A review of the occurrence of bats (Chiroptera) on islands in the North East Atlantic and on North Sea installations.

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ABSTRACT

The bats recorded from Iceland, the Faroe Islands, the Shetland Islands, the Orkney Islands, and North Sea installations are reviewed to the end of 2012. In total 12 species have been positively identified, while a considerable proportion of all records are sightings of unidentified bats. The largest number of species (8) has been recorded in Iceland, but the greatest number of individuals (180) has been found in Orkney. The most numerous species was *Pipistrellus pipistrellus*, which was only found in Orkney where summer roosts were recorded from 1994-2010. All other species have been recorded only as vagrants or stowaways. The next most common bats of European origin were *Pipistrellus nathusii* and *Vespertilio murinus,* while other European species included *Eptesicus nilssonii*, *E. serotinus*, *Nyctalus leisleri*, *N. noctula*, and *Plecotus auritus.* Four species of North American bats, *Eptesicus fuscus*, *Lasiurus cinereus*, *Myotis lucifugus* and *M. septentrionalis*, are of rare occurrence. The bat invasion on the Faroe Islands in 2010 is without precedence, when 70 observations of a minimum of 45 individuals were noted. Most bat observations in the study area occurred in the autumn, with fewer in the spring. Most observations were of single animals, but there were also multiple sightings of up to 12 individuals. There has been a marked increase in bat records in the past three decades. We discuss whether this is a real increase, or due to improved communications, increased public awareness, increased shipping, and / or the effects of climate change. All factors appear to be involved.

INTRODUCTION

The order Chiroptera is widespread through most parts of the World. The greatest proportion of families, genera and species are found in the tropics and sub-tropics, with a lower proportion in temperate zones. Within temperate zones, the number of species decreases with increasing latitude. In temperate zones, the insectivorous bats are restricted to

those areas that are capable of providing good supplies of food to sustain them through the spring and summer breeding periods and enable them to build up adequate fat reserves in the late summer and autumn ready for their retreat into hibernation through the winter (Yalden and Morris, 1975; Hill and Smith, 1984; Rolland *et al*., 2014).

Migratory behaviour and vagrancy are particularly well-known in birds and bats (Ahlén, 1997; Hutterer *et al*., 2005; Ahlén *et al*., 2009). Their ability to fly makes it easier for them than for most other animals to disperse outside their normal range. Bats employ a variety of strategies to make best use of the available habitats. Some species occupy relatively small territories, travelling only short distances in search of food and between breeding roosts and winter hibernacula, while other species migrate for medium to long distances, in order to exploit resource-rich areas.

The North East Atlantic islands, comprising Iceland with its fluctuation between subarctic winters and temperate summers and the Faroe, Shetland and Orkney islands with temperate but cold winters and cool summers, with one exception do not have resident populations of bats. Nor are the islands considered to be on normal migration routes, although stragglers do reach them on occasion. The species involved and the frequency of these occurrences undoubtedly depends on the distance from their normal range, but a number of other factors, such as population numbers, vagrancy, and unintentional transport by humans, are also important. In the long run, global environmental changes such as climate change may also modify traditional distribution patterns.

The present study examines records of bats from the North East Atlantic islands of Iceland and the Faroe Islands to the end of December 2012, including those reported in previous publications (Koopman and Gudmundsson, 1966; Petersen, 1993, 1994; Baagøe and Bloch, 1994). Comparisons are made with published data on bats recorded from the Shetland

Islands and the Orkney Islands, off the north coast of Scotland, as well as oil and gas installations in the North Sea.

Information is provided on all of the species recorded from the study areas; the locations of the records are mapped and the species composition, distribution and seasonal occurrence analysed. The possible reasons for the marked increase in the occurrences of bats in these study areas, especially the unusual invasion of the Faroe Islands in 2010, are discussed.

