are increasingly important, especially in more inaccessible sites such as gardens attached to private residences or remote areas (Fraisl *et al*., 2022). Research on the pros and cons of citizen science is progressively being published, including the influence it has on policy, community relations, education, and the well-being of participants (Adler *et al*., 2020; Roche *et al*., 2021).

The National Biodiversity Data Centre (henceforth referred to as NBDC), based in County Waterford is one was Ireland's largest repository of flora and fauna records. Established by the Heritage Council in 2007, the centre is home to many historic datasets, from a variety of surveys across the island, in additional to large numbers of individual sightings from members of the public. As such, their datasets are invaluable for assessing the distribution and other aspects of many species of plants and animals in Ireland. They currently hold ~ 6 million submissions (21st December 2022). As well as collecting data on many native species, the NBDC also plays a vital role in the monitoring of new and invasive species to Ireland.

The other source of data was a citizen science campaign which was specifically designed and created by me to gather common lizard sights for this research – "Iveragh Lizards".

This current research aimed to be the most comprehensive work into the distribution of common lizards in Ireland to date. The main objectives were to use records from the NBDC, to form a picture of the national distribution of common lizards in Ireland. A more regional investigation looked at the Iveragh Peninsula and records gathered via the Iveragh Lizards citizen science program with the LIVE Project (WWW12). Comparing the national and regional studies helped to identify spatial biases or potential reasons for areas with no lizard records. The 2016 census showed that 40% of the Irish human population live within 5km of the coast (WWW13) so further analysis examined what influence this figure may have on the distribution of records. Phenological data, such as peak times of year for sightings or first and last observations of the year, was also gathered to examine any patterns between the distribution of records and seasonal activities of both lizards and humans. Knowing where common lizards are recorded in Ireland, and indeed where they are absent, is key to informing further research on the species such as habitat availability or population dynamics.

Methods

Records from National Biodiversity Data Centre

Records for the common lizard in Ireland were sourced from the NBDC archives. Of the 1,191 records available, one was disregarded due to a discrepancy between site name and GPS location. Records dated from September 1st 1902 to September 10th 2021 were used (Figure 2.1, accessed July 7th, 2022). These comprised of four open access datasets entitled:

- Reptiles and Amphibians Atlas, 1902 – 1978, 245 records.
- Ireland's Bioblitz, 2011 – Present, 7 records.
- Community Foundation for Ireland Records, 2020 – Present, 1 record.
- Amphibians and Reptiles of Ireland, 2004 – Present, (which holds all records submitted to the NBDC individually by observers), 938.

Information from the datasets included location and date of sighting plus the occasional note on the encounter but no specific information on habitat (See Figure App.4 NBDC sub form in Appendix). Quantitative analyses were performed using ArcGIS Version 10.6 and Excel.

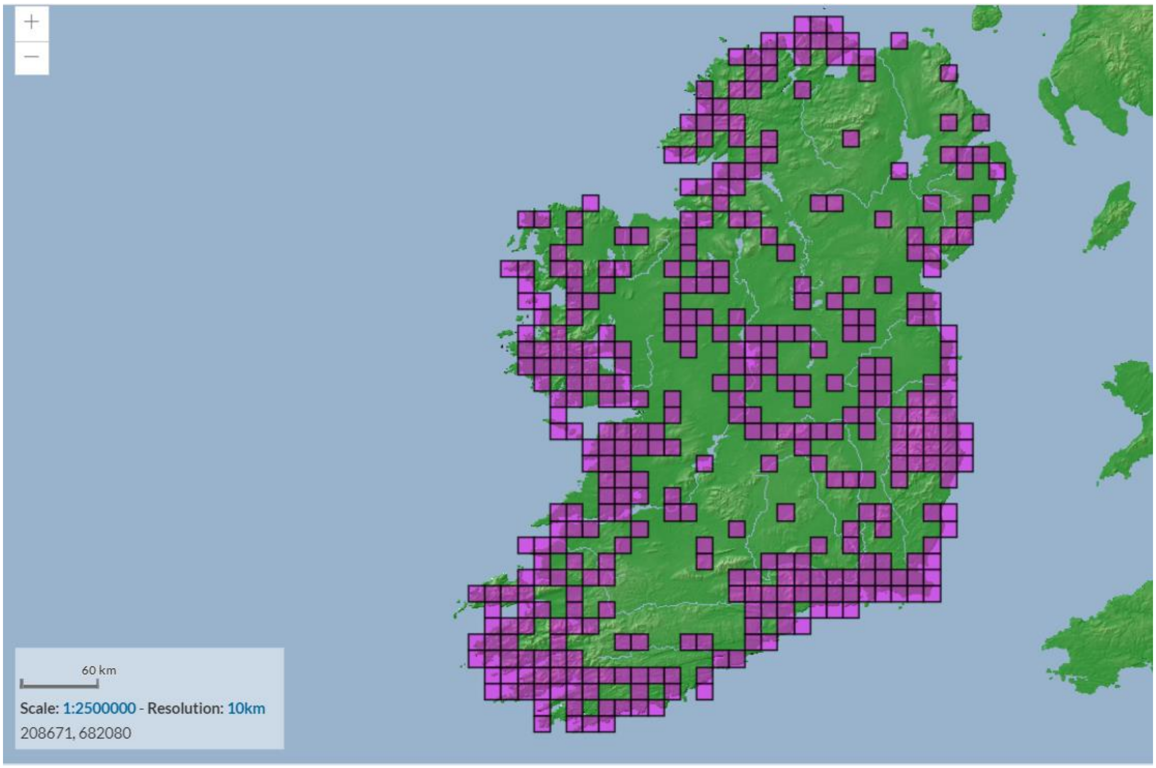


Figure 2.1 – The 'live map' view of records for *Zootoca vivipara* from the NBDC website (accessed July 7th 2022). Each purple box represents a $10km^2$ area.

Records from Iveragh Lizards

Part funded by the Ireland Wales co-operation programme, the LIVE Project (Llŷn Iveragh Ecomuseums) was established on the Iveragh Peninsula, County Kerry, in 2020. The project aims included promotion of sustainable, regenerative ecotourism by highlighting the natural capital of the coastal communities around the region. To do this, many unique aspects of the culture, heritage and wildlife of the area were researched, and public outreach initiatives were undertaken. A number of charismatic animal species were highlighted, and while working on this project, I conducted research on the common lizard in the region.

In May 2021, via the LIVE Project, the author made an appeal for records of common lizard sightings to be submitted from the public to 'Iveragh Lizards'. Residents of the Iveragh Peninsula, along with visitors, were specifically targeted. However, due to a wider audience on social media, print media and radio coverage, records from all over Ireland were anticipated. While the main aim of the public records was to gather data on distribution and habitat preference, an additional aim was to engage the participants in their local biodiversity. Ireland's only native lizard was a perfect species to feature as they are unheard of to many, unseen by most, and very little research has been conducted on their populations in Ireland.

Records were gathered from May 2021 to December 2022. Public records were submitted via ArcGIS Survey 123 V3.15 and participants were asked to complete a form including information on location, a selection of habitat options to choose from, a photo submission link, and an open text box for comments or additional information (Figure App.5 in Appendix). Participants were also advised via the portal that their records would be transferred to the NBDC on completion of the Iveragh Lizards study.

Public Engagement

To maximise the success of the Iveragh Lizards citizen science campaign, several resources were created before the launch date. These resources were housed on the project website and were free to access and download by members of the public. Resources had a variety of formats to make them as accessible as possible including audio versions of readable materials and an educational video in lieu of in person visits to schools (hindered due to Covid-19 restrictions). A full list of resources can be seen in Table 2.1. Resources provided information on the species, tips on how to spot them, along with best practice regarding responsible behaviour around wildlife. Most importantly, a resource was created to give both visual and descriptive guidance on how to differentiate a common lizard from a smooth newt, the only confusion species in Ireland.

Social media, print media, along with both local and national radio were all methods of promoting Iveragh Lizards to the public. In addition, eye-catching 'wanted' posters (Figure 2.2) were created, in both Irish and English, to encourage members of the Iveragh Gaeltacht communities to participate, and these were distributed following Covid 19 restriction guidelines. All promotional material provided participants with information on the species, contact information for the project, and a weblink or QR code via which to submit their sightings. A full list of public engagement work can be found in Table 2.1.

Figure 2.2 – A4 size 'Wanted posters' were displayed across Iveragh to highlight the study and were in available in both Irish and English to engage members of the Gaeltacht community.

Table 2.1 – List of resources and types of public engagement activities which the author created to help generate common lizard sightings for 'Iveragh Lizards'.

Resource/Engagement	Type	Outlet
Common lizard factsheet	Downloadable PDF	www.ecomuseumlive.eu
Tips for spotting lizards	Downloadable PDF	www.ecomuseumlive.eu
Is it a lizard or a newt	Downloadable PDF	www.ecomuseumlive.eu
Common lizard activity sheets	Downloadable PDF	www.ecomuseumlive.eu
My common lizard story	Blog & audio version	www.ecomuseumlive.eu
Common lizard educational video	Video	www.ecomuseumlive.eu & Youtube
Press release	Email/PDF	N/a
Common lizard update webinar	Video	www.ecomuseumlive.eu & Youtube
Community lizard gallery	Image gallery	www.ecomuseumlive.eu
Social media posts	Online posts	Twitter, Instagram & Facebook
Kerry Today	Radio interview	Kerry Radio
Mooney Goes Wild	Radio interview	RTÉ Radio 1
Newspaper promotion	Interview (x2)	Kerry's Eye Newspaper
Newspaper promotion	Common lizard article	Kerryman Newspaper
Local newsletter promotion	Article & press release	Sneem Newsletter
Local newsletter promotion	Common lizard article	West Kerry Live Newsletter
Local newsletter promotion	Advert	Skellig Coast Newsletter
Wanted campaign	Posters	Displayed in various locations

Results

National Records from NBDC

A literature review examined previous distribution maps created for the common lizard in Ireland. The map of 245 records from Ní Lamhna (1979) can be seen in Figure 2.3 next to the map from Marnell (2002), which contained >250 records submitted to an Irish Wildlife Trust campaign. While Ní Lamhna used a grid style point system and Marnell a more accurate location point system, comparisons can still be made in the distribution between the two studies with both showing clusters in the east and southeast of the country.

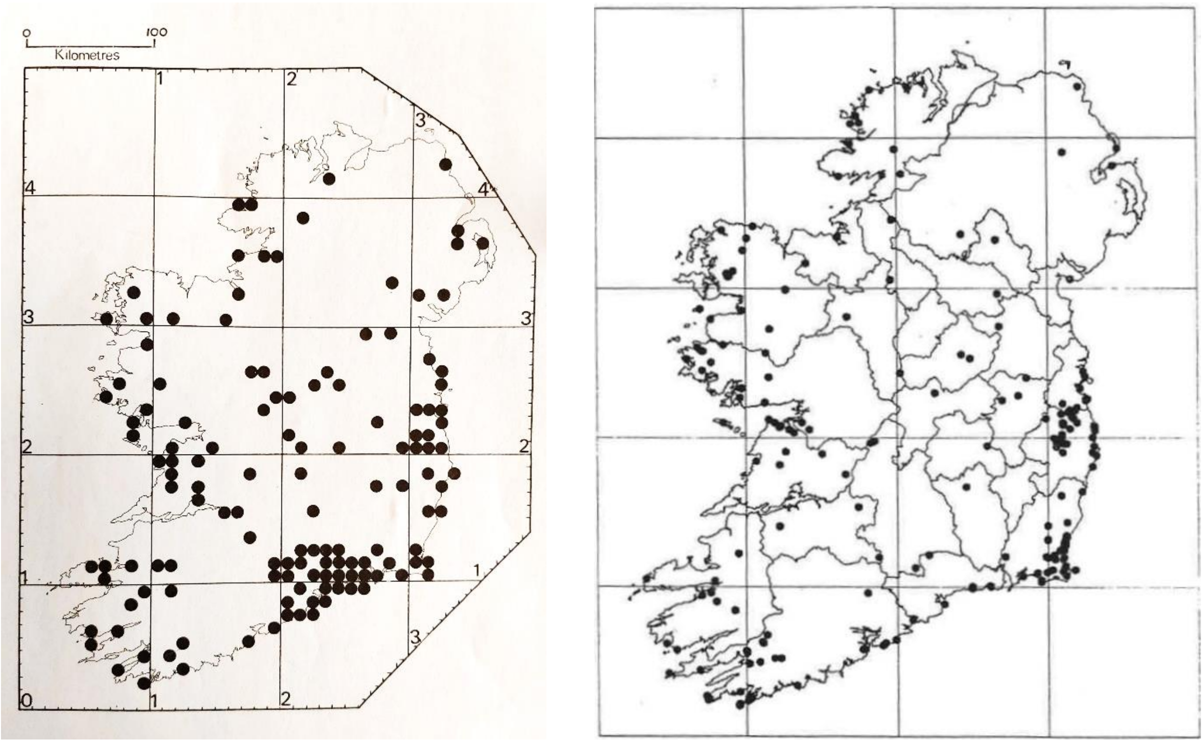


Figure 2.3 – Common lizard distribution maps from Ní Lamhna (1979) left, and Marnell (2002) on the right.

As mentioned above, although the NBDC was only established in 2007, it currently stores common lizard records dating from 1902 to 2021. To assess the impact of the establishment of the NBDC on knowledge of the distribution of *Z. vivipara* in Ireland, a map of the 250 records prior to 2006 was created to compare with records from 2007 onwards - which totalled 941. Both are seen in Figure 2.4. Some of the clusters from the previous studies by Ní Lamhna

(1979) and Marnell (2002) are again to be seen but are more pronounced. The trend for coastal areas to have more records is seen in both the pre-2007 and post-2007 maps. The positive impact of the all-island of Ireland approach of the NBDC can be seen in the second map with some pre-2007 blanks in the northern part of the country being filled in.

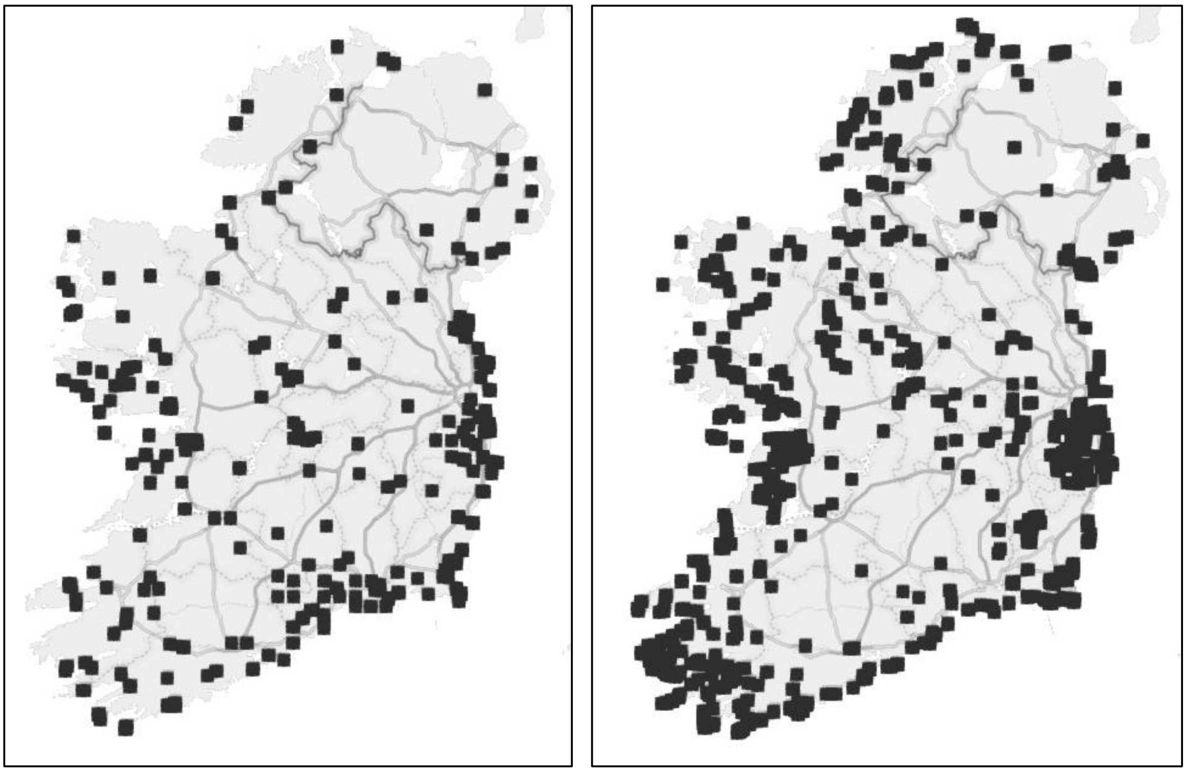


Figure 2.4 – Distribution of records on the NBDC database pre-dating the establishment of the national repository are seen on the left, 1902 to 2006. On the right, distribution of records from 2007 to 2021, when the NBDC was established. Maps: Bing, TomTom.

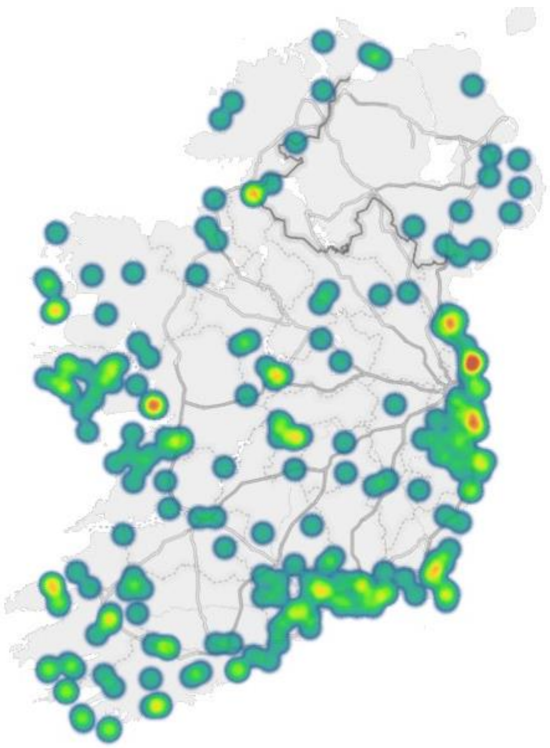


Figure 2.5 – A heatmap of all NBDC records for common lizards from 1902-2021. Map: Bing, TomTom.

Each of the all-Ireland distribution maps shown in Fig. 2.4 follow similar patterns. Clusters are found in popular recreational areas in the south-east of the country, such as the Wicklow mountains, Waterford and Wexford, and coastal areas in general. The heatmap in Figure 2.5 of all records from the NBDC repository shows this more clearly. Consistent 'blanks on the map', data gaps, are also apparent. Notable areas of no records are northwest Cork and into Limerick, east Galway, Tipperary, Kilkenny, and several other areas of the midlands.

The choropleth map in Figure 2.6 demonstrates that coastal counties have the majority of lizard records (85%). Kerry and Cork hold the highest totals with 168 and 158 records respectively. Despite their large size, Limerick, Tipperary and Kilkenny only account for 23 records between them. Derry, Monaghan and Fermanagh have just 13 records between them.

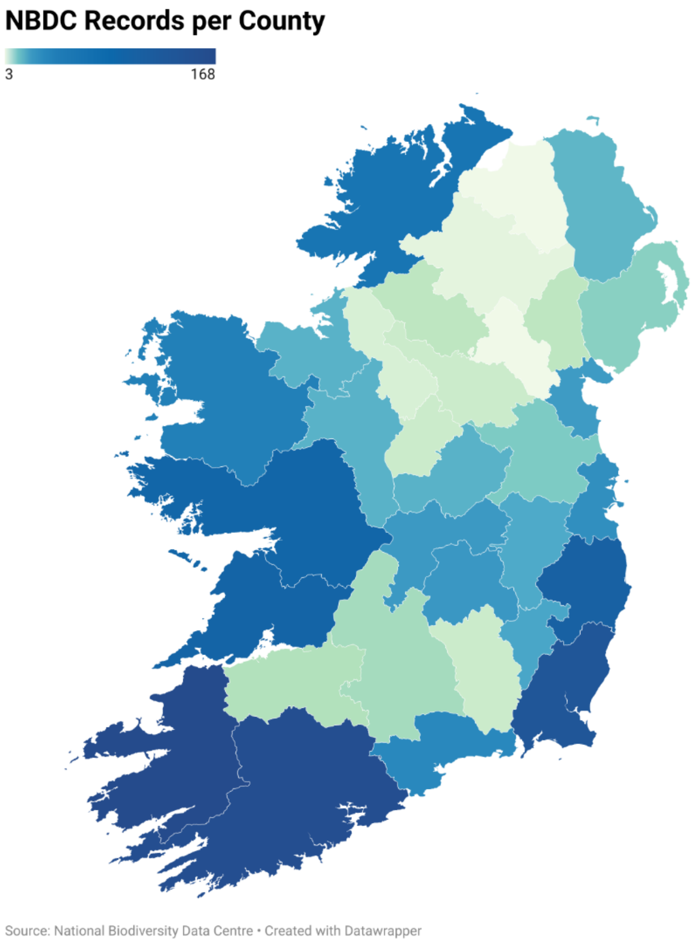


Figure 2.6 – A choropleth map showing the densities of records of lizards per county from NBDC data from 1902 to 2021.