MATERIALS AND METHODS

This study summarizes all available information to the end of 2012, based on specimens of bats preserved mainly in the collections of the Náttúrufræðistofnun Íslands (Icelandic Institute of Natural History) [IINH], with single specimens respectively at the Natural History Museum of Kópavogur and at Vestmannaeyjar Primary School (Appendix 1). Available Faroese specimens are preserved in the scientific collection of the Føroya Náttúrugripasavn (Faroese Museum of Natural History) [FMNH] (Appendix 2). It also includes published records of bats from the Orkney Islands, Shetland Islands, and from oil and gas installations in the North Sea (Appendices 3 – 5). The map (Fig. 1) shows the overall area covered by this study.

The specimens preserved in the collections of IINH and FMNH have been acquired opportunistically over many years by interested members of the public. Specimens were identified by the use of literature available at the time of acquisition and by consultation with staff in other European museums containing international collections of bats. Photographs are available as proof for some bat sightings, although the species could not be established in most cases. Sound recordings using a Pettersson Ultrasound detector D100 have also been used in the Faroe Islands. This detector type may only be used to locate flying bats but not for

species identification. In Iceland and the Faroes, sightings were assessed by interviews and requests for photographs because of the problems that exist due to the general public confusing bats with insects and birds. Insects which are especially likely to cause confusion are the larger moths (Jensen and Sivertsen, 2010), while small petrels (seabirds) have an erratic flight similar to that of bats and may be easily misidentified at a distance.

Records of bats from the Orkney and Shetland Islands, and from North Sea installations were obtained by literature searches. Records of bats from the Orkney Islands have been particularly well documented over the last two decades, as a result of observations by members of the very active Orkney Field Club (Booth, 1992 – Booth, 2012). Information for the Shetland Islands was initially derived from the website of the Shetland Biological Records Centre (http://www.nature-shetland.co.uk/brc/bats.htm) and (http://www.nature-shetland.co.uk/naturelatest/archives/), and for North Sea installations from Swift (2004); where possible these records have been traced back to the original references (Appendices 3 – 5).

Coordinates for localities on Iceland were determined using Google Earth (http://earth.google.com), while the website http://www.findlatitudeandlongitude.com was used for localities on the Faroe Islands. Coordinates for localities on the Shetland and Orkney Islands were principally located by reference to the gazetteer (Ordnance Survey, 1999) supplemented by Google Earth (http://earth.google.com). Coordinates for North Sea Installations not included in the original references were determined using maps of North Sea oil and gas fields (http://www.acorn-ps.com/web/page/oilgas/nsfields/snsmap.htm and http://tools.decc.gov.uk/en/content/cms/tools/quad_maps/quad_maps.aspx). Distribution maps were prepared using DMAP (http://www.dmap.co.uk).

RESULTS

To the end of December 2012, 12 species of bats all belonging to the family Vespertilionidae have been recorded from the area of study: eight species from Iceland, six species from the Shetland Islands, and five species each from the Faroe Islands, the Orkney Islands and North Sea installations and vessels. The results summarised in Table 1 show that the greatest number of records is 180 for Orkney, 96 for the Faroes, 58 for Shetland, with totals of 38 and 30 respectively for Iceland and North Sea installations. Information on each of these species is provided below.

The records

All the records for North Sea installations and the Shetland Islands were of single animals. In Iceland 31 of the records (94%) were of single animals, with one instance of two animals and another of six. This differs from the Faroe Islands, where 74 records (77%) were of single animals, 21 of two (10%), three (5%), or four (6%) animals. In the Orkney Islands four of the species were recorded as single animals, but there were many multiple sightings of *Pipistrellus pipistrellus* ranging from three to 12 animals.

A considerable proportion of the records are of unidentified bats. Less than half of the Icelandic and Orkney records fall into this category but as many as two-thirds of the Faroese records. This is explained by the variable nature of the records, for while only a third of the bat records from Iceland were sightings, the majority (76%) in the Faroe Islands were sightings. Just over half of the Icelandic records are of bats which were found alive, while this category was 16% for the Faroe Islands. For the Orkney Islands, although only 8% of the records are of identified individuals, 39% of the records are of sightings identified to species with the use of a bat detector and only 11% are sightings. In contrast all of the published records for North Sea installations are identified to species.