While recorder bias may be one reason for clusters and also gaps on the distribution of lizards on a national scale, land use and habitat type may also a factor. Using the landscape map of Ireland created by Carlier *et al*. (2021), lizard records were thus overlaid to look for connections between lizard distribution and habitat type (Figure 2.7). Distribution blanks without lizard records correspond with landscape listed as: 2- Extensive Lowlands, which is comprised of 70.3% agricultural pastures; 6 – Intensified Lowlands, which is comprised of 72.9% agricultural pastures; and 8 – Semi-intensified Lowlands, which is comprised of 63.9% agricultural pastures (Carlier *et al*., 2021).

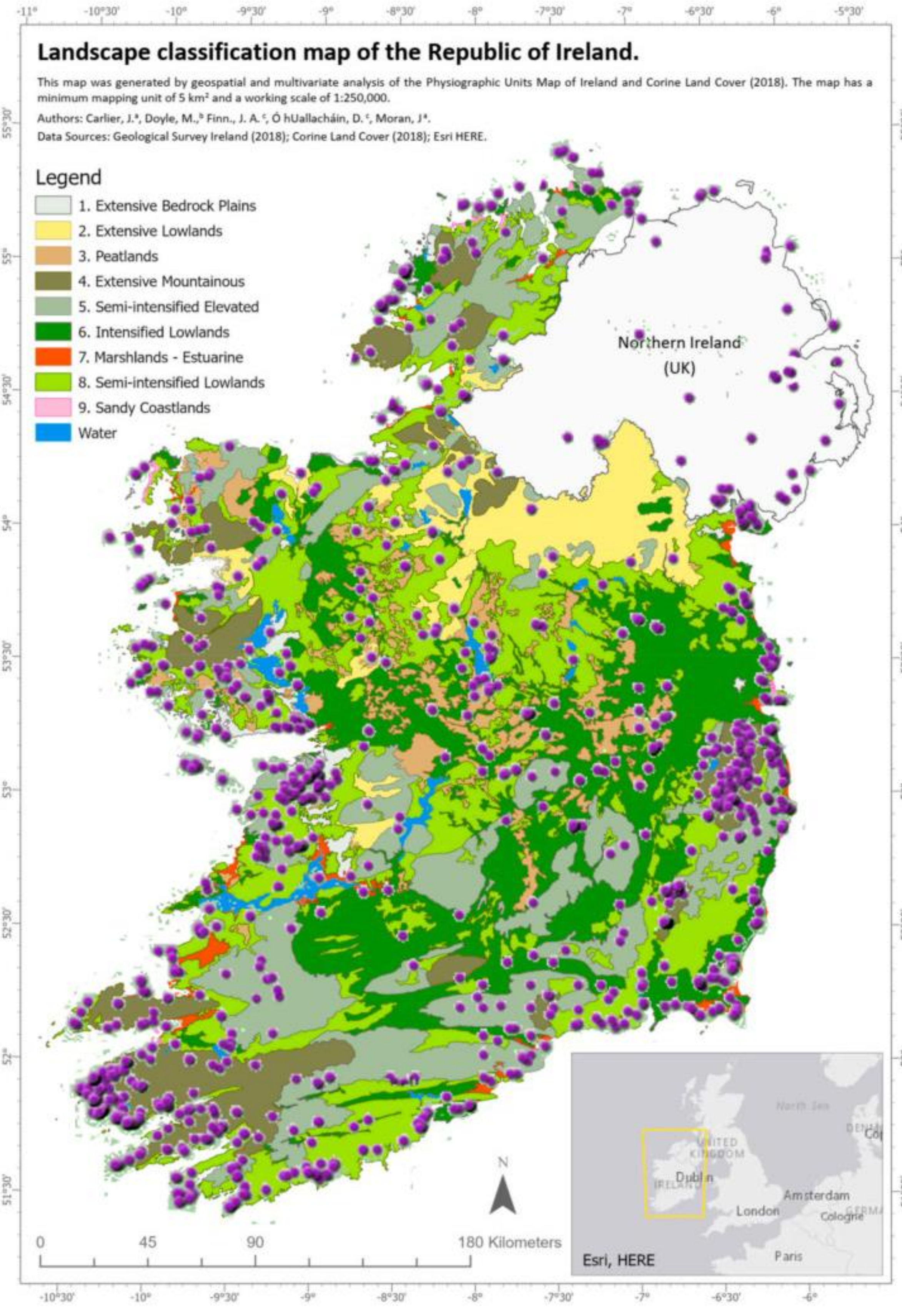


Figure 2.7 – A landscape map of Ireland from Carlier *et al.*, (2021) combined with the distribution of common lizards in Ireland from 1902 – 2020.

Regional Records from Iveragh Lizards

The Iveragh Lizards citizen science campaign received 102 submissions, of which 68 were for the Iveragh penisula (Figure 2.8), while 34 were from elsewhere in the country (Figure 2.9). Of these 102, 87 were verified by an image of the lizard observed, by the description of the observation, or by the expertise of the recorder being known to the author. The remainder were excluded from the study due to having no method of verification or the observer stated that they were unsure if it was a lizard or a newt that they had seen. Figure 2.8 shows that records from Iveragh were clustered to coastal areas with few records occurring from the central, inland areas. Figure 2.9 again shows a pattern for records coming from coastal areas elsewhere in Ireland outisde of the Iveragh peninsula focus area.

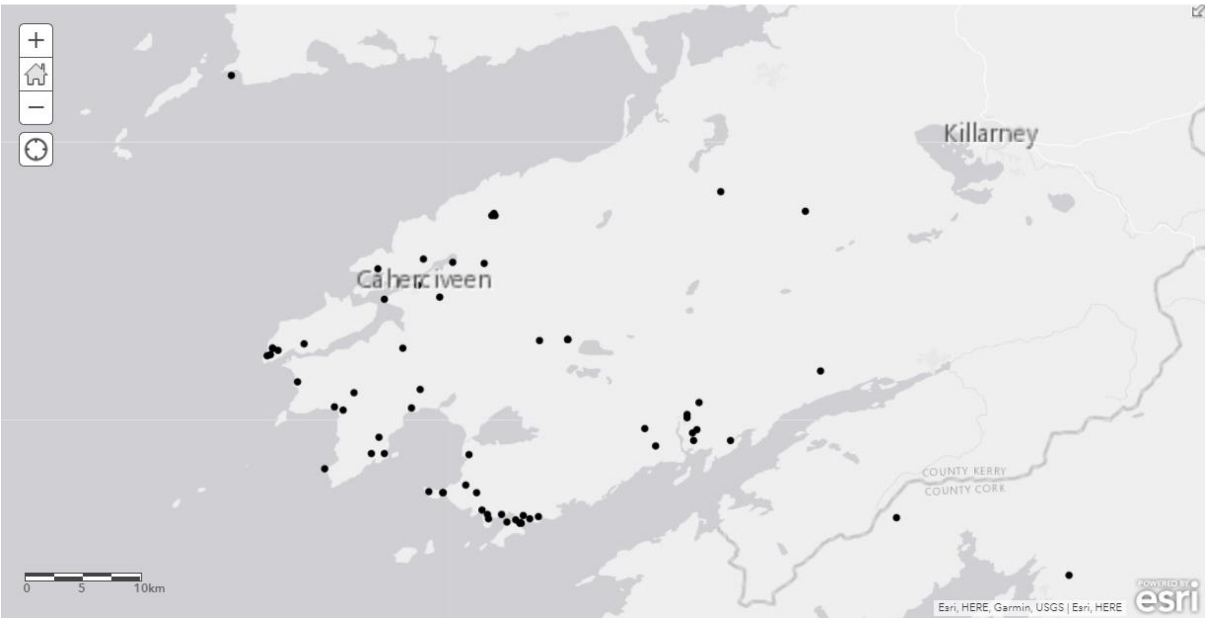


Figure 2.8 – Distrbution of the 68 submissions to the Iveragh Lizards portal from the focus study area of the Iveragh Peninsula, County Kerry, dating from 2021-2022.

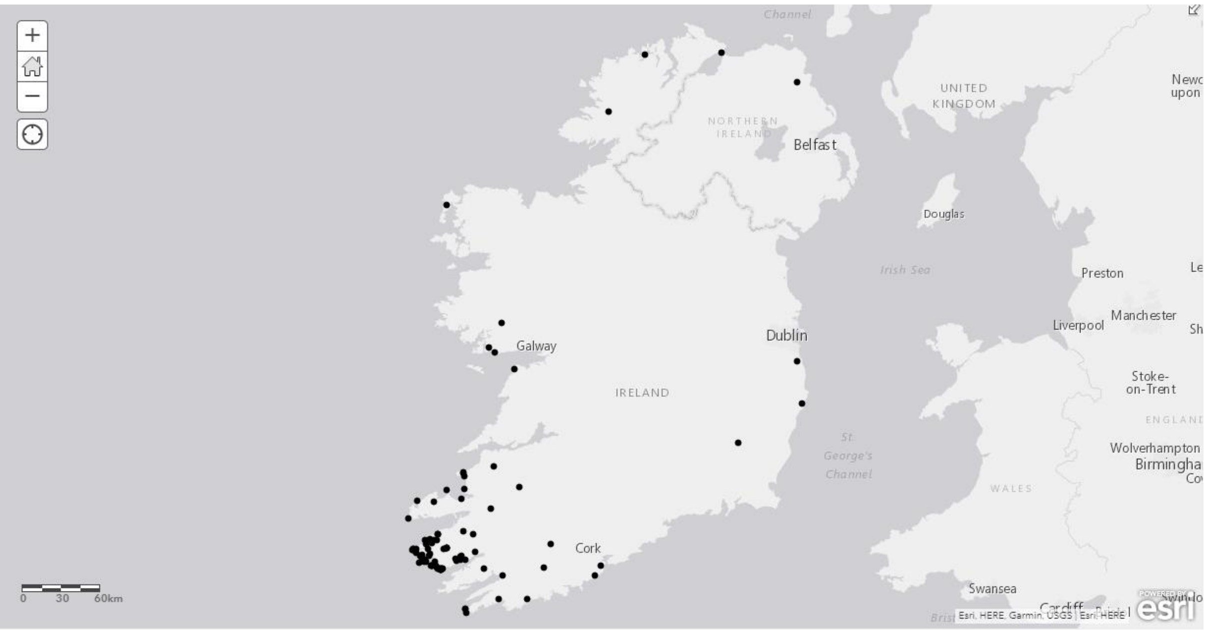


Figure 2.9 – National distribution of the 102 submissions to the Iveragh Lizards portal years, dating from 2021 to 2022.

Heatmaps seen in Figure 2.10 again highlight clusters for records of common lizards from areas popular for recreation, accessible to people, and close to urban centres. The coastal trend is also prevalent. The second heat map seen in Figure 2.11 shows the walking and biking trails of the region overlaid with the lizard records. While multiple factors are likely at play, it does emphasise that accessibility in certain areas may influence the number of records submitted.

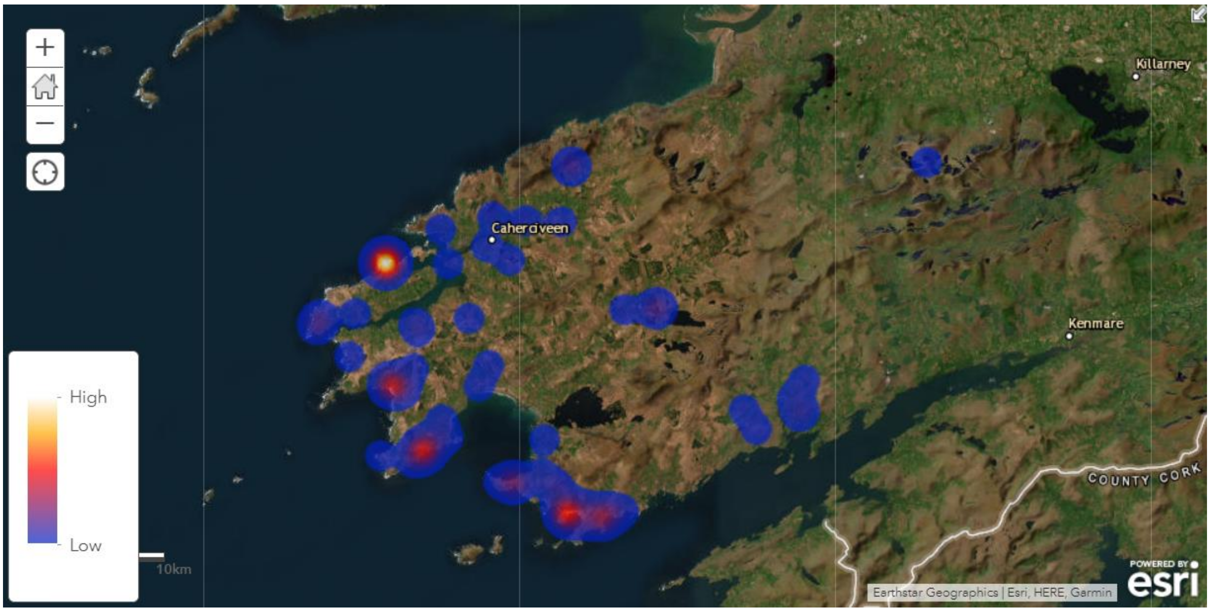


Figure 2.10 – A heatmap of the 68 submissions to the Iveragh Lizards portal from the focus study area of the Iveragh Peninsula, County Kerry, dating from 2021-2022.

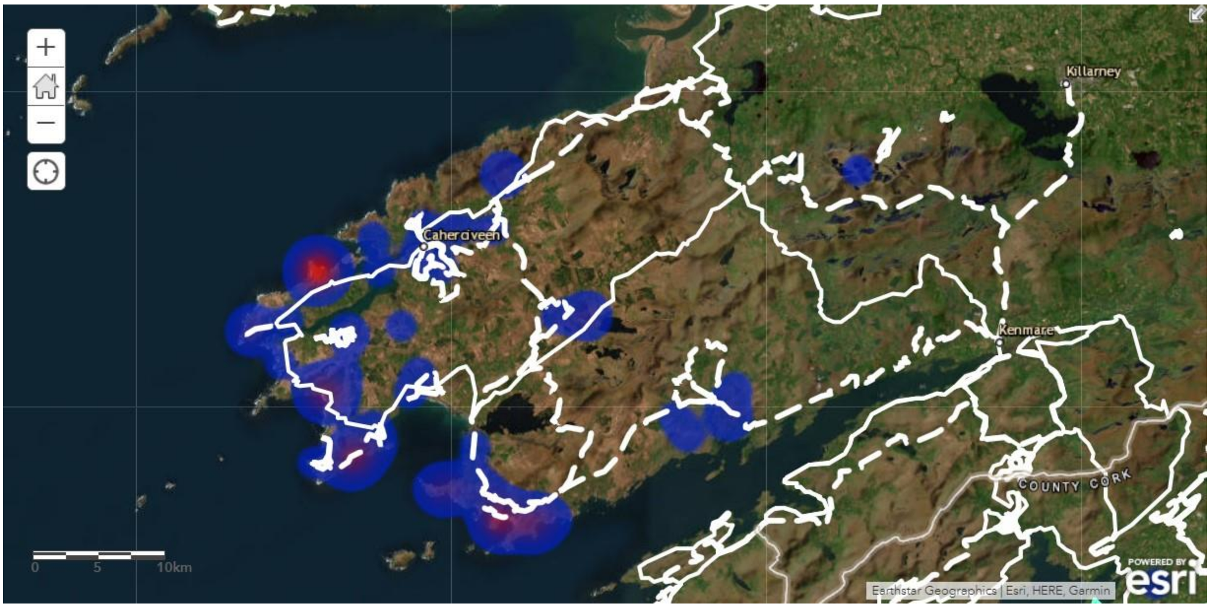


Figure 2.11 – A heatmap of lizard records from the Iveragh Peninsula overlayed with walking and cycling routes provided by Sport Ireland.

Using buffer zones created in ArcGIS version 10.6, Figure 2.12 highlights the distance from the coast where records occurred on Iveragh. The study area is encircled in red. The brown inland zone is more than 5km from the coasts and only accounted for 3.25% of records. Outwards from that, the blue and green zones combined covers the 5km range inland from the coast – the zone in which the CSO reports that 40% of the total Irish population inhabit – and this accounts for the remaining 96.75% of records. To emphasise the coastal bias for submitted records further, a 1km buffer from the coast is shown in green. This narrow strip accounts for 81.3% of all records in the study area.

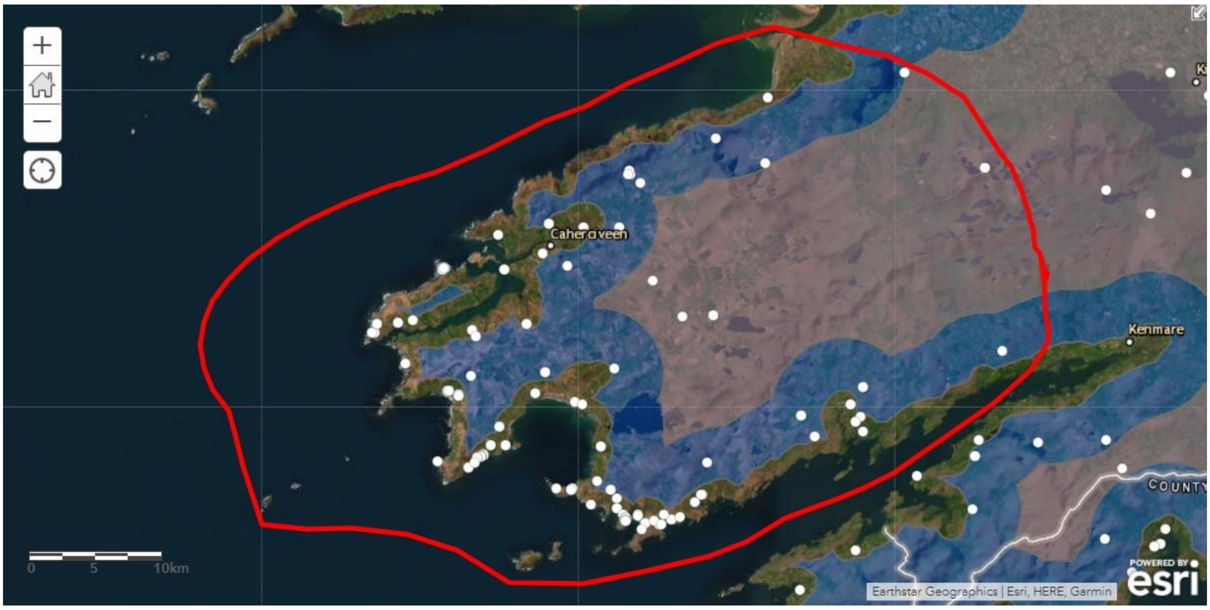


Figure 2.12 – Encircled in red is the Iveragh Peninsula study area. Buffer zones measure distance from the coast. The green buffer area is within 1km of the coast. The blue buffer zone combined with the green, extends to 5km from the coast. The brown zone is greater than 5km from the coast.

Phenology

The NBDC lists the earliest recording in a calendar year of the common lizard being sighted as January 30th (2019), in north-east of Waterville, County Kerry. The latest record on the NBDC shows a lizard being observed on December 22nd (2011), near Abbeyfeale, County Limerick.

The earliest record of neonate lizards was reported to Iveragh Lizards on the 15th July 2022 by citizen scientists, when two neonates were observed basking in Hog's Head, County Kerry. No NBDC records specified neonate observations.

Using data from the NBDC, 943 records dated from 2007 to 2021 were analysed for seasonal activity (Figure 2.13). Records prior to this date (before the NBDC was established) were omitted as they were skewed due to predominately being gathered, or accumulatively submitted to the NBDC, in September each year. Peak months for observations were April (146 records) and August (221 records).

Of the 88 verified records submitted to Iveragh Lizards, April (17 records) and July (33 records) were the peak months for sightings (Figure 2.14).

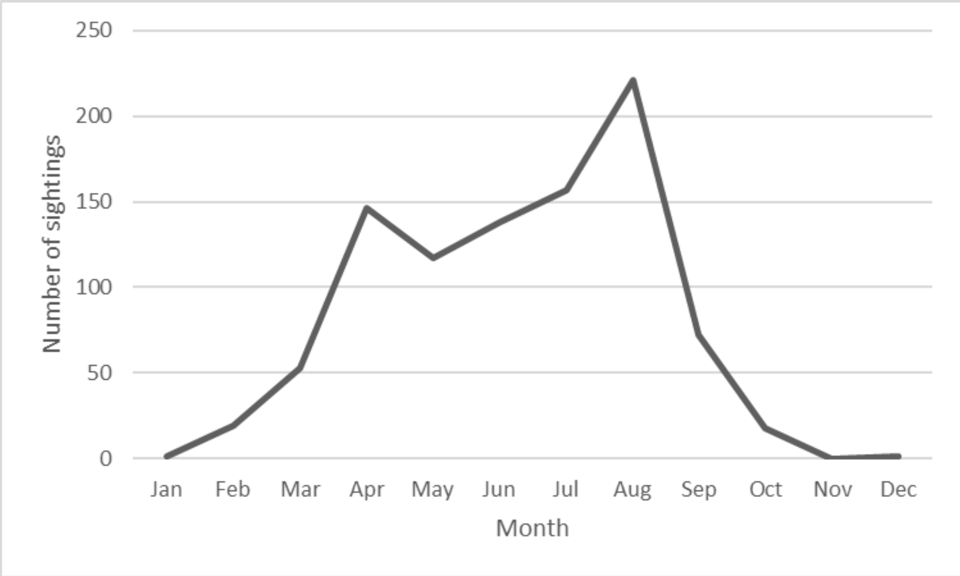


Figure 2.13 - Monthly breakdown of 943 lizard records from the NBDC, dated between 2006-2021.

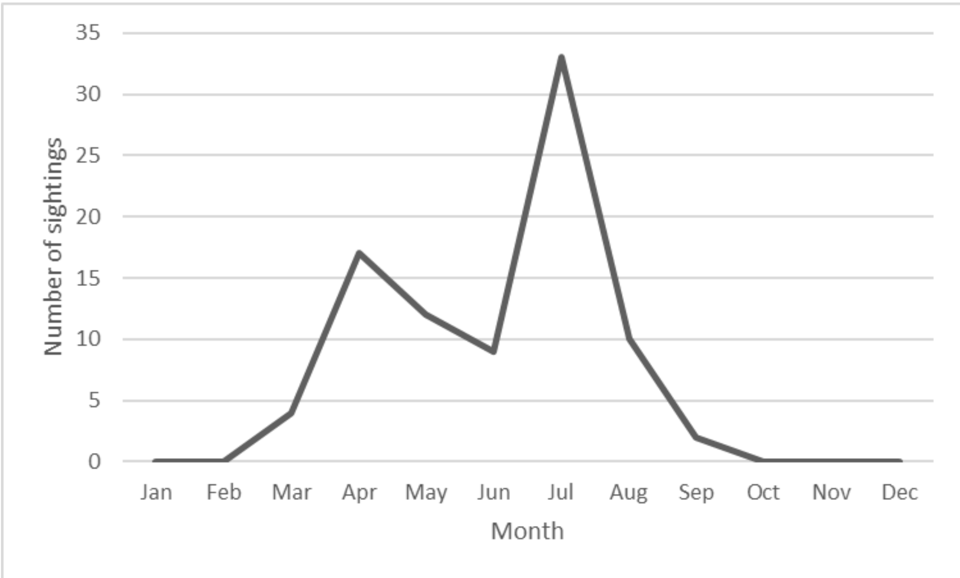


Figure 2.14 – The number of lizard sightings per month from submissions to the Iveragh Lizards citizen science portal from 2021 to 2022.

Time of day is not a prerequisite for NBDC records so only Iveragh Lizards sightings were analysed for Figure 2.15. Peak hours for lizard sightings were 11:00 (18 records) and 14:00 (21 records).

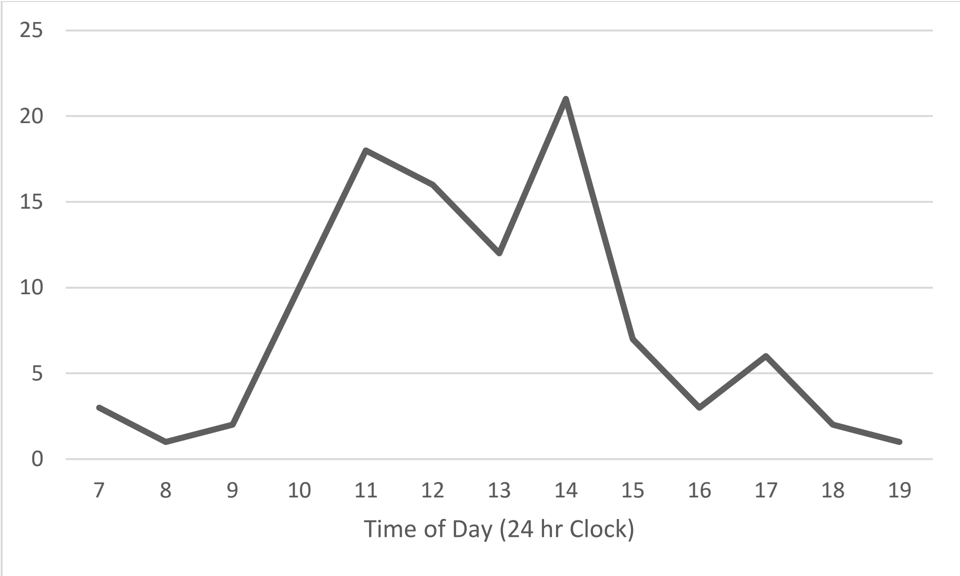


Figure 2.15 – The time of day at which common lizard sightings occurred from submissions to the Iveragh Lizards citizen science portal, dating from 2021 to 2022.

Discussion

Marnell (2002) pointed at the possibility of bias in the distribution of common lizard sightings in Ireland, with records occurring largely from areas where people frequent. This is a recognised risk with citizen science data and many studies bolster their work by including data collected by scientists (Bird *et al.*, 2014). A potential reason for spatial bias with records in Ireland is due to the figure from the Central Statistics Office (CSO), revealing that 40% of the Irish population (1.9 million) live with 5km of the coast while 63.65% of the Irish population live in urban areas (WWW14). Despite their large land area, counties Limerick, Tipperary and Kilkenny only account for 23 records between them. Counties Derry, Monaghan and Fermanagh have just 13 records between them., but this is possibly due to sightings from Northern Ireland being submitted to UK repositories rather than the NBDC. While counties are arbitrary boundaries in terms of the distribution of a species, they are useful in knowing which regions may need to be approached to conduct more focused studies to investigate these areas where data is absent.

The information provided with the NBDC datasets suggest that the records from the NBDC largely come from opportunistic encounters, rather than methodical surveys. This results in the maps produced from these datasets showing an incomplete picture of the distribution of lizards in Ireland. However, given the large spread of time (1902 to 2021), already covered by the NBDC records, the accuracy of the distribution may be enhanced by new records being added over time. The clusters seen in both the national and the focus study area on Iveragh, may, again, be down to recorder bias, but habitat fragmentation is another possibility. These 'hotspots' for lizard records are potentially home to habitat suitable for lizards to persist while blank areas may have no suitable habitat. Temperature is another possible factor. For example, the 30 year mean temperature for the inland Met Éireann station in Birr, County Offaly, being 9.8˚C while the coastal Valentia weather station recorded a warmer 30 year mean temperature of 10.9˚C (WWW15).

The lizard distribution overlaid with the landscape map of Ireland created by Carlier *et al* (2021), shows that some of the 'blank' areas with no lizard records correspond with areas of agricultural pastures, especially in the midlands (Figure 2.7). Further analysis shows that these pastures are also present in areas where clusters of records are seen, such as the southern coastline of Ireland and in the southeast. The reason for this is perhaps the intensity and size of the pastures. Common lizards have been recorded previously in agricultural grasslands in

Ireland, but only in very small numbers (Meehan, 2007; Farren *et al*., 2010). In other parts of their range, *Z. vivipara* which were studied in this agricultural pasture habitat encountered high predation rates and suffered from high stress-related parasite loads (Ekner *et al*., 2008; Majláthová *et al*., 2010).

This current research study has identified that there are certain micro-habitats which lizards tend to prefer (see Chapter 3, Habitats). When large monoculture pastures are created, microhabitats such as old stone walls, earth banks, and hedgerow boundaries are often removed, thereby exposing common lizards to predators. Where agricultural pastures are on a smaller scale, these microhabitats are often left intact to mark land boundaries between owners or to create shelters for livestock (Atkin-Willoughby *et al*., 2022). This type of less intensive agricultural land is often more prevalent on coastal tracts of land (*pers. obs.)*. In some cases, the strip of land between the coast and agricultural pastures is frequently left as a scrub boundary, often allowing for a public access walking trail. These largely undisturbed areas experience very little land management, ideal for lizard lifecycles (WWW16).

Coastal areas are also valued for dwellings and there are obvious risks of habitat removal or modification to allow for construction (Cooper & McKenna, 2008; Sánchez-Arcilla *et al*., 2016). However, a potential benefit might be the coastal dwellings come with more space between them compared to the densities of urban dwellings and therefore more chance of land being left as garden or scrub habitat. Boundaries between these coastal dwellings have the potential to be the microhabitats which suit lizards, such as vegetated banks or old stone walls.

But does all these mean common lizards are a predominately coastal species? Figure 2.16 highlights that the annual mean sunshine hours for coastal areas are higher than inland areas in Ireland using data gathered by Met Éireann. This is as a result of coastal areas accumulating less cloud cover compared to inland and upland areas due to convection (WWW17). Sunshine hours is potentially an important factor in the distribution of any ectotherm species, such as *Z. vivipara* (Van Damme *et al*., 1987; Inns 2009). The combination of coastal sunshine and coastal recreation by humans during fine weather perhaps increases the chances of people spotting and reporting lizard sightings. However, sunshine cannot be the only factor at play in distribution as Figure 2.16 shows a decrease in sunshine hours moving from east to west across Ireland, but this pattern is not reflected in the distribution of maps seen in Figure 2.4.

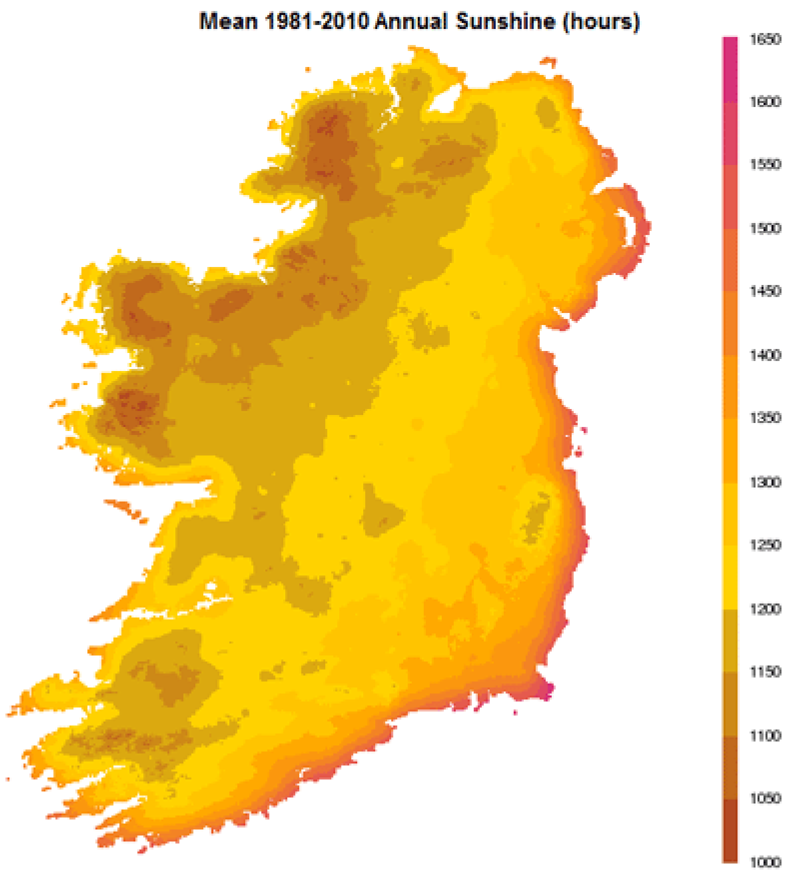


Figure 2.16 – A map showing the mean annual sunshine in hours from data gathered by Met Éireann between 1981 and 2010. (WWW17)

The milder ice-free coastal areas also provide an ideal climate for common lizards; however, they are known to survive freezing temperatures and to inhabit altitudes up to 3,000m (Berman *et al.*, 2016; as read in Gvoždík, 2002). It is more likely that there are a number of factors influencing the distribution of common lizards in Ireland including that opportunistic sightings of common lizards submitted to the NBDC and to the Iveragh Lizards survey by members of the public peaked during the summer months. The summer is a time when lizards are active and when humans head to the coast for their holidays. The April peak in lizard records on both the national scale (Figure 2.13) and regional scale (Figure 2.14) is likely explained by lizards emerging from hibernation for annual mating (Beebee & Griffith, 2000) coinciding with Easter school holidays, the July and August peaks are potentially linked to human recreation. While more data is required from focused studies to prove this, the heatmap of lizard records overlaid with recreational walking trails (Figure 2.11) would support this hypothesis.

Records from the midlands are sparse and clustered around areas which are accessible to recreational activities in what is considered to be suitable habitat for *Z. vivipara*. The sparse midlands records are likely due to lower human population, large swathes of agricultural pastures being unsuitable habitats for lizards, and perhaps fewer outdoor recreational numbers of people during summer months compared to coastal regions.

These trends can all be seen on the regional study maps of the Iveragh Peninsula. Lizard records are most frequent in coastal areas and in hotspots which are summer holiday destinations, such as Derrynane and Ballinskelligs. These are also areas with higher densities of population, and thus activity, for the region. The mountainous landscape of the central Iveragh region is perhaps a reason for fewer records from inland areas. While parts of the inland region are popular for recreational activities, Atlantic blanket bog and scree slopes render much of the area inaccessible to humans. Agriculture is less intensive on Iveragh with banks and stone walls dividing fields into smaller sections which are potential lizard microhabitats. The sparse human population here and accessibility issues are likely the reason for lizards being under-recorded and records that are present occurring close to dwellings or walking trails.

Conclusions

Since records began in 1902, the number of records of common lizards has steadily increased. However, the establishment of the NBDC in 2007 greatly increased the number of sightings of the species and aided in describing its distribution in Ireland. Given the blanks in the map are consistent over time, despite the increase in the number of records gathered, would suggest habitat unsuitability is a main reason for the absence of lizard records in some parts of its distribution. The species appears to be widespread but clusters of records in proximity to the coast show a spatial bias by recorders but perhaps this is also where lizards are present in higher numbers. The active season of common lizards coinciding with summer holiday recreation periods appears to have a strong influence on the distribution of records. Lizards are potentially present in more inaccessible areas where suitable habitat is present, something that only methodical scientific surveys can prove. Focused surveys for *Z. vivipara* in areas where no data is present is important to (i) identify if lizards are present/absent, (ii) explain if habitat type or recorder effort is the reason why lizards are present/absent from these areas, and (iii) establish if the temporal peaks in records occur due to increased lizard activity or increased human outdoor recreation. Furthermore, a population density study of *Z. vivipara* in coastal areas compared to inland areas is required to establish if lizard abundance is higher in coastal areas meaning there is a higher chance for people to encounter them here.

Chapter 3

Habitats of the common lizard (*Zootoca vivipara*) in Ireland

Abstract

Habitat loss and habitat fragmentation are major threats to biodiversity. Identifying what habitats species use and how they use them is a key factor in how best to maximise the benefits of conservation protocols. Often, protection is about large-scale habitats such as woodland or peatland, however, smaller ‘microhabitats’ within these large-scale habitats can often be overlooked. Using a combination of citizen science, artificial refugia and transect surveys in the field, this research aimed to identify microhabitats used by the common lizard, *Zootoca vivipara*, in Ireland. Results show that upland heath, old stone walls, and areas close to human locations, are important areas for this reptile. Reduced windspeeds ($P<0.05$) within microhabitats was identified and potentially provides increased thermoregulatory advantages for *Z. vivipara* within these spaces. Long-term studies are recommended to establish how *Z. vivipara* utilises these microhabitats, examining factors such as lizard population dynamics and prey abundance. Threats to these microhabitats needs to be quantified and a method for monitoring and conservation of these microhabitats needs to be established.

Introduction

Research from various parts of the geographical range of the common lizard, *Zootoca vivipara*, shows that they are found in a variety of habitats from lowlands and peatlands, to sub-boreal forests and mountains over 1000m (Strijbosch, 1988; Čeirāns, 2004; Chamaillé-Jammes *et al*., 2006; Cornetti *et al.*, 2014). They are vulnerable to local extinctions or displacement due to habitat modification or habitat loss (Strijbosch, 1995; McInerny, 2016; Doherty *et al.*, 2020) and the predator stresses which may come with such changes can increase parasite loads (Wu *et al*., 2022). Furthermore, environmental stresses from the effects of climate change can also have detrimental effects on fitness including reproduction, growth, and survival rates (Masó *et al*., 2019; Horreo *et al*., 2021).

Using data gathered from surveys conducted by the Irish Wildlife Trust (IWT), Ulster Wildlife Trust and sightings submitted in response to a newspaper advertisement, Marnell (2002), identified sand dunes and boglands as habitats the species occupied in Ireland. However, the study gathered just "*>250 records*" across the island of Ireland over a twelve-year period (1990-2002) and it is unclear what methods were used for the respondents to categorise and indicate in what habitat types they found the lizards.

The degradation of sand dune and bogland habitats was identified by a later Irish Wildlife Trust (IWT) report as a major threat to the Irish lizard population (Meehan, 2007). This, the most recent national survey of the species in Ireland, analysed the distribution and habitats of common lizards, based on 219 lizard sightings, from 2006 and 2007. The data for 2007 was solely from public submissions, with 90% of them coming from coastal counties. Peak lizard sightings occurred in July and many records came from habitats with high human traffic, such as rural gardens and walking trails – all of which indicates that the records may be slightly skewed to the time of year when people are outdoors more frequently and to areas which are visited more often. In their Northern Ireland study, Farren *et al.* (2010) also referred to the issues of habitat loss and fragmentation, resulting in many populations of common lizards being in small and isolated pockets of bog and heath, with coastal dune systems also being identified as important habitat.

The Irish Herpetological Society have been championing Irish reptiles and amphibians since 2009. The charity has been involved in educational outreach, conservation, and habitat restoration projects including those related to the common lizard. Two reports, for Fingal

County Council and Dublin City Council, focused on the Howth peninsula (Gandola, 2019) and North Bull Island (Gandola & Ennis, 2015). In Howth, old stone walls were cited as a favoured habitat for lizards along with heathland and cliff-top grasslands. Minimal management of vegetation was suggested to ensure the availability of basking spots and hibernation sites. Also, there are guidelines for the least disruptive times of the lizards' annual active season, between the 1st of March and 31st October, in which to carry out such works (Gandola, 2019). Disturbance by humans and dogs off lead were highlighted as risk factors for the lizards of North Bull Island, where the use of artificial refugia was suggested as a potential benefit for the population there (Gandola & Ennis, 2015).

A number of final year projects have been conducted by UCC students on the large common lizard population at Ballycotton, County Cork. O'Reilly (2013) classified the habitat types at the cliff walk site as being Dry Calcareous & Neutral Grassland using the Fossitt's habitat guide. The study showed a positive correlation between the increase in lizard sightings and the increase in bare rock within grass (*Lolium* and *Festuca* sp.) dominated habitat. O'Toole (2014) noted the drop-off in plant and invertebrate biodiversity when moving from the habitat of the cliff walk trail to the adjacent agricultural land. The study infers that this habitat change could reduce lizard numbers and suggested various statistical models for predicting lizard numbers in various habitat types. Lyne (2017) also focused on the Ballycotton population and recorded >120 individuals on a 1km transect of the cliff walk trail. It was suggested that the vegetation along the walking trail created a barrier against winds and formed a microclimate effect in which the lizard population appeared to thrive. This, plus aspect and minimal land management of the scenic walking trail, were contributing factors to explaining the large numbers of lizards seen at the site, in comparison to numbers seen elsewhere. The study also compared lizard dorsal colouration with habitat type but found no correlations between the two.