Species accounts

Eptesicus fuscus (Palisot de Beauvois, 1796)

Occurs from South Canada to Colombia and North Brazil; Alaska, Greater and Lesser Antilles, Bahamas (Simmons, 2005). There are two records from England of imported specimens (Hutson, 2008a).

A single individual was found alive in March 2000 in a store in Reykjavík, Iceland that imports fruits and live plants from different parts of the World. The bat was believed to have arrived in a container of bananas from South America. This species is very similar to and may be conspecific with *E. serotinus* (Simmons, 2005). The specimen was identified on the basis of its smaller size and probable origin.

Eptesicus nilssonii (Keyserling and Blasius, 1839)

Occurs in central and eastern Europe (Dietz *et al*., 2009). It is considered to be the most common and widespread species of bat in Norway and also in Sweden, where it has been recorded north of the Arctic Circle in both countries (Syvertsen *et al*., 1995; Ahlén, 2011; Frafjord, 2013). It occurs above 64° N in northern Finland (Siivonen and Wermundsen, 2008). There are very few records in England (Hutson, 2008b).

Single individuals have been recorded respectively in August 1993 from the "Dundee Explorer" oil platform in the North Sea (Speakman *et al*., 1995) and from the Faroes in May 1994 (Fig. 2).

Eptesicus serotinus (Schreber, 1774)

Occurs throughout Europe as far north as 55° N (Dietz *et al*., 2009) and also in southern Sweden (Ahlén, 2011). In England it is found mainly in the southeast, but also in central and northwest England and Wales (Entwistle *et al*., 2001; Hutson, 2008b).

There is a single record from Whalsay, Shetland in October 1991 (Fig. 3) and a recently deceased specimen was found in timber storage on the Faroes in April 2007 (Fig. 2) and may have arrived by ship.

Lasiurus cinereus (Palisot de Beauvois, 1796)

Occurs in Canada, throughout the USA, Mexico, Guatemala, most of South America, Bermuda and the Galapagos Islands (Simmons, 2005). This species has a broad range to the maximum latitude of 64° 20' N in the USA and Canada (Pierson, 1998). However this latitude corresponds to the extralimital record on Southampton Island mentioned by Hill and Yalden (1990), who give the summer limit far lower at latitude c 53° N in southern Canada, whereas in winter the limit is up to 38° N in the USA. Cryan (2003) provided information on distribution patterns throughout the year in North America.

A single individual was found alive in Orkney in 'about September' 1847 and was considered to have arrived via a ship (Wolley, 1849, 1850) (Fig. 4). There are four records from Iceland in October 1943, October and December 1957, and October 1964 (Guðmundsson 1943, 1957; Ryberg 1947; Baldursdóttir 1960; Hayman, 1959; Koopman and Gudmundsson, 1966; Jakobsson 1967; Petersen, 1994) (Fig. 5).

Myotis lucifugus (LeConte, 1831)

This species has a broad range to a maximum latitude of 66° 34' N in the USA and Canada (Pierson, 1998), occurring from Labrador and Newfoundland in Canada to Alaska, southern California, northern Arizona and northern New Mexico in the USA (Simmons, 2005). There is a single record from England of an imported specimen (Hutson, 2008a).

A single immature specimen was recorded from Reykjavik, Iceland in August 1944 (Guðmundsson 1944; Ryberg 1947; Hayman, 1959; Koopman and Gudmundsson, 1966; Jakobsson 1967; Petersen, 1994). Another specimen was found August 1981 on board a ship arriving in Reykjavik harbour from the east coast of the USA (Fig. 5).