Certain environmental factors, such as relative humidity or temperature rates, are required by reptiles, such as *Z. vivipara*, to suit their physiological parameters (Guillon *et al*., 2014; Dupoué *et al*., 2018; Rozen-Rechels *et al*., 2020; Rutschmann *et al*., 2020). House *et al*., (1980) showed that *Z. vivipara* emerged earlier in the day than the larger *Lacerta agilis* (sand lizard, present in the UK but not Ireland) in a natural habitat enclosure. The research observed that *Z. vivipara* alternated basking and activity in short bouts and likely used the topography and vegetation within its microhabitat to maximise efficiency of daily activities such as feeding and thermoregulating (House *et al*., 1980). In addition, the amount of light reaching the ground level influences the distribution of *Z. vivipara* in certain habitats, such as forestry plantations in the UK, the species is restricted to ridges between blocks of trees (Dent & Spellerberg, 1987). Captive studies in France have shown that *Z. vivipara* dispersal distance is negatively affected by lack of vegetative cover, likely due to a fear of predation (Zajitschek *et al*., 2012).

At present, research on *Z. vivipara* in Ireland is limited to knowing the types of habitats in which they occur. Understanding why the species is present or absent in certain habitats, how they use the habitats in which they are found, and why certain habitats are unsuitable for the species in Ireland, is valuable information for their conservation here.

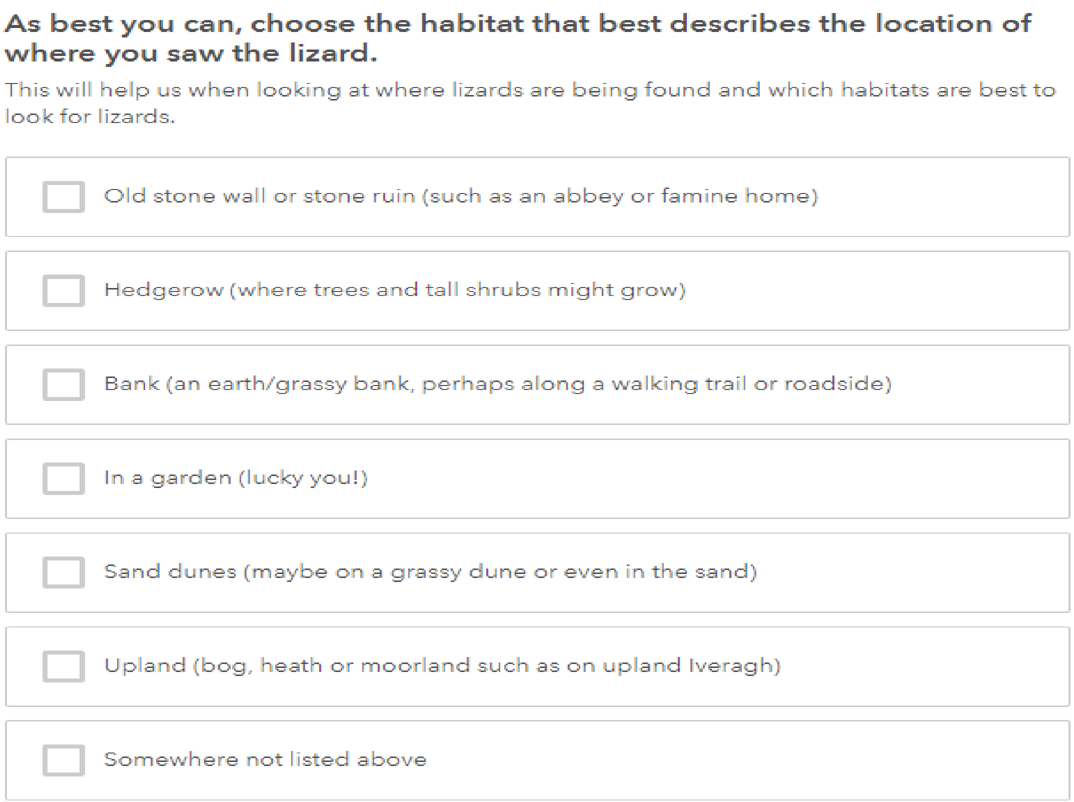
This current research established the Iveragh Lizards citizen science project (see Chapter 2 - Distribution, Methods, Page 34), to gain information about where and in which habitats common lizards were found on the Iveragh Peninsula, County Kerry, as well as engaging the public with a charismatic native species. This regional study provided broadscale information while the field study described in this Chapter focused on microhabitats within the landscape, to assess the possibilities of common lizards utilizing areas of microclimates within microhabitats. Evidence of climatic advantages, such as higher temperatures or lower wind speed, which may aid thermoregulation, was examined for in the microhabitats in which Irish common lizards occupy.

In other work, the distribution records for common lizard sightings in Ireland is skewed towards areas which people frequent, such as recreational hubs and walking trails (see Chapter 2 - Distribution, Page 41). Artificial reptile refugia tiles are commonly used in many wildlife studies as they can increase the number of sightings in certain habitats for smaller cryptic species such as *Z. vivipara* (Fish, 2016; Lettink & Cree, 2007; Cowan *et al*., 2021). This study utilised artificial refugia tiles along the study transects to increase the chance of lizard sightings.

Materials and Methods

Citizen Science

Participants of the Iveragh Lizards citizen science program were asked to report sightings of *Z. vivipara* and to choose from a list of six identified habitat types or add their own description of where they observed a lizard (Figure 3.1). This information plus any supplementary details provided in a free text box were then analysed for habitat occurrence. Out of the choice of 6 habitats that were offered to participants, multiple options could be chosen.


As best you can, choose the habitat that best describes the location of where you saw the lizard.

This will help us when looking at where lizards are being found and which habitats are best to look for lizards.

- [ ] Old stone wall or stone ruin (such as an abbey or famine home)
- [ ] Hedgerow (where trees and tall shrubs might grow)
- [ ] Bank (an earth/grassy bank, perhaps along a walking trail or roadside)
- [ ] In a garden (lucky you!)
- [ ] Sand dunes (maybe on a grassy dune or even in the sand)
- [ ] Upland (bog, heath or moorland such as on upland Iveragh)
- [ ] Somewhere not listed above

Figure 3.1 – The habitat options offered to participants when submitting a sighting to the Iveragh Lizards survey portal.

Field Survey using Artificial Refugia Tiles

A cryptic species, lizards can be difficult to see. To test the hypothesis that it is easier to see common lizards along the edges of habitat, such as walking trails, versus away from these edges, two line transects were established at three sites on Iveragh – one along a trail and a second was set back from the trail. In June 2022, corrugated bitumen tiles measuring 50cm x

50cm x 2.6mm (corrugation depth = 40mm) were placed in three field study sites, on the Iveragh Peninsula, to act as artificial refugia for common lizards. The three sites were Lisbawn (Cahersiveen), Rinneen (Waterville) and Abbey Island (Caherdaniel) (Figure 3.2). These three sites were chosen as lizards had previously been recorded in the area. Sites were also chosen for their security in terms of low risk of humans tampering with the study tiles and also where permission could be gained from landowners/managers to conduct the study. See below for details about each of the sites. Three other potential survey sites were excluded due to high human recreation activity (sand dunes in Derrynane), close proximity of road vehicles (rural road in Caherdaniel), and no access due to farm animals (Dohilla, Valentia Island).

A pair of transects were established at each field site and five refugia tiles were placed at 5-10m intervals depending on the size of the site with ten tiles distributed per site. The first transect followed a path or trail, which is the type of environment in which citizen science sightings often occur (*pers. obs.* and see Chapter 2, page 41). The second transect was set back from the trail where lizards may still occur but be more difficult to see due to access difficulties off-trail. Sites were surveyed for lizard presence/absence, both on natural substrates and on the visible top surface of the artificial refugia, at weekly intervals during July, August, and September 2022, on days which were deemed to be suitable for lizard activity (i.e., no rain and at least broken cloud sunshine). During these weekly surveys, refugia tiles were not lifted to check for lizard presence underneath due to the need to weigh down the tiles to prevent them from being blown away from their sites in the coastal Atlantic winds. Tile were approached slowly from a distance during lizard searches and great care was taken not to make noise while moving through vegetation.

To gain data on environmental conditions of lizard habitats and to record microclimate parameters, the sites were visited four times each during July and September 2020 (table – give dates). (a) Refugia tile surface temperature was measured using a handheld BluSmart non-contact infrared thermometer. (b) Wind-speed, (c) air temperature, and (d) humidity levels were recorded using a handheld JDC Skywatch Atmos weather station. During each visit, a single measurement (b, c and d) was taken at tile level to gain the data for lizard habitat level and repeated at 'air' level, a height of approximately 2m (the height of the weather station held aloft at arm's reach of the author), to gain the local measurements.

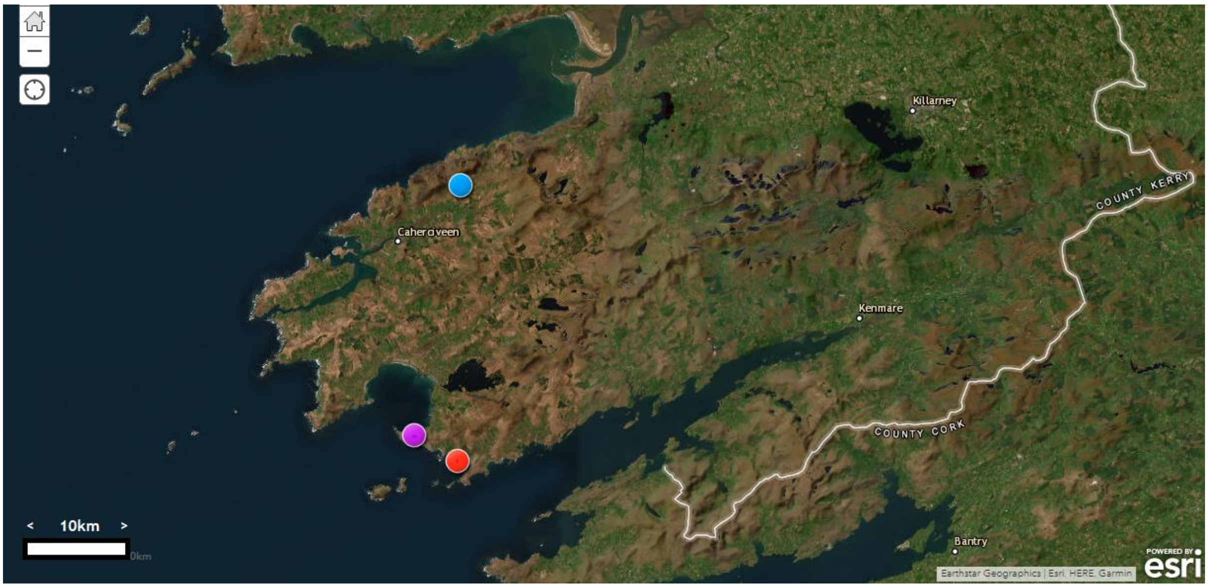


Figure 3.2 – The three study sites at which artificial reptile refugia tiles were established: 1 – Lisbawn (blue); 2 – Hog's Head (pink); 3 – Abbey Island (red).

Details of Artificial Refugia Study Sites:

Site 1 – Lisbawn, Cahersiveen, -51.994250, -10.138333.

This steep hillside farmland comprises of wet heath and is grazed by sheep and cattle (Figure 3.4). Common lizards had been seen in the area by colleagues but never by the landowners. The 'trail' transect (blue stars on solid line in Figure 3.3) followed a peat bank along the edge of a farm vehicle access road. Five tiles were placed at approximately 10m apart in south facing aspects at the edge of vegetation such as heather or gorse. Another five tiles were placed at approximately 10m intervals along the 'off-trail' transect (blue dots on broken line in Figure 3.3) which was set approximately 3m back and parallel to the 'trail' transect.

Figure 3.3 – The trail transect (blue stars) and parallel off-trail transect (blue dots) on the hillside at Lisbawn.

Figure 3.4– A refugia tile *in situ* in typical vegetation of the Lisbawn site.

Site 2 - Rinneen, Hog's Head, Waterville, 51.779123, -10.202562.

Common lizards had been seen in the area by both the author and the landowners. The 'trail' transect (pink stars on solid line in Figure 3.5) followed an old stone wall along a local access road popular with walkers (Figure 3.6). Five refugia tiles were placed in south facing aspects, approximately 10m apart and weighed down with stones to prevent them being blown away. Another five refugia tiles were placed approximately 10m apart on an 'off-trail' transect (pink dots on broken line in Figure 3.5). This followed a route through similar habitat but was away from the road/walking route used by locals and visitors.

Figure 3.5 – The trail transect (pink stars) and off-trail transect (pink dots) on the road and hillside at Hog's Head.

Figure 3.6 – A refugia tile *in situ* in vegetation typical of the Hog's Head site.

Site 3 – Abbey Island, Derrynane, Caherdaniel, 51.757864, -10.142878.

Lizards had been recorded around the Abbey ruins by the author. Five tiles were placed along a 'trail' transect (red stars on solid line in Figure 3.7) approximately 5m apart within the Abbey site along a trail frequented by visitors. Five more tiles were placed approximately 5m apart outside the Abbey site perimeter for an 'off-trail' transect (red dots on broken line in Figure 3.7). Permission was granted, with thanks, from local representatives from both Kerry County

Council (Abbey ruin site) and the OPW (Abbey Island) to establish the study at the site (Figure 3.8).

Figure 3.7 – The trail transect (red stars) and off-trail transect (red dots) in and around the Abbey ruin site on Abbey Island.

Figure 3.8 – A refugia tile *in situ* in typical vegetation of the Abbey Island site.

Results

Figure 3.9 and figure 3.10, below, illustrate typical lizard habitat found on Iveragh and how a proposed microhabitat may have its own microclimate. Vegetation or stones, may act as wind breaks or wind deflectors while exposed surfaces such as bare soil or stones are utilised as basking sites.

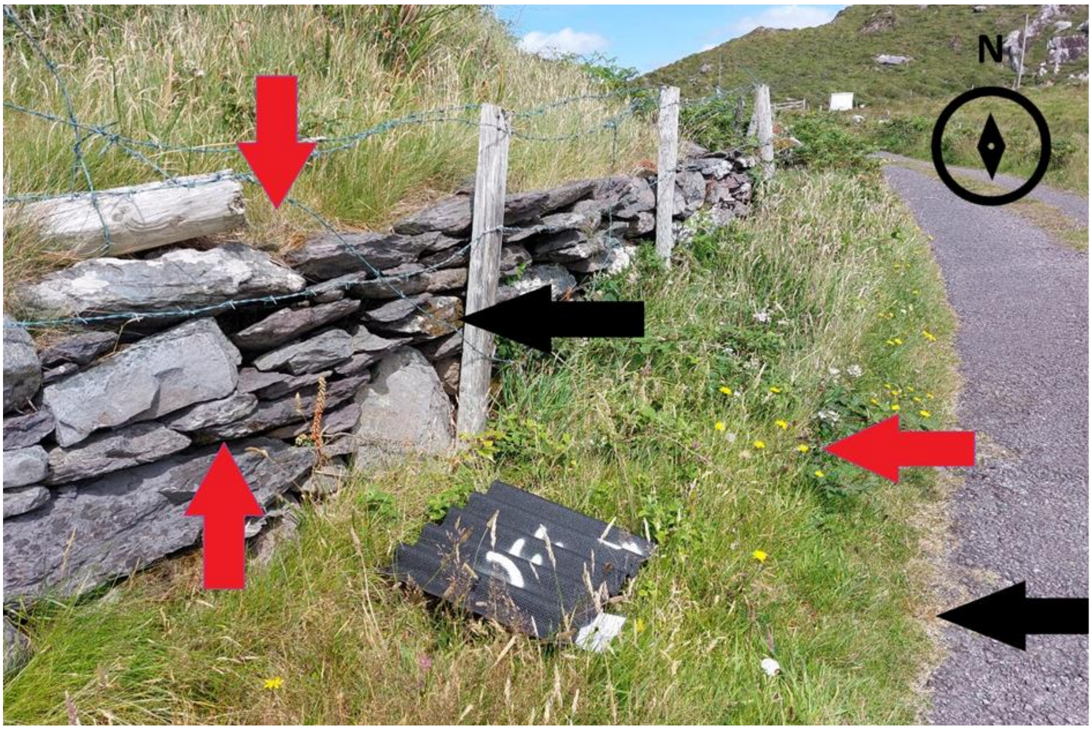


Figure 3.9 – An image of typical lizard habitat taken from the Hog's Head refugia survey site. Red arrows indicate areas of potential microclimates while black arrows indicate edges of habitat.

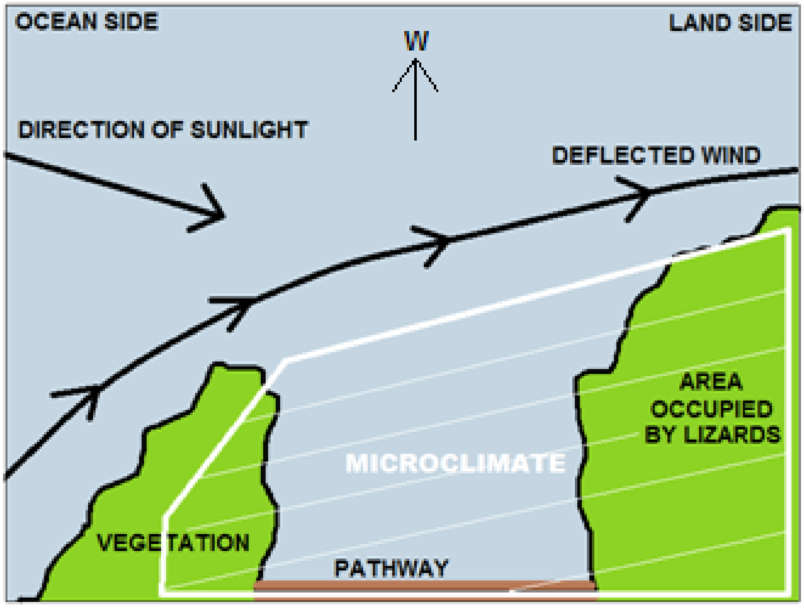


Figure 3.10 – An illustration to explain why there may be a potential microhabitat at Ballycotton Cliff Walk, County Cork (Lyne, 2017).

Habitat records from citizen science observations.

The Iveragh Lizards citizen science campaign received 102 submissions, of which 68 were for the Iveragh penisula, while 34 were from elsewhere in the country (see Figures 2.8 and 2.9, Chapter 2, Pages 39-40). Of these 102, 87 were verified by either an image of the lizard observed, by the description of the observation, or by the expertise of the recorder being known to the author. The remainder were excluded from the study due to having no method of verification or the observer stated that they were unsure if it was a lizard or newt that they had seen.

As mentioned above, participants could choose multiple options out of the choice of 6 habitats that were offered (Figure 3.1). Of the 87 verified records, the habitat choice with the highest records at 23% was Upland, which was described to participants as ‘bog, heath or moorland such as upland Iveragh’. Gardens made up 17% of observations, while earth/grass banks, described as ‘perhaps alongside a walking trail or roadside’, followed closely at 16%. Old stone walls or stone ruins made up 12% of records while hedgerows and sand dunes accounted for 9% of records. The option ‘Other’ was chosen 20 times by participants. Based on the 20 descriptions supplied, 15 of those could be classified as ‘manmade’ environments such as indoor locations (homes, businesses, etc.), see Figure 3.11 and Table 3.1.

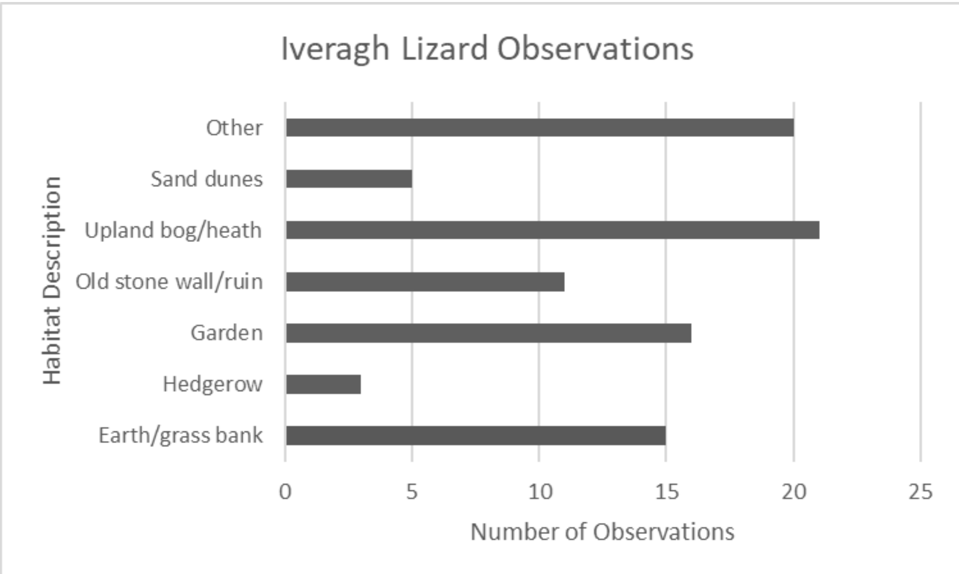


Figure 3.11– The number of times each habitat option was chosen by submissions to the Iveragh Lizards citizen science portal for all 87 records.

Table 3.1 – Of the 20 records which were submitted as 'Other', 15 were classified as 'Manmade' based on the description given by participants.

Habitat Description	Category	Times
Indoors in home or business	Manmade	8
Concrete footpath	Manmade	3
Road	Manmade	2
Concrete wall	Manmade	1
Tent	Manmade	1
Multiple sightings at various locations	Not specified	1
Beach/sand dunes	Sand dunes	2
Garden ditch	Garden	1
Woodland	Woodland	1

Environmental parameters of field study sites.

Lizards were not observed on any survey during visits to the Lisbawn field study site between July-September 2022 (Table 3.2).

Hog's Head resulted in 25 lizard observations, with 16 occurring on natural substrates (Table 3.2). The remaining 9 observations were of lizards being seen on top of one specific survey tile at the site and no records came from any other tiles. Neonates accounted for 7 of the 9 records observed from survey tiles (78%). All 25 observations occurred from the trail transect. A single lizard was observed on the off-trail transect in early October, but this was not during the surveys.

Abbey Island resulted in 13 lizard observations, 8 of which occurred on natural substrates (Table 3.2). The remaining 5 occurred on 3 different survey tiles. Neonates accounted for 4 of the 5 records observed from survey tiles (80%). All records came from the trail transect. Lizards were observed on 2 of the off-trail tiles at the site but again, not during an official survey.

No lizards were observed underneath the artificial refugia when collecting tiles on completion of the study on September 20th, 2022.

Table 3.2 – The total number of adult and neonate lizards observed between July-Sept. 2022, per transect type and substrate type, at each study site (16 site visits in total).

Transect / substrate	Lisbawn Adult	Lisbawn Neonate	Hog's Head Adult	Hog's Head Neonate	Abbey Island Adult	Abbey Island Neonate	Total
Trail / tile	0	0	2	7	1	4	14
Trail / natural	0	0	14	2	7	1	24
Off-trail / tile	0	0	0	0	0	0	0
Off-trail / natural	0	0	0	0	0	0	0
Total	0	0	16	9	8	5	38

To test the microclimate hypothesis that there were environmental differences between the habitat level which lizards occupy (tile level) versus the larger habitat of the area (air level), several factors were measured across the three sites. Figure 3.12 shows the humidity, temperature, and wind speed from recordings for the Lisbawn site, Figure 3.13 for the Hog's Head site, and Figure 3.14 for the Abbey Island survey site. The biggest differences can be seen in the wind speed measurements taken at tile height and air height, ~2m (Figure 3.16). Table 3.4 shows that only the wind speed showed statistical significance at all three sites, with a P-value of <0.001 in a two-sample t-test assuming unequal variance. This shows that wind at tile height, the level which lizards occupy, is much lower within the proposed microhabitat compared to that at air level (2m height).

It can also be seen in Figures 3.12 to 3.14 and in 3.15, that Lisbawn has the lowest relative humidity but the highest temperatures when compared to Hog's Head and Abbey Island.

The differences in humidity at tile and air heights across the three survey sites is much less obvious in Figure 3.15. The standard deviations around the means are wider in humidity when compared to temperature and wind, suggesting humidity levels are much more variable from tile to tile.

Similar results can be seen when comparing temperatures. Two-sample T-test assuming unequal variables show no significance at any of the three sites: Lisbawn $t(77) = 1.852$, $p = 0.068$; Hog's Head $t(111) = 1.201$, $p = 0.232$; Abbey Island $t(92) = 0.689$, $p = 0.493$ (Table

3.3). Standard deviation for temperatures was lowest at the Abbey Island site suggesting that the microhabitat here has a more consistent temperature range.

Table 3.4 shows the results of a single factor/one-way analysis of variance (ANOVA) carried out to compare the means of environmental parameters recorded at the three different study sites. The ANOVA results from humidity measurements recorded across the three study sites show there was a significant difference at both ground level ($F(2,147) = 20.271$, $p = 0.001$) and air level ($F(2,142) = 15.161$, $p = 0.001$). Results also revealed a significant difference in the mean temperature measurements recorded at ground level ($F(2,142) = 17.999$, $p = 0.001$) and at air level ($F(2,142) = 12.748$, $p = 0.001$) across the study sites.

When comparing the means of wind speeds recorded across the different study sites, ANOVA results showed no significant difference at ground level ($F(2,142) = 1.068$, $p = 0.346$) or at air level ($F(2,142) = 1.474$, $p = 0.232$). These results were not significant ($P > 0.05$) and therefore the means of wind recordings taken at ground and air heights at the three sites varied. This indicates that wind speeds are a more variable factor and likely to have more influence on microclimate conditions within microhabitats at the sites.

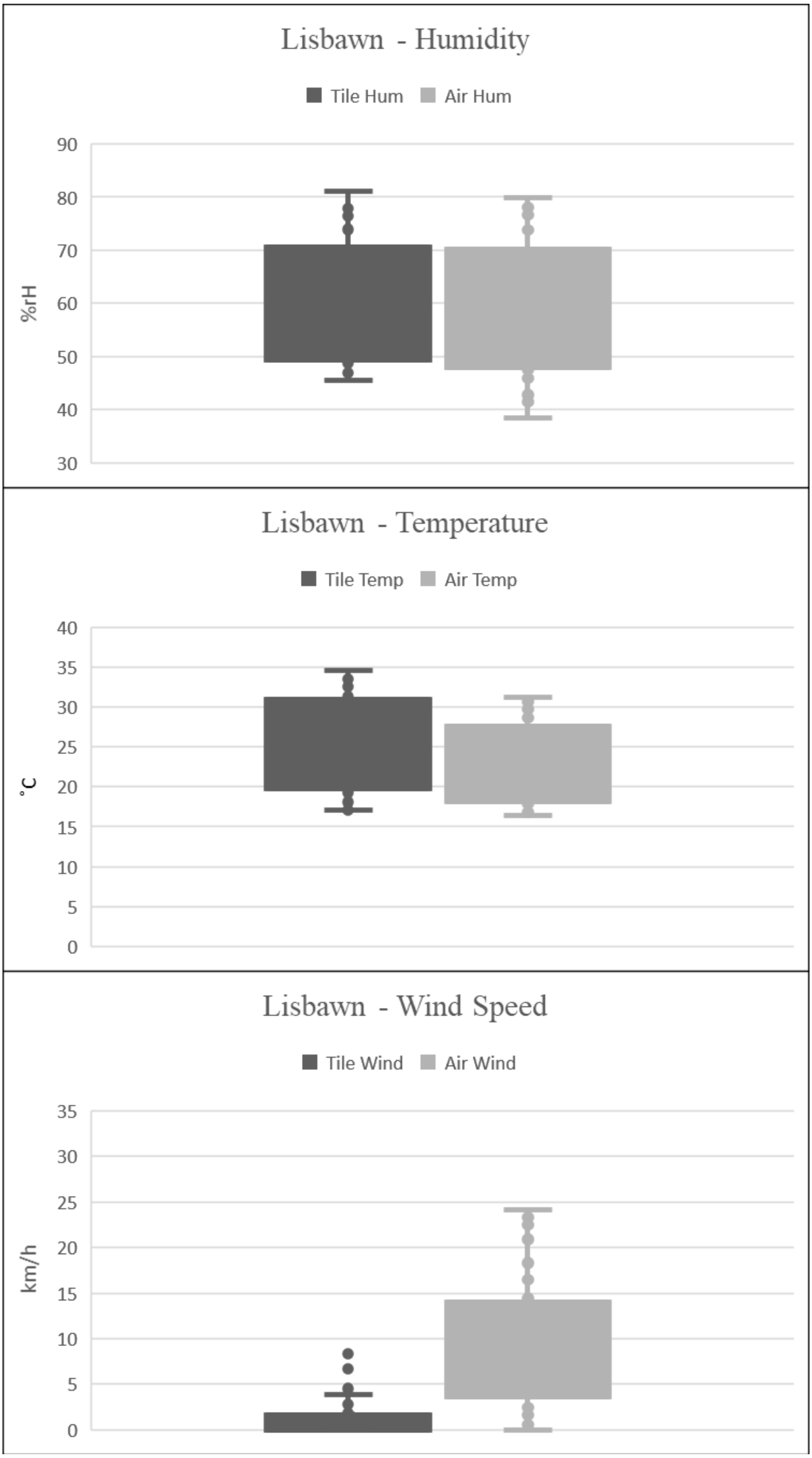


Figure 3.12 – Visual representation of the humidity (%rH), temperature (˚C) and wind (km/h) of the 39 paired measurement recordings taken at Lisbawn.

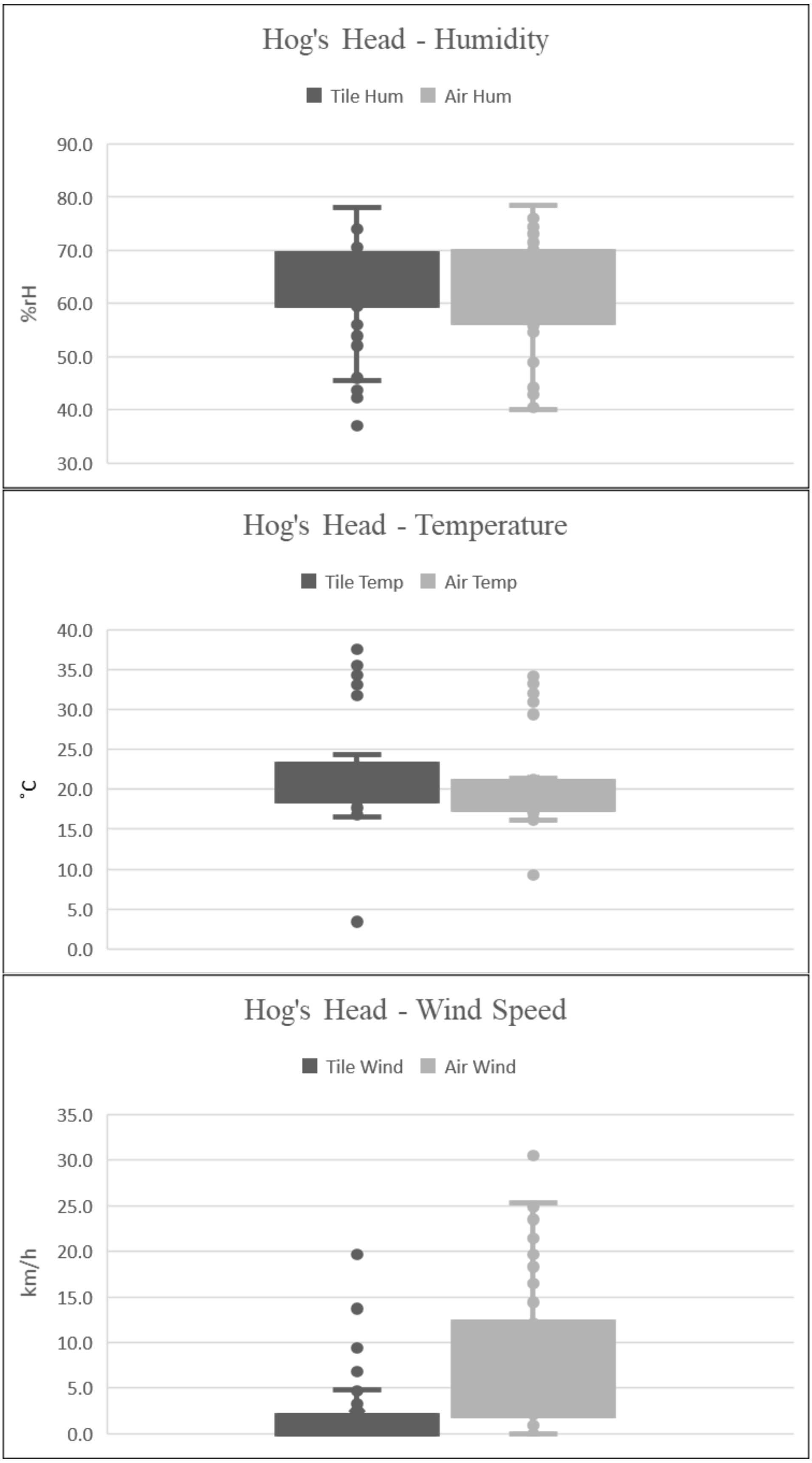


Figure 3.13 – Visual representation of the humidity (%rH), temperature (˚C) and wind (km/h) of the 57 paired measurement recordings taken at Hog's Head.

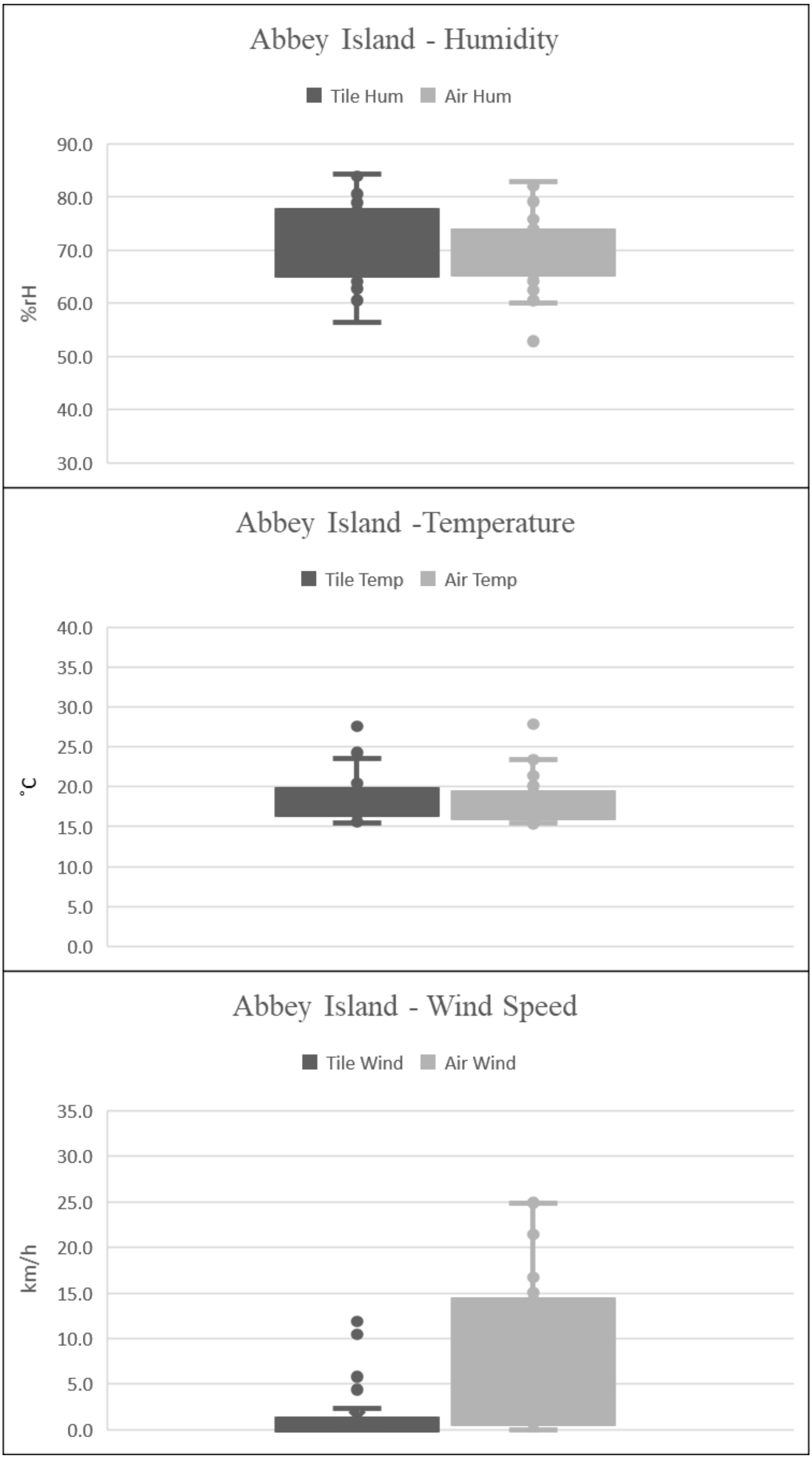


Figure 3.14 – Visual representation of the humidity (%rH), temperature (˚C) and wind (km/h) of the 47 paired measurement recordings taken at Abbey Island.

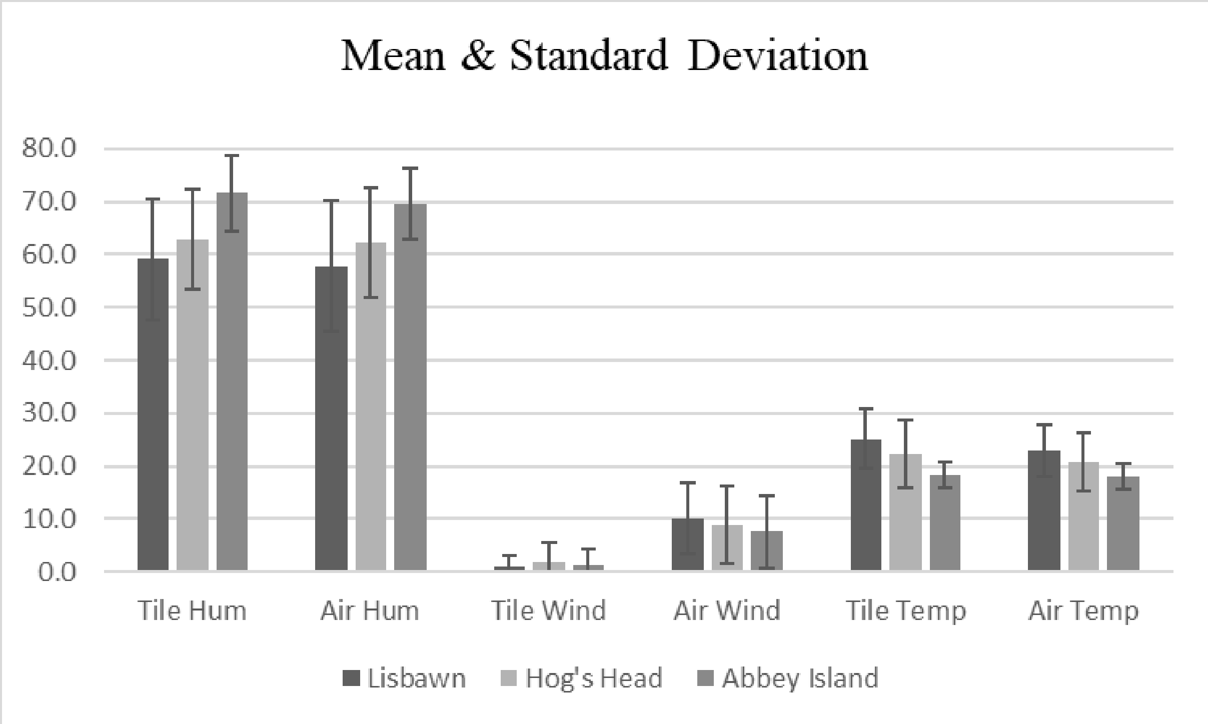


Figure 3.15 – The mean and standard deviation of paired environmental parameter recordings taken from each of the three study sites at ground level and at 2m height.

Table 3.3 – Results of two-sample T-tests assuming unequal variances conducted on the paired environmental parameter recordings taken from each of the three study sites at ground level and at 2m height.

Site / Recordings		**Humidity**	**Temperature**	**Wind Speed**
Lisbawn / 40	**t Stat** **df** **P value**	0.516 78 0.607	1.852 77 0.068	-8.112 45 0.001
Hog's Head / 58	**t Stat** **df** **P value**	0.272 113 0.786	1.201 111 0.232	-6.445 82 0.001
Abbey Island / 47	**t Stat** **df** **P value**	1.42 91 0.157	0.689 92 0.493	-5.594 61 0.001

Table 3.4 – Results from single factor ANOVA (analysis of variance) tests of paired environmental parameter recordings taken from each of the three study sites at ground level and at 2m height.