Myotis septentrionalis (Trouessart, 1897)

Found in Eastern United States and Canada west to British Columbia, E. Montana, E Wyoming and south to Alabama, Georgia and Florida Panhandle (Simmons, 2005). This

species has a broad range in Canada, intermediate in the USA to the maximum latitude of 61° 25' N (Pierson, 1998). There are no reports of this species from the British Isles.

Petersen (1994) recorded two specimens as *Myotis keeni septentrionalis* from Iceland in August 1981 and August 1993. *Myotis keeni* and *M. septentrionalis* are currently regarded as distinct species (Simmons, 2005). The 1981 specimen was found at the same time as another North American species, *Myotis lucifugus*, and four other bats that were discarded before they could be identified. All specimens were found on board a ship that came from the east coast of the USA, so the identification of this specimen is consistent with *M. septentrionalis*, whereas *Myotis keeni* (Merriam, 1895) is distributed on the west coast of the USA (Alaska Panhandle to West Washington (Simmons, 2005). The other Icelandic individual flew into a house and died, but could have arrived by ship at the nearby Hafnarfjörður harbour.

Nyctalus leisleri (Kuhl, 1817)

Occurs throughout western Europe to the Urals, Caucasus and Turkey to nearly 57° N, however there are no records from Denmark and Scandinavia, except for southern Sweden (information from Simmons, 2005; Dietz *et al*., 2009; Ahlén, 2011). Although rare, this species occurs throughout the British Isles, mainly in central and southern counties of England, also in south western Scotland, a few records from northeast Scotland, and it is widespread and common in Ireland (Haddow and Herman, 2000; Entwistle et al., 2001; Sheil *et al*., 2008).

Single individuals have been recorded respectively from the Faroes in July 1984 (Baagøe and Bloch, 1994) (Fig. 2), Iceland, where it was captured alive in May 2000 (Fig. 5), and on an oil rig in 2002 (Swift, 2004). There are three records from Shetland in July 1968, August 1978, October 1996 (Corbet, 1970; Shetland Biological Records Centre) (Fig. 3). The

reference to a record from Orkney (Swift, 2004) is probably in mistake for one of those from Shetland.

Nyctalus noctula (Schreber, 1774)

The species is widespread in Europe to the Urals and the Caucasus (Dietz *et al*., 2009). It has been recorded rarely in southern Norway (Syvertsen et al., 1995) and has an uneven distribution in central and southern Sweden (Ahlén, 2011). The species is widespread in England, Wales and southwest Scotland but is absent from Ireland (Haddow and Herman, 2000; Entwistle *et al*., 2001; Mackie and Racey, 2008).

A few bats of this species have been recorded from all study areas except Faroes. A pregnant female was recorded from Orkney in June 1976 (Racey, 1977), others in September 1978 and October 1988 (Booth, 1979, 1989) (Fig. 4); three individuals were recorded in July 1977, August 1986 and a female in November 1987 from Shetland (Shetland Biological Records Centre) (Fig. 3); two were recorded on North Sea rigs in 1980 and 1988 (Haddow and Herman, 1995; Swift, 2004); a single specimen was recorded in June 2010 from Iceland (Fig. 5).

Pipistrellus nathusii (Keyserling and Blasius, 1839)

Occurs in western Europe, from southern Scandinavia southwards to France and northern Spain and eastwards to the Urals and Caucasus (Dietz *et al*., 2009). It has been recorded in Norway (Syvertsen *et al*., 1995; Swenson *et al*., 2010) and is found in central and southern Sweden as far north as 61° 21’ N (Ahlén, 2011). Occurs in southern and eastern Scotland, most of England and Wales, and eastern and central Ireland (Russ *et al*., 2001; Russ, 2008).