Tile Humidity		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Between Groups	3660.73	2	1830.367	20.27139	0.001
	Within Groups	12821.63	142	90.29315		
	Total	16482.36	144			
Air Humidity		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Between Groups	3088.547	2	1544.273	15.16137	0.001
	Within Groups	14463.52	142	101.8558		
	Total	17552.07	144			
Tile Wind		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Between Groups	18.81067	2	9.405333	1.068461	0.346
	Within Groups	1249.982	142	8.802688		
	Total	1268.792	144			
Air Wind		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Between Groups	150.4272	2	75.21362	1.474225	0.232
	Within Groups	7244.713	142	51.0191		
	Total	7395.14	144			
Tile Temperature		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Between Groups	995.2668	2	497.6334	17.99853	0.001
	Within Groups	3926.095	142	27.64855		
	Total	4921.362	144			
Air Temperature		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
	Between Groups	527.4203	2	263.7101	12.74806	0.001
	Within Groups	2937.455	142	20.6863		
	Total	3464.875	144			

Discussion

Habitat observations

Upland peat/heath had the highest number of records (23%) from the submissions to the Iveragh Lizards citizen science survey. Heathland habitat is characterised by purple moorgrass, heathers and gorse, and is a known habitat type for several species of reptile including *Z. vivipara* in areas such as the UK and mainland Europe (Beebee & Griffiths, 2000; Stumpel & van der Werf, 2012). The high proportion of lizard sightings (both dead and alive) from homes and gardens seen in the citizen science results from Iveragh Lizards is potentially down to recorder bias. Both Marnell (2002) and Meehan (2007), whose papers were largely based on citizen science records, referred to lizards often occurring around human habitations and those studies also suggested recorder bias. Domestic cats are known predators for a range of wildlife, including reptiles (Trouwborst *et al*., 2020; Woods *et al*., 2003) and certainly a likely reason for lizards turning up in people's homes/gardens. Observations around homes and gardens could mean lizards are seeking a mate or a hibernation chamber, while conductive surfaces may lead lizards to bask on manmade surfaces such as paths or tiles. The rural setting of much of Iveragh's homes, even in towns and villages, will often mean that suitable lizard habitat is not far from the doorstep.

Environmental parameters

Of the 15 lizard sightings on refugia tiles, 12 of them were neonates. The low numbers of lizards seen on artificial refugia could be down to several factors. Many species are known to have different personality traits including some being more neophobic than others (Waters *et al*., 2017). This fear of new things might result in adult common lizards avoiding the new objects in their environment, the refugia tiles, while the neonates perhaps had no such fear. This form of neophobia has been recorded in birds but research is lacking in this area for reptiles (Biondi *et al*., 2010). There are also possibly different thermoregulatory requirements between adult and neonate *Z. vivipara* as seen in other lizards (e.g.: Middendorf & Simon, 1988; Hitchcock & McBrayer, 2006). A long-term study where the tiles are left *in situ* for multiple seasons in a variety of habitats may garner a higher rate of lizards per tile.

Three neonate lizards were observed, from a distance of approximately 3m, basking together on an off-trail tile in long grass at the Abbey Island site. This did not occur during an official survey. This sighting suggests that tiles could be a useful tool in monitoring lizard presence in habitats where lizards might be difficult to see, such as longer vegetation (Lettink & Cree, 2007). While great care was taken to cause minimal disturbance during all transect observation, it is possible that moving through longer vegetation on the off-trail transects alerted lizards to observer presence. This research did not study flight initiated distance (FID), but perhaps there is a difference between the FID of lizards which occupy areas close to human activity (trail) compared to those further away (off-trail) (Capizzi *et al*., 2007; McGowan *et al*., 2014).

The microclimate analysis shows that temperature and windspeed may be important factors which may influence microhabitats. The two are linked, with higher wind speed reducing temperatures via the wind chill factor (Osczevski & Bluestein, 2005). Similar to Howth Head (Gandola, 2019), the present research found lizards occupying smaller microhabitats such as old stone walls and pockets within heather-covered heath on the Iveragh peninsula. This may be because such spaces provide either stones or vegetation as wind breaks or wind deflectors. Having shelter from the wind means that these smaller spaces would be warmer and thus provide the ideal environment for an ectotherm to thermoregulate (Bakken, 1992). Factors such as how long the sun was shining on a particular area or what the moisture levels were in the surrounding vegetation are also likely to have influence.

Where microhabitats are lacking, a thermoregulatory advantage may be missing. It might explain why lizards are absent in certain areas, such as agricultural farmland, or only found in small pockets within what might be considered suitable habitat for lizards (Zajitschek *et al*., 2012). If there is no temperature advantage provided from wind breaks, then thermoregulatory efficiency is slowed, and lizards are more vulnerable to predators as they need to bask for longer (Avery, 1982). It is possible that microhabitats also provide a temperature advantage during hibernation months. Being sheltered from higher winds may keep temperatures in hibernacula more consistent and conducive with hibernation (Bauwens, 1981; Beebee & Griffiths, 2000). It's possible that the lack of lizard sightings in the Lisbawn study site is as a result of unsuitable environmental parameters while Hog's Head and Abbey Island had conditions more conducive with the thermoregulatory needs of *Z. vivipara.* For example, relative humidity was lowest at Lisbawn and water constraints are recorded as having a negative affect on *Z. vivipara* growth rates in some populations (Lorenzon *et al*., 1999; Lorenzon *et al*., 2001.

Knowing the life-history traits of a species and the microhabitats they occupy can greatly increase the effectiveness of conservation policy and its outcomes (Foufopoulos & Ives, 1999; Ludwig *et al*., 2001). Understanding these factors when conducting necessary or scheduled works on certain habitats could prevent or mitigate impact on wildlife such as common lizards – similar to policies which protect nesting birds or hibernating bats (WWW18). Habitat restoration or management could also be informed by such knowledge, in order to recommend the protection, or construction, of smaller microhabitats such as old stone walls or vegetated banks which line many of the walking trails, field boundaries, and rural roads of Iveragh. A minimal amount of maintenance could also be considered to benefit lizards such as careful trimming of longer vegetation to expose basking sites to sunshine (Gandola, 2019). Artificial refugia or hibernacula, made from natural materials, could be installed in areas where habitat disturbance may have removed suitable basking spots or overwintering spaces. Similarly, any plans for planting of vegetation could include regular small breaks in cover to allow for natural basking sites and the habitat edges which lizards tend to prefer (WWW19).

Agricultural grassland and conifer monocultures are low in biodiversity compared to native woodland (McAdam & McAvoy, 2009; Felton *et al*., 2010). A mixed mosaic of habitats, including microhabitats, is the best approach if any form of habitat restoration/conservation is being considered for the common lizard in Ireland. If wildlife corridors are being considered, the needs of smaller species to travel safely should also be included in plans. While birds can fly or larger mammals can avail of travelling quickly between hedgerows or trees, smaller animals such as lizards would benefit from vegetated banks or fallen branches to provide cover (Beier *et al*., 2008; Zajitschek *et al*., 2012).

Conclusions

This study found that peat/heath habitat, old stone walls/vegetated banks, and gardens close to human habitations are habitats where *Z. vivipara* can be observed in Ireland. This is in line with previous research on the species here (Marnell, 2002; Meehan, 2007) and from other parts of their global range (Beebee & Griffiths, 2000; Stumpel & van der Werf, 2012). Wind is known to influence the microclimate conditions of microhabitats which thermoregulators occupy (Bakken, 1992) and this research identified significant variations in wind speed at ground level when compared to 2m height. In addition, factors such as life stage, personality traits, or visibility to predators can affect how easily lizards are visible in their environments (House *et al*., 1980; McGowan *et al*., 2014; Zajitschek *et al*., 2012), and these also may have influenced sightings during this study. A long-term study is recommended, whereby *Z. vivipara* are monitored for thermoregulatory behaviours to examine for microclimate benefits within microhabitats, in addition to prey abundance comparisons between microhabitat types.

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Please note that Chapter 4 (pp. 75-89) is unavailable due to a request by the author.

Chapter 5

Overall Conclusions

The main findings of this research are: (i) distribution of records for *Zootoca vivipara* in Ireland are predominantly from coastal areas and are clustered around areas of human outdoor recreation; (ii) there are consistent geographical data gaps in the distribution of records of the species in Ireland from records dating 1902 to 2021; (iii) peatland, old stone walls/vegetated banks, and gardens are habitats in which *Z. vivipara* occurs in Ireland; (iv) wind speed is potentially an important environmental parameter within the microhabitat level which lizards occupy; (v) this research confirms for the first time that Irish common lizards belong to the Western viviparous clade (Clade E); (vii) Irish common lizards differ from Western viviparous clade lizards elsewhere by 1bp in the VB1 haplotype, representing a unique lineage in Ireland; and (viii) geographically disparate populations of Irish *Z. vivipara* differ by 2bp from each other in the ND2 haplotype which suggests multiple lineages are present in Ireland.

Zootoca vivipara is a cryptic species with an average length of just 14cm (Beebee & Griffiths, 2000), making it a difficult animal to survey for. Field work was limited to days with weather suitable for lizard activity (dry, sunshine) and during the short active season of the species in Ireland (approximately March to October). For these reasons, this research utilised a wide range of techniques in order to gather as much information as possible in the short window of a Masters study. These included gathering and analysing data from the National Biodiversity Data Centre records, literature reviews, establishing and promoting a citizen science program to gather localised data, surveying for lizards using artificial reptile refugia tiles, and recording environmental parameters in lizard habitats.

This research provides the most comprehensive view of the distribution of records for *Z. vivipara* in Ireland, following on from earlier studies on the species here by Ní Lamhna, 1979, Marnell, 2002, and Meehan, 2007. The data gaps in distribution records were shown to be consistent across the maps from earlier studies and many are still present in maps produced by this research. However, data gaps in Northern Ireland were seen to be reduced following the inception of the National Biodiversity Data Centre in 2007 (See Chapter 2, Figure 2.4, page 35). This suggests that focused studies or appeals for records at regional levels could fill in some of the data gaps which are still present. For example, the study area on the Iveragh Peninsula in the south-west of Ireland now has an increased number of records for *Z. vivipara* following the data gathered for this research. This does not necessarily represent a higher population of lizards on Iveragh, but rather an increased sampling effort.

Beebee & Griffiths (2000) includes a map showing a widespread distribution for *Z. vivipara* in the UK. However, apart from this, there is surprisingly little research on the UK distribution of *Z. vivipara* and only local area population studies could be found (e.g.: Dent & Spellerberg, 1987; McInerny, 2016). Instead, research on reptiles in the UK focuses mainly on endangered or protected species such as *Vipera berus* or *Lacerta agilis* (e.g.: *Reading et al*., 1996; Phelps, 2004; Woodfine, *et al*., 2017). It is therefore difficult to ascertain if the coastal trend seen in the distribution of *Z. vivipara* in this research (Chapter 2) is reflected in other areas with similar climate and habitats. Future work to include factors such as sunshine hours in coastal areas or lizard abundance in coastal areas versus inland habitat may establish potential reasons for the distribution patterns seen in Chapter 2.

How lizards use microhabitats can result in populations persisting in areas where habitats are threatened by change (Smith & Ballinger, 2001). *Z. vivipara* has been identified to use microhabitats in other parts of the species' range (Van Damme *et al*., 1987; Strijbosch, 1988; Herczeg *et al*., 2004). Environmental parameters examined potential for thermoregulatory advantages at lizard level within microhabitats on the Iveragh Peninsula (see Chapter 3). Such environmental parameters have been identified as playing important roles in thermoregulation and population dynamics within habitats in which reptiles are found (Guillon *et al*., 2014; Rozen-Rechels *et al*., 2020; Rutschmann *et al*., 2020). An extension of this research on Irish *Z. vivipara* would benefit from analysing distribution of records of the species in conjunction with microhabitat suitability, particularly where there are geographical data gaps for sightings of lizards.

Results from genetic sequencing of *Z. vivipara* conducted during this research have confirmed, for the first time, that Irish common lizards belong to the Western viviparous clade (Clade E). This had been suggested in phylogeographic research on the species from mainland Europe, but without confirmation via inclusion of specimens from Ireland (Surget-Groba *et al*., 2001; Odierna *et al*., 2004; Horreo *et al*., 2018).

Furthermore, the results of this study showed that Irish specimens differed by 1bp from the closest European haplotypes (VB1) in data available through GenBank. In addition, geographically disparate Irish samples gathered in Counties Cork and Kerry, differed by 2bp from each other in the ND2 haplotype. Glaciation events during the end of the last ice-age contributed to how *Z. vivipara* colonised parts of its mainland Europe range (Horreo *et al*., 2008). A similar effect can be found in the distribution of another wide-ranging viviparous reptile, *Vipera berus* (Ursenbacher *et al*., 2006). The sequencing of specimens from more widespread regions around Ireland could infer how *Z. vivipara* dispersed around Ireland following its arrival here. If separate populations showed more lineages, such as those found in this study (Chapter 4), it may establish if multiple separate introductions occurred or if diversification occurred following its initial arrival in Ireland.

As Ireland's only native terrestrial reptile, the common lizard (*Zootoca vivipara*) is worthy of its protection under the Wildlife Act (1976). Understanding why it is present or absent in certain areas will greatly help in any conservation plans for the species. This research has established it is a unique haplotype in Ireland, and that several separate lineages occur here. This research recommends continued studies on the phylogeography of the species in Ireland, perhaps in tandem with distribution of records here to identify any connections between lineages occurring in specific habitats or regions.

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WWW5 – Le Galliard labs at CEREEP:

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WWW7 – Melanistic lizard sighting in Derrynane, County Kerry:

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WWW14 – Statista, market and consumer data:

https://www.statista.com/statistics/455844/urbanization-in-ireland/#statisticContainer

Accessed 11th January 2023.

WWW15 – Met Éireann, Irish meteorological service:

https://www.met.ie/climate/30-year-averages

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WWW16 – ARG UK, Amphibian and Reptile Group UK:

https://www.arguk.org/info-advice/advice-notes?format=html

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WWW17 - Met Éireann, Irish meteorological service:

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WWW20 – NBDC sightings portal:

https://records.biodiversityireland.ie/

Accessed 10th January 2023

Appendix

Training & personal development

Title	Description	Link	Where	When
LAST Course	Two day training course required for the use of animals in scientific studies.	https://www.last-ireland.ie/last-new /	Online	February 2021
Reptile Handling	Handling and buccal swabbing training for research on wild reptiles.	Tailored by UCC Animal Experimentation Ethics Committee.	Ballycotton, County Cork.	September 2021
NPWS license	NPWS license granting permission to handle wild *Zootoca vivipara*.	https://www.npws.ie/licencesandconsents	Online	April 2021
PG6001, STEPS – Scientific Training for Enhanced Postgraduate Studies https://ucc-ie-public.courseleaf.com/modules/	Postgraduate module focusing on scientific writing, publications, and dissemination of research.	https://ucc-ie-public.courseleaf.com/modules/	University College Cork	Semester 1 & 2, 2021/22
PG6029, Skills in public engagement of science	Skills in presenting research to the public, media, and scientific audiences.	https://ucc-ie-public.courseleaf.com/modules/	University College Cork	Semester 2, 2021/22

Certificates

LAST IRELAND

LAST –Ireland

Day 1-5 day 2 Wildlife

Category; A,B,C,D Species : Wildlife

Cert Number: 10111004

This is to certify that

Linda Lyne

attended a course and passed an assessment of the course, based on the **EU EWG guidelines contained in the framework document, which fulfill the requirements under article 23 and 24 of directive 2010/63 EU for the categories of persons stated below.#

Module	Title of Core Module
1	National Legislation (Irish SI 543/12)
2	Ethics, Animal welfare and the 3 Rs (level 1)
3.1	Basic and Appropriate Biology (species noted on certificate)
4	Animal care, health and management (species noted on certificate)
5	Recognition of pain, suffering and distress (species noted on certificate)
6.1	Humane methods of euthanasia (theory)
7	Minimally invasive procedures without anaesthesia.
9	Ethics, Animal welfare and the 3 Rs (level 2)
10	Design of procedures and projects (level 1)
11	Design of procedures and projects (level 2)
	Title of Practical Module
3.2*	Basic and appropriate biology (species noted on certificate)
8 *	Minimally invasive procedures without anaesthesia
6.2 *	Humane methods of euthanasia
	Title of Additional Module
20	Anaesthesia for minor procedures
22	Principles of surgery
30	Introduction to local environment

** extract from National Competent Authorities for the implementation of Directive 2010/63/EU on the protection of animals used for scientific purposes A working document on the development of a common education and training framework to fulfill the requirements under Articles 23 and 24 - Replacing consensus document I of 22-23 March 2012 – 18/19 Sept 2013

* These units are not taught in the module but are taught and demonstrated when applicable in each individual institute.

Signed

Peter Nowlan

Digitally signed by Peter Nowlan DN: cn=Peter Nowlan, o, ou=LAST Ireland, email=sec@Last-ireland.ie, c=IE Date: 2021.02.13 16:15:02 Z

Peter F. Nowlan (Course organiser)
Contact information:

E-Mail: sec@last-ireland.ie ; www.last-ireland.ie

#Category A: Persons carrying out procedures on animals, Category B: Persons designing procedures and projects
Category C: Persons taking care of animals, Category D: persons performing euthanasia

Figure App. 1 - Certificate for successful completion of LAST Course.

Revision 2021/001

UCC | University College Cork
Biological Services Unit

TRAINING RECORD

ANIMAL HANDLING SKILLS AND PROCEDURES PERFORMED

ON ANIMALS USED FOR EXPERIMENTAL OR OTHER SCIENTIFIC PURPOSES.

Trainee Full Name: Ms. Linda Lyne

Trainee's Qualifications: BSc (Hons) – MSc Student

PI Name and Affiliation: Dr. Fidelma Butler (BEES)

Individual Authorisation: AE19130/ N/A

Establishment Number: AE19130

Training Officer: Jason Radford

Conditions:

Page **1** of **2**

Revision 2021/001

Any harm caused to animals or refusal to handle through fear or ignorance warrants failure.
Each level of training must be completed before proceeding to next level. This may require each level being carried out more than once.

1) *Training on-going, close supervision required*
2) *Competent, procedure to be performed under supervision*
3) *Competent and can work independently*
4) *Competent and experienced and can teach others.*

Procedure Category	Skill/Technique Description	Species	Level 1 Training officer Signature/Date	Level 2 Training officer Signature/Date	Level 3 Training officer Signature/Date	Level 4 Training officer Signature/Date
Field Work	Capture and Handling	Lizard	09/2021	09/2021	09/2021	09/2021
	Morphometric Data Collection	Lizard	09/2021	09/2021	09/2021	09/2021
	Buccal swab	Lizard	09/2021	09/2021	09/2021	09/2021

Training Officers:

Name	Job Title	Qualification
Jason Radford	Senior Technical Officer	*B.Sc (Hons)., M.Sc.*
Noelle Sexton	Senior Technical Officer	*M.I.A.T*
Colette Manley	Senior Technical Officer	*M.I.A.T*

Training Officer Comments:

Date:	Comment:	Signature:	Action:
20/09/2021	JR observed LL handle lizards (viviparous) in Ballycotton, Cork.		No further action required, LL is confident and competent and is an experienced field researcher.

Page **2** of **2**

Figure App. 2 – Certificate for successful completion of reptile handling training.

National Parks & Wildlife Services

LICENCE

An Roinn Tithíochta,
Rialtais Áitiúil agus Oidhreachta
Department of Housing,
Local Government and Heritage

Licence No. C 140/2021

NATIONAL PARKS & WILDLIFE SERVICE

Wildlife Acts 1976 to 2018 – Sections 23 and 34

LICENCE TO CAPTURE PROTECTED WILD ANIMALS FOR EDUCATIONAL, SCIENTIFIC OR OTHER PURPOSES

The Minister for Housing, Local Government and Heritage in exercise of the powers conferred on him by Sections 9, 23 and 34 of the Wildlife Acts 1976 to 2018 authorises:

Linda Lyne
Madam's Hill, Killarney, Kerry, V93HTX2

To disturb specimens of the species specified in Column 1 of the Schedule hereunder in the area specified in Column 2 by the means specified in column 3 for scientific, educational or other purposes during the period beginning on **14th April 2021** and ending on **30th September 2022**, subject to the conditions listed overleaf.