This is the only species of pipistrelle reliably recorded from North Sea installations, Shetland, Faroes and Iceland, where it is also the most commonly recorded species of bat (Table 1; Figs. 2-3, 5-6). It has also been recorded on the Orkneys (Fig. 4), but here it is less

frequently encountered than is *P. pipistrellus* (7% of the total *P. pipistrellus* and *P. nathusii* records and only 3% of the total records of bats from the Orkneys). The earliest record of this species dates from Shetland in November 1940 (Herman, 1992), the other records from Shetland cover the period from 1987 to 1998, with most records during the autumn and winter months (Russ *et al*., 2001). Similarly, most of the 17 records from the Faroes were in the autumn and winter months and, of the 20 individuals recorded from North Sea rigs in the period from 1988 to 2001, most were in September (Speakman *et al*., 1991, 1993; Russ *et al*., 2001). There were six records from Iceland dating from 1971 to 2012, most in autumn and winter, with one in May. Of the records from Orkney from 1995 to 2010, two were in June and three in September. Four of these were reliably identified specimens, the fifth a sighting confirmed by use of a bat detector (Booth, 1996, 2003, 2007, 2011). It is possible that some of the earlier unidentified *Pipistrellus* records in all study areas are also representatives of this species.

Pipistrellus pipistrellus (Schreber, 1774)

Widespread in Europe, more common than *P. pygmaeus* in central Europe, but rare or absent in the Netherlands and Scandinavia (Jones and Racey, 2008; Ahlén, 2011). Details of distribution remain uncertain on mainland Europe. Occurs throughout the British Isles (Barlow and Jones, 1999; Jones and Racey, 2008).

Reliable records of *P. pipistrellus*, based on professionally identified specimens and the use of bat detectors, have only been obtained from the Orkney Islands (Table 1 and Fig. 4), where it is by far the most commonly recorded species (75% of the total records of *Pipistrellus* and 39% of the records of bats from the Orkneys). There are 71 reliably identified records of this species dating from the earliest record in September 1908 (Spence, 1909) while the majority of the records cover the period from 1992 to 2011. Over this period

the earliest sighting occurred in April, the latest in November, with the majority of sightings occurring from May to September.

Although the Orkney Islands may be considered marginal for the existence of resident bats, there is evidence of summer roosts of *P. pipistrellus* from Melsetter, Hoy from 1994 to 2002 (Holmes, 1994; Holmes *et al*., 1995; Booth, 1995-2003); from the Finstown area of Mainland from 2000 to 2010 (Booth, 2001-2011); from Binscarth Wood, Mainland from 2007 to 2008 (Booth, 2008-2009); and there were sightings during the summer months from Evie, Mainland and on Hoy during 2010 (Booth, 2011) (Fig. 7). Although a summer roost was apparently well established at Melsetter on Hoy for nine years, there have been no subsequent reports from this locality (Booth 2008).

Plecotus auritus (Linnaeus, 1758)

Occurs throughout Europe and Scandinavia (Dietz *et al*., 2009). It is found throughout the lowlands of southern Norway as far north as 63° 25' N (Syvertsen *et al*., 1995), is common in southern and central Sweden (Ahlén, 2011) and occurs above 64° N in northern Finland (Siivonen and Wermundsen, 2008). Widespread in the British Isles, except for the far north of Scotland (Haddow and Herman, 2000; Entwhistle *et al*., 2001; Entwistle and Swift, 2008).

There are four records of this species from Orkney: one in February 1931 (Marwick, 1931), another in October 1948 (Booth, 1986), one observed over a period of eight days in August 1987 (Booth, 1989) and a sighting in September 2006 (Booth, 2007) (Fig. 4). One was recorded from Shetland in December 1947 (Venables and Venables, 1955), another in 1983 and a third in March 1987 (Shetland Biological Records Centre) (Fig. 3).

Vespertilio murinus Linnaeus, 1758

Occurs in Europe eastwards and northwards from eastern France (Dietz *et al*., 2009). It occurs in scattered coastal localities in southern Norway as far north as c. 61° 56' N

(Syvertsen *et al*., 1995) and also has an uneven distribution in southern Sweden (Ahlén, 2011). Occasional records from the British Isles are considered to be of vagrants and migrants (Racey *et al*., 2008).

There have been 17 records of this species from all study areas except Orkney (Table 1; Figs. 2-3, 5-6). The first was from Whalsay, Shetland in March 1927 (Ritchie, 1927), with a further six records in November of 1981, 1984 and 2001, August 2003, June 2009 and June 2011 (Shetland Biological Records Centre; Racey *et al*., 2008). An adult male was recorded in June 1965 from a North Sea oil rig (Stansfield, 1966) and further individuals were recorded from North Sea installations in July 1992, November 2001, December 2001, January 2002 and November 2004 (Racey *et al*., 2008). Two were recorded in Faroes in June 1988 (Baagøe and Bloch, 1994) and September 2010. Specimens were recorded in October 2004 and August 2011 in Iceland.

The invasion in 2010

The bat invasion in the Faroe Islands in 2010 has no precedence. It began on September 12th with two bats caught alive but which later died; one was *Vespertilio murinus*, the second record for the Faroe Islands, and the other *Pipistrellus nathusii,* the 14th record for the islands. After the first two bats were discovered, the general public was asked for information on the local radio. During the next seven weeks (until November 2nd) 70 observations were recorded in 20 towns and villages on 10 of the 17 inhabited islands (Fig. 8). Some of these observations were possibly of the same individuals but during this invasion a minimum of 45 individual animals were observed. No further bats were identified to species.

During the invasion period, two unidentified bats were recorded in Iceland and three in Shetland, which may signify a connection with the phenomenon in the Faroes. None were

recorded on North Sea installations at this time and it is unlikely that the two records of *P. pipistrellus* in Orkney during this period were relevant to the situation in the Faroes.

Seasonal data

The seasonal occurrence of the bats found in all study areas is shown in Figs. 9-10. The majority of *P. nathusii* records peak in September but are also high in October, with a moderate number of records through the autumn and winter but few, if any in July and August (Fig. 9). This contrasts markedly with the seasonal occurrence of *P. pipistrellus* in which high numbers have been recorded from May to September, with a sharp reduction in October and November and no further records for the remainder of the winter. For all other species of bats (Fig. 10), a similar pattern may be seen to that of *P. nathusii*, with the majority of records occurring in September and October.

Frequency data

Records on North Sea installations peaked in 1990-1999 (Table 2). In contrast, there has been a measurable increase in records for the other study areas, in which records in Iceland and the Orkneys peaked in 2000-2009 and were also very high in the next three years. There was a marked increase for Shetland in 1980-1989, with similar numbers recorded for the following two decades but also another sharp increase during 2010-2012. Records in the Faroes have shown a steady increase from the 1990s onwards but because of the exceptional number of records for 2010, the records for 2010-2012 exceed those in any of the previous decades.

DISCUSSION

Monitoring of all wildlife may be considered the duty of any independent nation and the incursion of any non-native species is a matter of interest for a variety of reasons. Bats are of particular interest as they have been recorded as being very rare and irregular vagrants on

the north east Atlantic islands and North Sea installations over the course of many years. The first mention of bats in Iceland is a second-hand report in Pennant (1784). Since this reference does not include a Latin name, identification of the species would be impossible were it not for the reference to an earlier work (Pennant, 1781) in which "411 Common [bat]" clearly refers to *Vespertilio murinus*. Subsequent authors such as Preyer (1862) chose to interpret Pennant's common bat as *Pipistrellus pipistrellus*, while Krzanowski (1977) suggested that *Lasiurus cinereus* was a more likely candidate. However while some species may be more likely than others, such speculation about the species involved is impractical, since Pennant was merely reporting another person's observations.

Further north and west, bats have also occasionally been observed on Greenland, and are understood to have been blown over from North America according to Møbjerg and Rosing (2001). These authors state that the bats have both an East Greenlandic name "Avangiarlik" (the one which resembles a lemming) and in West Greenland, "Imangertaq" (the one which has been silenced). This indicates that bats have been recorded on both sides of the huge Greenland ice-shield, although individual records with locality and date do not seem to be available.