SCHEDULE

1	2	3
Species	**Area**	**Means of capture**
Common Lizard *(Zootoca vivipara)*	**Iveragh Peninsula,Co. Kerry; Ballycotton, Co. Cork; Burren, Co. Clare; Bull Island, Co. Dublin.**	**Capture by hand**

Dated 14th April 2021

For the Minister for Housing, Local Government and Heritage

Claire Cooley

Figure App. 3 – NPWS license obtained for handling *Zootoca vivipara.*

Achievements

Winner of the University College Cork School of BEES Education and Public Engagement Award, 2022.

Awarded for the best contribution to public engagement by an early career researcher in the School of Biological, Earth and Environmental Sciences based on the 'Iveragh Lizards' citizen science project.

Figure App. 4 – Award certificate for the UCC School of BEES Education and Public Engagement award.

Chapter 2

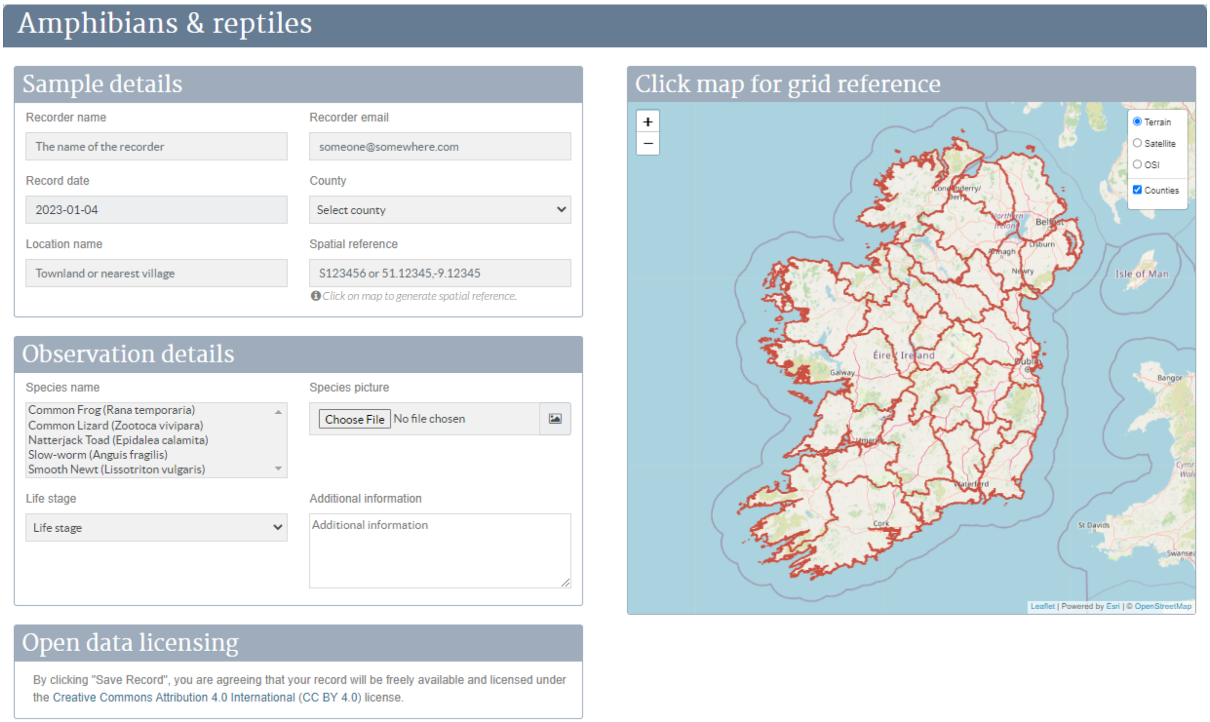
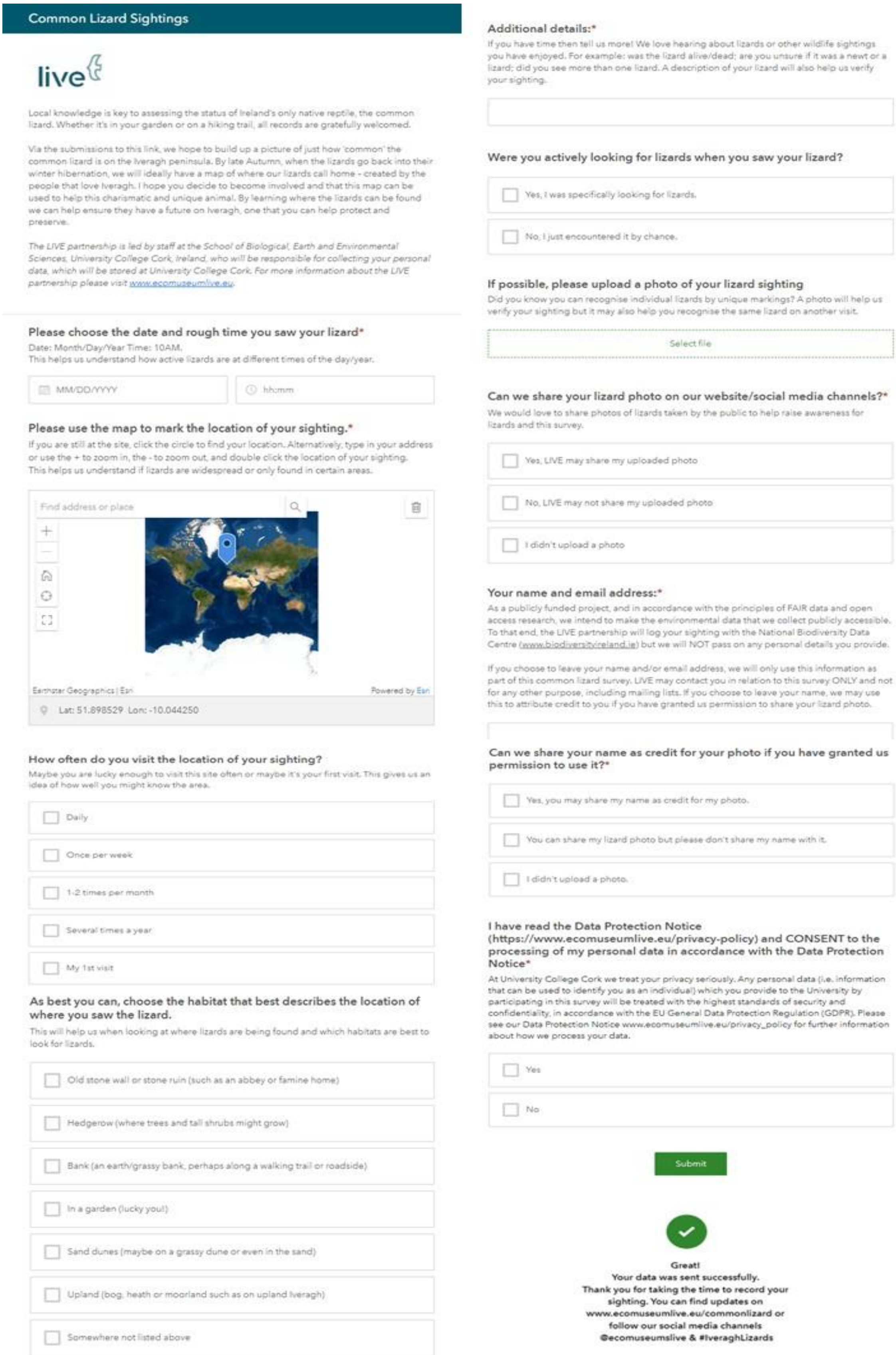


Figure App. 4 – The NBDC sightings portal showing the information requested when submitting an observation under the amphibians & reptiles option (WWW20).



Common Lizard Sightings

live

Local knowledge is key to assessing the status of Ireland's only native reptile, the common lizard. Whether it's in your garden or on a hiking trail, all records are gratefully welcomed.

Via the submissions to this link, we hope to build up a picture of just how 'common' the common lizard is on the Iveragh peninsula. By late Autumn, when the lizards go back into their winter hibernation, we will ideally have a map of where our lizards call home - created by the people that love Iveragh. I hope you decide to become involved and that this map can be used to help this charismatic and unique animal. By learning where the lizards can be found we can help ensure they have a future on Iveragh, one that you can help protect and preserve.

The LIVE partnership is led by staff at the School of Biological, Earth and Environmental Sciences, University College Cork, Ireland, who will be responsible for collecting your personal data, which will be stored at University College Cork. For more information about the LIVE partnership please visit www.ecomuseumlive.eu.

Please choose the date and rough time you saw your lizard*

Date: Month/Day/Year Time: 10AM.
This helps us understand how active lizards are at different times of the day/year.

MM/DD/YYYY | hh:mm

Please use the map to mark the location of your sighting.*

If you are still at the site, click the circle to find your location. Alternatively, type in your address or use the + to zoom in, the - to zoom out, and double click the location of your sighting.
This helps us understand if lizards are widespread or only found in certain areas.

Find address or place

Earthstar Geographics | Esri — Powered by Esri

Lat: 51.898529 Lon: -10.044250

How often do you visit the location of your sighting?

Maybe you are lucky enough to visit this site often or maybe it's your first visit. This gives us an idea of how well you might know the area.

- Daily
- Once per week
- 1-2 times per month
- Several times a year
- My 1st visit

As best you can, choose the habitat that best describes the location of where you saw the lizard.

This will help us when looking at where lizards are being found and which habitats are best to look for lizards.

- Old stone wall or stone ruin (such as an abbey or famine home)
- Hedgerow (where trees and tall shrubs might grow)
- Bank (an earth/grassy bank, perhaps along a walking trail or roadside)
- In a garden (lucky you!)
- Sand dunes (maybe on a grassy dune or even in the sand)
- Upland (bog, heath or moorland such as on upland Iveragh)
- Somewhere not listed above

Additional details:*

If you have time then tell us more! We love hearing about lizards or other wildlife sightings you have enjoyed. For example: was the lizard alive/dead; are you unsure if it was a newt or a lizard; did you see more than one lizard. A description of your lizard will also help us verify your sighting.

Were you actively looking for lizards when you saw your lizard?

- Yes, I was specifically looking for lizards.
- No, I just encountered it by chance.

If possible, please upload a photo of your lizard sighting

Did you know you can recognise individual lizards by unique markings? A photo will help us verify your sighting but it may also help you recognise the same lizard on another visit.

Select file

Can we share your lizard photo on our website/social media channels?*

We would love to share photos of lizards taken by the public to help raise awareness for lizards and this survey.

- Yes, LIVE may share my uploaded photo
- No, LIVE may not share my uploaded photo
- I didn't upload a photo

Your name and email address:*

As a publicly funded project, and in accordance with the principles of FAIR data and open access research, we intend to make the environmental data that we collect publicly accessible. To that end, the LIVE partnership will log your sighting with the National Biodiversity Data Centre (www.biodiversityireland.ie) but we will NOT pass on any personal details you provide.

If you choose to leave your name and/or email address, we will only use this information as part of this common lizard survey. LIVE may contact you in relation to this survey ONLY and not for any other purpose, including mailing lists. If you choose to leave your name, we may use this to attribute credit to you if you have granted us permission to share your lizard photo.

Can we share your name as credit for your photo if you have granted us permission to use it?*

- Yes, you may share my name as credit for my photo.
- You can share my lizard photo but please don't share my name with it.
- I didn't upload a photo.

I have read the Data Protection Notice (https://www.ecomuseumlive.eu/privacy-policy) and CONSENT to the processing of my personal data in accordance with the Data Protection Notice*

At University College Cork we treat your privacy seriously. Any personal data (i.e. information that can be used to identify you as an individual) which you provide to the University by participating in this survey will be treated with the highest standards of security and confidentiality, in accordance with the EU General Data Protection Regulation (GDPR). Please see our Data Protection Notice www.ecomuseumlive.eu/privacy_policy for further information about how we process your data.

- Yes
- No

Submit

Great!
Your data was sent successfully.
Thank you for taking the time to record your sighting. You can find updates on www.ecomuseumlive.eu/commonlizard or follow our social media channels @ecomuseumslive & #IveraghLizards

Figure App. 5 – Details of the sightings submission form for Iveragh Lizards portal (WWW12).

Chapter 4

Supplementary Data

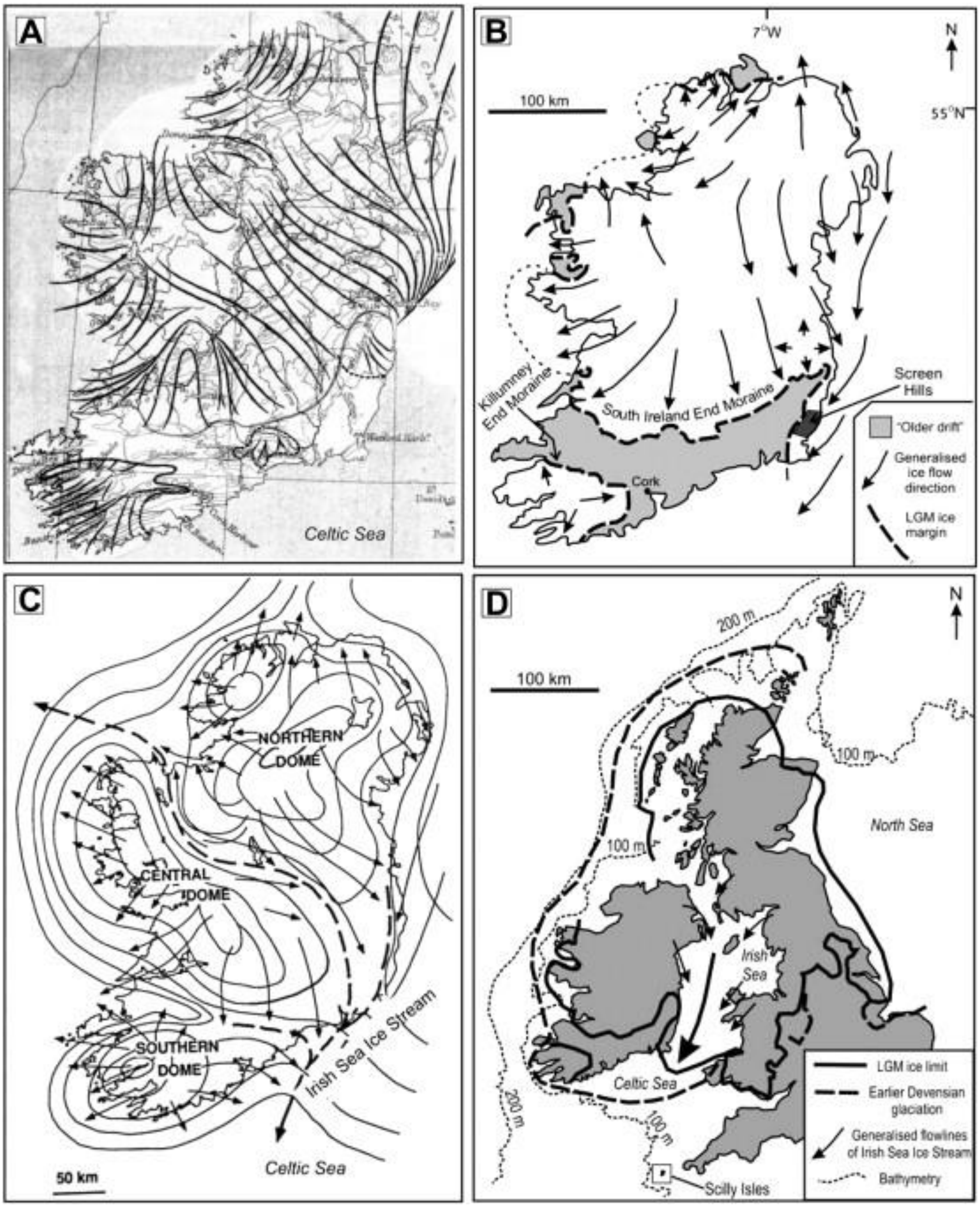


Figure App. 6 – Maps of glaciation extent in Ireland from Ó'Coifaigh *et al*., 2006.

Sequence alignments (not narrowed down to haplotypes):

```
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```

```
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ZV_ND2for_04_cork
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ZV_ND2CONS_06_Portmagee
CCtTTACTAATGAACCCCTTTATTTTATCCATAATAATTTCCAACTTAGCCCTCGGAACA        60
ZV_ND2_CONS_07_Valentia
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ZV_ND2_CONS_08_CGregory
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                             **************************************************
*********

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ZV_ND2_CONS_08_CGregory
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                             **************************************
*********************

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ZV_ND2_CONS_03_cork
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ZV_ND2for_04_cork
CTAGCTATTATTCCAATTTTAGCTAAACAACACCACCCACGAGCTACTGAAGCTGCTACA        180
ZV_ND2for_05_cork
CTAGCTATTATTCCAATTTTAGCTAAACAACACCACCCACGAGCTACTGAAGCTGCTACA        180
ZV_ND2_cons_02_CDaniel
CTAGCTATTATTCCAATTTTAGCTAAACAACACCACCCACGAGCTACTGAAGCTGCTACA        180
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ZV_ND2CONS_06_Portmagee
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ZV_ND2_CONS_08_CGregory
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************************************************************

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ZV_ND2for_05_cork
GCCTATCATACAGGAACCTGAGATATTACCCAACTAACTACTCATCCAACTCCCTCCCTA        300
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GCCTATCATACAGGAACCTGAGATATTACCCAACTAACTACTCATCCAACTCCCTCCCTA        300
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ZV_ND2_CONS_08_CGregory
GCCTATCATACAGGAACCTGAGATATTACCCAACTAACTACTCATCCAACTCCCTCCCTA        300

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ZV_ND2_cons_01_cork
CTAACAATTGCACTGGCCATAAAACTAGGCCTCGTCCCAATACACTTTTGACTACCAGAA        360
ZV_ND2_CONS_03_cork
CTAACAATTGCACTGGCCATAAAACTAGGCCTCGTCCCAATACACTTTTGACTACCAGAA        360
ZV_ND2for_04_cork
CTAACAATTGCACTGGCCATAAAACTAGGCCTCGTCCCAATACACTTTTGACTACCAGAA        360
ZV_ND2for_05_cork
CTAACAATTGCACTGGCCATAAAACTAGGCCTCGTCCCAATACACTTTTGACTACCAGAA        360
ZV_ND2_cons_02_CDaniel
CTAACAATTGCACTGGCCATAAAACTAGGACTCGTCCCAATACACTTTTGACTACCAGAA        360
ZV_ND2CONS_06_Portmagee
CTAACAATTGcACTGGCCATAAAACTAGGACTCGTCCCAATACACTTTTGACTACCAGAA        360
ZV_ND2_CONS_07_Valentia
CTaACAATTGCACTGGCCAtAAAAcTAGGACTCGTCCCAATACACTTTtGACTACCAGAA        360
ZV_ND2_CONS_08_CGregory
CTAACAATTGCACTGGCCATAAAACTAGGACTCGTCCCAATACACTTTTGACTACCAgAA        360
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ZV_ND2_cons_01_cork
GTTATACAAGGTGTTAACACAATAACAGCCTTAATTATTACAACATGACAAAAACTACCA        420
ZV_ND2_CONS_03_cork
GTTATACAAGGTGTTAACACAATAACAGCCTTAATTATTACAACATGACAAAAACTACCA        420
ZV_ND2for_04_cork
GTTATACAAGGTGTTAACACAATAACAGCCTTAATTATTACAACATGACAAAAACTACCA        420
ZV_ND2for_05_cork
GTTATACAAGGTGTTAACACAATAACAGCcTTAATTATTACAACATGACAAAAACTACCA        420
ZV_ND2_cons_02_CDaniel
GTTATACAAGGTGTTAACACAATAACAGCCTTAATTATTACAACATGACAAAAACTACCA        420
ZV_ND2CONS_06_Portmagee
GTTATACAAGGTGtTAACACAATAACAGCCTTAATTATTACAACATGaCAAAAACTACCA        420
ZV_ND2_CONS_07_Valentia
GTTATACAAGGTGTTAACACAATAACAGCcTTAATTATTACAACATGACAAAAACTACCA        420
ZV_ND2_CONS_08_CGregory
GTTATACAAGGTGTTAACACAATAACAGCCTTAATTATTACAACATGACAAAAACTACCA        420

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ZV_ND2_cons_01_cork
CCAATATTTCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTA        480
ZV_ND2_CONS_03_cork
CCAATATTTCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTA        480
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ZV_ND2for_04_cork
CCAATATTTCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTA        480
ZV_ND2for_05_cork
CCAATATTTCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTA        480
ZV_ND2_cons_02_CDaniel
CCAATATTTCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTA        480
ZV_ND2CONS_06_Portmagee
CCAATATTTCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTA        480
ZV_ND2_CONS_07_Valentia
CCAATATTTCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTA        480
ZV_ND2_CONS_08_CGregory
CCAATATTTCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTA        480