The origin of the species differs between islands. Four of the 12 species (*E. fuscus, L. cinereus, M. lucifugus* and *M. septentrionalis*) are of New World origin, while eight are Old World species. All four of the American species and four European species were recorded on Iceland. With the exception of one record of *L. cinereus* on Orkney, all the other species on the Faroes, Shetland, Orkney and North Sea installations are of European origin.

Most of the bats found in Iceland were recorded in the south and southwest. The largest number has been found in the capital city of Reykjavik, where most of the population lives and where most of the international shipping and air traffic is received. Many of the bats were recorded under such situations that point to assisted passage, either with imported

goods, on board ship or in storage containers. Others found inside houses, or alive outside may also have been assisted rather than arriving independently.

As far as the other island groups are concerned, the inadvertent transport of bats by humans is apparently of less importance. In the Faroe Islands most bats have been observed when catching insects attracted to the street lights in the small settlements around the entire Faroe Islands. While there are four records of bats from the port and capital of Lerwick, and two from the main airfield of Sumburgh there are no other instances of the close proximity of bats to ports or airfields in Shetland, with other records more or less randomly distributed in the islands. Similarly while there are records of three species on South Ronaldsay, the closest island to the Scottish mainland, there are no obvious connections in Orkney to the inadvertent transport of bats by humans.

Movements

The bats recorded from the study areas may be broadly divided into sedentary or migratory species as follows. The tendency to vagrancy and migratory behaviour, which greatly varies between bat species, no doubt has much bearing on whether bats reach the islands without assistance.

Sedentary bats

All three species of *Eptesicus*, two of the three species of *Pipistrellus, Plecotus auritus* and *Myotis septentrionalis* are regarded as largely sedentary species of bats. Both the European species of *Eptesicus, E. nilsonii* and *E. serotinus* have small home ranges, moving only short distances between roosts, but with occasional longer distance dispersal flights in Europe (Hutterer *et al*., 2005; Hutson 2008b). There are, however indications that *E. serotinus* may be spreading slowly northwards (Dietz *et al*., 2009). *Eptesicus fuscus* is a more or less sedentary species according to Hutson (2008a). *Plecotus auritus* is considered to be a relatively sedentary species (Hutterer *et al*., 2005; Baagøe, 2007; Entwistle and Swift, 2008).

Corbet (1970) commented that a specimen found in the autumn on a lightship about 48 km east of Norfolk, UK may have originated from the continent, as this was coincident with a massive fall of birds from Scandinavia. Although recorded rarely in the study areas and then over a long period of time, there are more records of this species than of the other sedentary species. The New World *M. septentrionalis* is a short-range migrant reported to travel a distance of up to 56 km between the summer habitat and the winter hibernacula (Caceres and Barclay, 2000). There are very few records from the study areas of any of these sedentary species (Table 1) and only one individual of a sedentary species, *E. nilsonii* has been recorded from an oil rig. Most of these are believed to be vagrants, whose presence may be attributed to inadvertent transportation by humans.

Most populations of *P. pipistrellus* in central Europe are sedentary, travelling only short distances between winter and summer roosts, although this species may be more migratory in eastern Europe (Hutterer *et al*., 2005; Jones and Racey, 2008). The presence of *P. pipistrellus* on Orkney is a special case, as it is the only species with apparent breeding roosts so far North in Britain. The results show that summer roosts have only been recorded on the largest of the Orkney Islands, namely Mainland and Hoy, with no reports of this species on any of the northern or eastern islands. The locations of summer roosts have changed over time, sometimes with some overlap, when two roosts co-existed for several years. This suggests that there may be sufficient bats for the formation of splinter groups, which may or may not be sustainable depending on conditions. The reasons for these shifts from one location to another may be due to a number of factors, such as weather conditions, adequate food supplies, not only for the spring and summer months for breeding and raising the young but also for building up sufficient fat reserves for the long hibernation period. While the status of this species on the Orkneys may be accepted as that of a resident, it

should also be recognised that the populations may be vulnerable, as they are at the northern boundary of their distributional range.