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ZV_ND2_cons_01_cork
GCCATTTCTTCTACACTAATCAGCGGATGATCTGGACTTaACCAAACaCAACtACGAAAA        540
ZV_ND2_CONS_03_cork
GCCATTTCTTCTACACTAATCAGCGGATGATCTGGACTTAACCAAACACAACTACGAAAA        540
ZV_ND2for_04_cork
GCCATTTCTTCTACACTAATCAGCGGATGATCTGGACTTAACCAAACACAACTACGAAAA        540
ZV_ND2for_05_cork
GCCATTTCTTCTACACTAATCAGCGGATGATCTGGACTTAACCAAACACAACTACGAAAA        540
ZV_ND2_cons_02_CDaniel
GCCATTTCTTCtAcaCTAatCAGTGGATGATCTGGACTTAACCAAACACAACTaCGAAAA        540
ZV_ND2CONS_06_Portmagee
GCCATTTCTTCTACACTAATCAGCGGATGATCTGGACTTAACCAAACACAACTACGAAAA        540
ZV_ND2_CONS_07_Valentia
GCCATTTCTTCTACACTAATCAGCGGATGATCTGGACTTAACCAAACACAACTACGAAAA        540
ZV_ND2_CONS_08_CGregory
GCCATTTCTTCTACACTAATCAGCGGATGATCTGGACTTAACCAAACACAACTACGAAAA        540
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ZV_ND2_cons_01_cork
ATTATAGcATaTTCATcAaTTGGaCaCTTaGGATGAATGTTTGCTATCCTATCCACTTCC        600
ZV_ND2_CONS_03_cork
ATTATAGCATATTCATCAATTGGACACTTAGgATGAATGTTTGCTATCCTATCCACTtCC        600
ZV_ND2for_04_cork
ATTATAGCATATTCATCAATTGGACACTTAGGATGAATGTTTGCTATCCTATCCACTTCC        600
ZV_ND2for_05_cork
ATTATAGCATATTCATCAATTGGACACTTAGGATGAATGTTTGCTATCCTATCCACTTCC        600
ZV_ND2_cons_02_CDaniel
ATTATAGcATaTTCATcAaTTGGACACTTaGGATGAATGTTTGCTATCCTATCCACTTCC        600
ZV_ND2CONS_06_Portmagee
ATTATAGCATATTCATCAaTTGGACACTTAgGATGAATGTTTGCTATCCTATCCACTTCC        600
ZV_ND2_CONS_07_Valentia
ATTATAGCATATTCATCAATTGGACACTTAGGATGAATGTTTGCTATCCTATCCACTTCC        600
ZV_ND2_CONS_08_CGregory
ATTATAGCATATTCATCAaTTGGACACTTAGGATGAATGTTTGCTATCCTATCCaCTTCC        600

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ZV_ND2_cons_01_cork
CAAAAACTACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTtTTTTA        660
ZV_ND2_CONS_03_cork
CAAAAACTACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTTTTTTA        660
ZV_ND2for_04_cork
CAAAAACTACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTTTTTTA        660
ZV_ND2for_05_cork
CAAAAACTACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTTTTTTA        660
ZV_ND2_cons_02_CDaniel
CAAAAACTACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTtTTTTA        660
ZV_ND2CONS_06_Portmagee
CAAAAACTACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTTTTTTA        660
ZV_ND2_CONS_07_Valentia
CAAAAACTACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTTTTTTA        660
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ZV_ND2_CONS_08_CGregory
CAAAAACTACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTTTTTTA        660

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ZV_ND2_cons_01_cork
ATTCtTATTACCTCAACAACAAAAACCATTAAGGACCTAGGaATaCTAtGAACAACCTCC        720
ZV_ND2_CONS_03_cork
ATTCTTATTACCTCAACAACAAAAACCATTAAGGACCTAGGAATACTATGAACAACCTCC        720
ZV_ND2for_04_cork
ATTCTTATTACCTCAACAACAAAAACCATTAAGGACCTAGGAATACTATGAACAACCTCC        720
ZV_ND2for_05_cork
ATTCTTATTACCTCAACAACAAAAACCATTAAGGACCTAGGAATACTATGAACAACCTCC        720
ZV_ND2_cons_02_CDaniel
ATTCTTATTACCTCAACAACAAAAACCATTAAGGACCTAGGaATaCTAtGAACAACCTCC        720
ZV_ND2CONS_06_Portmagee
ATTCTTATTACCTCAACAACAAAAACCATTAAgGACCTAGgAATACTATGAACAACCTCC        720
ZV_ND2_CONS_07_Valentia
ATTCTTATTACCTCAACAACAAAAACCATTAAGGACCTAGGAATACTATGAACAACCTCC        720
ZV_ND2_CONS_08_CGregory
ATTCTTATTACCTCAACAACAAAAACCATTAAGGACCTAGGAATACTATGAACAACCTCC        720

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ZV_ND2_cons_01_cork
CCaaCAtCatGCACAATAACAATAATTATTTTCATAGCAtTAGGAGGCcTCCCTCCCtta        780
ZV_ND2_CONS_03_cork
CCAACATCATGCACAATAACAATAATTATTTTCATAGCATTAGGAGGCCTCCCTCCCTTA        780
ZV_ND2for_04_cork
CCAACATCATGCACAATAACAATAATTATTTTCATAGCATTAGGAGGCCTCCCTCCCTTA        780
ZV_ND2for_05_cork
CCAACATCATGCACAATAACAATAATTATTTTCATAGCATTAGGAGGCCTCCCTCCCTTA        780
ZV_ND2_cons_02_CDaniel
CCaaCAtCatGCACAATAACAATAATTATTTTCATAGCAtTAGGAGGCcTCCCTCCCtta        780
ZV_ND2CONS_06_Portmagee
CCAacatcatgcacaataacaataattatTTTCATAGCATTAGGAGGCCTCCCTCCCTTA        780
ZV_ND2_CONS_07_Valentia
CCAACATCATGCACAATAACAATAATTATTTTCATAGCATTAGGAGGCCTCCCTCCCTTA        780
ZV_ND2_CONS_08_CGregory
CCAACATCATGCACAATAACAATAATTATTTTCATAGCATTAGGAGGCCTCCCTCCCTTA        780

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ZV_ND2_cons_01_cork
TctGGCTTCCTACCCAAATGATTAATTCTAGAAGaGtTAACCACTAACCACCTCATCCCA        840
ZV_ND2_CONS_03_cork
TCTGGCTTCCTACCCAAATGATTAATTCTAGAAGAGTTAACCACTAACCACCTCATCCCA        840
ZV_ND2for_04_cork
TCTGGCTTCCTACCCAAATGATTAATTCTAGAAGAGTTAACCACTAACCACCTCATCCCA        840
ZV_ND2for_05_cork
TCTGGCTTCCTACCCAAATGATTAATTCTAGAAGAGTTAACCACTAACCACCTCATCCCA        840
ZV_ND2_cons_02_CDaniel
TctGGCTTCCTAcCCAAATGATtAATTCTAGAAGaGtTAACCACTAACCaCCTCATCCCA        840
ZV_ND2CONS_06_Portmagee
TCTGGCTTCCTACCCAAATGATTAATTCTAGAAGAGTTAACCACTAACCACCTCATCCCA        840
ZV_ND2_CONS_07_Valentia
TCTGGCTTCCTACCCAAATGATTAATTCTAGAAGAGTTAACCACTAACCACCTCATCCCA        840
ZV_ND2_CONS_08_CGregory
TCTGGCTTCCTACCCAAATGATTAATTCTAGAAGAGTTAACCACTAACCACCTCATCCCA        840

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ZV_ND2_cons_01_cork
CTAGCAACCACACTTACTCTTaCAtCAcTTTTaAGCcTAATaTtttATATGCGctTAACA        900
ZV_ND2_CONS_03_cork
CTAGCAACCACACTTACTCTTACATCACTTTTAAGCCTAATATTTTATATGCGCTTAACA        900
ZV_ND2for_04_cork
CTAGCAACCACACTTACTCTTACATCACTTTTAAGCCTAATATTTTATATGCGCTTAACA        900
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ZV_ND2for_05_cork
CTAGCAACCACACTTACTCTTACATCACTTTTAAGCCTAATATTTTATATGCGCTTAACA        900
ZV_ND2_cons_02_CDaniel
cTAGCAACCACACTTACTCTTACATCAcTTTTaAGCcTAATATtttATATGCGctTAACA        900
ZV_ND2CONS_06_Portmagee
CTAGCAACCACACTTACTCTTACATCACTTTTAAGCCTAATATTTTATATGCGCTTAACA        900
ZV_ND2_CONS_07_Valentia
CTAGCAACCACACTTACTCTTACATCACTTTTAAGCCTAATATTTTATATGCGCTTAACA        900
ZV_ND2_CONS_08_CGregory
CTAGCAACCACACTTACTCTTACATCACTTTTAAGCCTAATATTTTATATGCGCTTAACA        900

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ZV_ND2_cons_01_cork          TATACtaCAACACT        914
ZV_ND2_CONS_03_cork          TATACTACAACACT        914
ZV_ND2for_04_cork            TaTACTAcaacact        914
ZV_ND2for_05_cork            TATACTACAACACT        914
ZV_ND2_cons_02_CDaniel       TATACtaCAACACT        914
ZV_ND2CONS_06_Portmagee      TATACTACAACACT        914
ZV_ND2_CONS_07_Valentia      TATACTACAACACT        914
ZV_ND2_CONS_08_CGregory      TATACTACAACACT        914
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Percentage identity matrix:

	ND2_01_cork	ND2_03_cork	ND2_04_cork	ND2_05_cork	ND2_02_CDaniel	ND2_06_P'magee	ND2_07_Valentia	ND2_08_CGregory
ND2_01_cork	100	100	100	100	99.78	99.78	99.78	99.78
ND2_03_cork	100	100	100	100	99.78	99.78	99.78	99.78
ND2_04_cork	100	100	100	100	99.78	99.78	99.78	99.78
ND2_05_cork	100	100	100	100	99.78	99.78	99.78	99.78
ND2_02_CDaniel	99.78	99.78	99.78	99.78	100	99.78	99.78	99.78
ND2_06_P'magee	99.78	99.78	99.78	99.78	99.78	100	100	99.78
ND2_07_Valentia	99.78	99.78	99.78	99.78	99.78	100	100	99.78
ND2_08_CGregory	99.78	99.78	99.78	99.78	99.78	99.78	99.78	100

Sequence alignments of Irish haplotypes:

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ZV_ND2_HAP1_cork
AATGAACCCCTTTATTTTATCCATAATAATTTCCAACTTAGCCCTCGGAACAATCATTAC        60
ZV_ND2_HAP2_CDaniel
AATGAACCCCTTTATTTTATCCATAATAATTTCCAACTTAGCCCTCGGAACAATCATTAC        60
ZV_ND2_HAP3_PmageeValen
AATGAACCCCTTTATTTTATCCATAATAATTTCCAACTTAGCCCTCGGAACAATCATTAC        60
ZV_ND2_HAP4_CGregory
AATGAACCCCTTTATTTTATCCATAATAATTTCCAACTTAGCTCTCGGAACAATCATTAC        60
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ZV_ND2_HAP1_cork
TGCTGCCAGCTATCATTGATTTATAGCATGGGTTGGCCTAGAAATAAATACACTAGCTAT        120
ZV_ND2_HAP2_CDaniel
TGCTGCCAGCTATCATTGATTTATAGCATGGGTTGGCCTAGAAATAAATACACTAGCTAT        120
ZV_ND2_HAP3_PmageeValen
TgcTGcCAGCTATCATTGATTTATAGCATGAGTTGGcCTAGAAATAAATACACTAGCTAT        120
ZV_ND2_HAP4_CGregory
TGCTGCCAGCTATCATTGATTTATAGCATGGGTTGGCCTAGAAATAAATACACTAGCTAT        120
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ZV_ND2_HAP1_cork
TATTCCAATTTTAGCTAAACAACACCACCCACGAGCTACTGAAGCTGCTACAAAATATTT        180
ZV_ND2_HAP2_CDaniel
TATTCCAATTTTAGCTAAACAACACCACCCACGAGCTACTGAAGCTGCTACAAAATATTT        180
ZV_ND2_HAP3_PmageeValen
TATTCCAATTTTAGCTAAACAACACCACCCACGAGCTACTGaAGCTGcTACAAAATATTT        180
ZV_ND2_HAP4_CGregory
TATTCCAATTTTAGCTAAACAACACCACCCACGAGCTACTGAAGCTGCTACAAAATATTT        180

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ZV_ND2_HAP1_cork
TATTATTCAAATAACAGCCTCATCCATTATCTTATTTTCTAGCATCTTTAACGCCTATCA        240
ZV_ND2_HAP2_CDaniel
TATTATTCAAATAACAGCCTCATCCATTATCTTATTTTCTAGCATCTTTAACGCCTATCA        240
ZV_ND2_HAP3_PmageeValen
TATTATTCAAATAACAGCCTCATCCATTATCTTATTTTCTAGCATCTTTAACGCCTATCA        240
ZV_ND2_HAP4_CGregory
TATTATTCAAATAACAGCCTCATCCATTATCTTATTTTCTAGCATCTTTAACGCCTATCA        240

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ZV_ND2_HAP1_cork
TACAGGAACCTGAGATATTACCCAACTAACTACTCATCCAACTCCCTCCCTACTAACAAT        300
ZV_ND2_HAP2_CDaniel
TACAGGAACCTGAGATATTACCCAACTAACTACTCATCCAACTCCCTCCCTACTAACAAT        300
ZV_ND2_HAP3_PmageeValen
TACAGGAACCTGAGATATTACCCAACTAACTACTCATCCAACTCCCTCCCTACTAACAAT        300
ZV_ND2_HAP4_CGregory
TACAGGAACCTGAGATATTACCCAACTAACTACTCATCCAACTCCCTCCCTACTAACAAT        300

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ZV_ND2_HAP1_cork
TGCACTGGCCATAAAACTAGGCCTCGTCCCAATACACTTTTGACTACCAGAAGTTATACA        360
ZV_ND2_HAP2_CDaniel
TGCACTGGCCATAAAACTAGGACTCGTCCCAATACACTTTTGACTACCAGAAGTTATACA        360
ZV_ND2_HAP3_PmageeValen
TGcACTGGCCATAAAACTAGGACTCGTCCCAATACACTTTTGACTACCAGAAGTTATACA        360
ZV_ND2_HAP4_CGregory
TGCACTGGCCATAAAACTAGGACTCGTCCCAATACACTTTTGACTACCAgAAGTTATACA        360
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ZV_ND2_HAP1_cork
AGGTGTTAACACAATAACAGCCTTAATTATTACAACATGACAAAAACTACCACCAATATT        420
ZV_ND2_HAP2_CDaniel
AGGTGTTAACACAATAACAGCCTTAATTATTACAACATGACAAAAACTACCACCAATATT        420
ZV_ND2_HAP3_PmageeValen
AGGTGtTAACACAATAACAGCCTTAATTATTACAACATGaCAAAAACTACCACCAATATT        420
ZV_ND2_HAP4_CGregory
AGGTGTTAACACAATAACAGCCTTAATTATTACAACATGACAAAAACTACCACCAATATT        420

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ZV_ND2_HAP1_cork
TCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTAGCCATTTC        480
ZV_ND2_HAP2_CDaniel
TCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTAGCCATTTC        480
ZV_ND2_HAP3_PmageeValen
TCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTAGCCATTTC        480
ZV_ND2_HAP4_CGregory
TCTACTTTACCTAACCGCCAACCAACTTCCAATAGTAATCTTACTATTATTAGCCATTTC        480

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ZV_ND2_HAP1_cork
TTCTACACTAATCAGCGGATGATCTGGACTTaACCAAACaCAACtACGAAAAATTATAGc        540
ZV_ND2_HAP2_CDaniel
TTCtAcaCTAatCAGTGGATGATCTGGACTTAACCAAACACAACTaCGAAAAATTATAGc        540
ZV_ND2_HAP3_PmageeValen
TTCTACACTAATCAGCGGATGATCTGGACTTAACCAAACACAACTACGAAAAATTATAGC        540
ZV_ND2_HAP4_CGregory
TTCTACACTAATCAGCGGATGATCTGGACTTAACCAAACACAACTACGAAAAATTATAGC        540
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ZV_ND2_HAP1_cork
ATaTTCATcAaTTGGaCaCTTaGGATGAATGTTTGCTATCCTATCCACTTCCCAAAAACT        600
ZV_ND2_HAP2_CDaniel
ATaTTCATcAaTTGGACACTTaGGATGAATGTTTGCTATCCTATCCACTTCCCAAAAACT        600
ZV_ND2_HAP3_PmageeValen
ATATTCATCAaTTGGACACTTAgGATGAATGTTTGCTATCCTATCCACTTCCCAAAAACT        600
ZV_ND2_HAP4_CGregory
ATATTCATCAaTTGGACACTTAGGATGAATGTTTGCTATCCTATCCaCTTCCCAAAAACT        600

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ZV_ND2_HAP1_cork
ACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTtTTTTAATTCtTAT        660
ZV_ND2_HAP2_CDaniel
ACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTtTTTTAATTCTTAT        660
ZV_ND2_HAP3_PmageeValen
ACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTTTTTTAATTCTTAT        660
ZV_ND2_HAP4_CGregory
ACTACTCTTTACCCTAACAATATATCTCCTCATAACTATCCCCATTTTTTTAATTCTTAT        660

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ZV_ND2_HAP1_cork
TACCTCAACAACAAAAACCATTAAGGACCTAGGaATaCTAtGAACAACCTCCCCaaCAtC        720
ZV_ND2_HAP2_CDaniel
TACCTCAACAACAAAAACCATTAAGGACCTAGGaATaCTAtGAACAACCTCCCCaaCAtC        720
ZV_ND2_HAP3_PmageeValen
TACCTCAACAACAAAAACCATTAAgGACCTAGgAATACTATGAACAACCTCCCCAacatc        720
ZV_ND2_HAP4_CGregory
TACCTCAACAACAAAAACCATTAAGGACCTAGGAATACTATGAACAACCTCCCCAACATC        720

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ZV_ND2_HAP1_cork
atGCACAATAACAATAATTATTTTCATAGCAtTAGGAGGCcTCCCTCCCttaTctGGCTT        780
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ZV_ND2_HAP2_CDaniel
atGCACAATAACAATAATTATTTTCATAGCAtTAGGAGGCcTCCCTCCCttaTctGGCTT        780
ZV_ND2_HAP3_PmageeValen
atgcacaataacaataattatTTTCATAGCATTAGGAGGCCTCCCTCCCTTATCTGGCTT        780
ZV_ND2_HAP4_CGregory
ATGCACAATAACAATAATTATTTTCATAGCATTAGGAGGCCTCCCTCCCTTATCTGGCTT        780

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ZV_ND2_HAP1_cork
CCTACCCAAATGATTAATTCTAGAAGaGtTAACCACTAACCACCTCATCCCACTAGCAAC        840
ZV_ND2_HAP2_CDaniel
CCTAcCCAAATGATtAATTCTAGAAGaGtTAACCACTAACCaCCTCATCCCAcTAGCAAC        840
ZV_ND2_HAP3_PmageeValen
CCTACCCAAATGATTAATTCTAGAAGAGTTAACCACTAACCACCTCATCCCACTAGCAAC        840
ZV_ND2_HAP4_CGregory
CCTACCCAAATGATTAATTCTAGAAGAGTTAACCACTAACCACCTCATCCCACTAGCAAC        840

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ZV_ND2_HAP1_cork
CACACTTACTCTtaCAtCAcTTTTaAGCcTAATaTtttATATGCGctTAACATATACtaC        900
ZV_ND2_HAP2_CDaniel
CACACTTACTCTTACATCAcTTTTaAGCcTAATATtttATATGCGctTAACATATACtaC        900
ZV_ND2_HAP3_PmageeValen
CACACTTACTCTTACATCACTTTTAAGCCTAATATTTTATATGCGCTTAACATATACTAC        900
ZV_ND2_HAP4_CGregory
CACACTTACTCTTACATCACTTTTAAGCCTAATATTTTATATGCGCTTAACATATACTAC        900

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ZV_ND2_HAP1_cork             AACACT       906
ZV_ND2_HAP2_CDaniel          AACACT       906
ZV_ND2_HAP3_PmageeValen      AACACT       906
ZV_ND2_HAP4_CGregory         AACACT       906
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