There is little available information on *Pipistrellus pygmaeus* (Leach, 1825), because most predates the taxonomic separation from *P. pipistrellus*, although Dietz *et al*. (2009) suggested that at least some short-range migration occurs in *P. pygmaeus*. Details of the distribution of this species remain uncertain but it is widespread in Europe and southern Scandinavia. It occurs throughout the British Isles but is apparently less common than *P. pipistrellus* in northern mainland Scotland (Barlow and Jones, 1999; Jones and Racey, 2008). To date this species has not been recorded from any of the study areas but could conceivably be included amongst the records of unidentified *Pipistrellus*. There is one equivocal reference to a bat detector recording in Orkney of a pipistrelle calling in the 50 – 55 kHz range which was attributed to *P. pipistrellus* (Booth, 2010) although calls above 52 kHz are in the range of *P. pygmaeus*. In this study it has been included as an unspecified *Pipistrellus*.

Migratory species

Nyctalus leisleri is considered to be a long-distance migrant, showing regular seasonal NE to SW movements between the summer and winter habitat in Europe (Hutterer *et al*., 2005; Sheil *et al*., 2008). It seems unlikely that migration was a factor in most of the records in the study areas which, apart from two of the records for Shetland in October and December, are mainly in the summer. However strong winds may have affected dispersal in some instances (Corbet, 1970).

In contrast *Nyctalus noctula* is not considered to be such a long range migrant in all areas; it is migratory in eastern Europe, but probably less so in western Europe (Strelkov, 1969; Hutterer *et al*., 2005) and populations are not known to migrate from England in the winter (Mackie and Racey, 2008). A few individuals have been recorded migrating from southern Sweden in the autumn (Ahlén, 1997) however, while the species is migratory within

Sweden, the extent to which it migrates beyond this country is unknown. Information on migratory activity in Scandinavia has been recorded by Baagøe (2007) and Ahlén *et al*. (2009). Records from the Orkneys, Shetlands and North Sea installations are regarded as vagrants from Europe (Mackie and Racey, 2008) and perhaps some may originate from Scandinavia. The single specimen from Iceland was found on board a freighter, arriving from Europe, and was undoubtedly ship-assisted.

Pipistrellus nathusii is known to be a seasonal long-distance migrant in Europe (Strelkov, 1969; Pētersons, 2004; Hutterer *et al*., 2005). Despite the fact that it is regarded as a rare species in Sweden, Ahlén (1997) reported dispersal and migratory behaviour in this species in late August and early September, with bats accumulating in coastal areas in numbers ranging from less than ten to more than two hundred individuals. Some of these bats were observed to fly out over the open sea in a southern or south-westerly direction and specimens marked in Sweden have been recorded in Germany and Belgium. Of the seven specimens recorded from Iceland, three were found amongst timber imported from Germany and Holland, so were probably ship assisted. However it is not inconceivable that the specimen recorded in May 2003 on the island of Heimaey could have been a storm-borne migrant.

Pipistrellus nathusii was first recorded from the British Isles by Stebbings (1970) and for the next two decades it was considered to occur only as an occasional vagrant in Britain. With an increase in the number of records in the late 1980s, it was subsequently considered to be a winter migrant (Speakman *et al*., 1991; Hutson, 1993). More recently the discovery of three summer maternity colonies in England and Northern Ireland (Hutson, 1997; Russ *et al*., 1998, 2001) means that this species in Britain and Ireland is now considered to consist of both a resident breeding population present throughout the year, and a migratory population present during autumn, winter and spring (Russ, 2008). The increasing number of records in

the study areas over the same period mirrors the situation in mainland Britain. Similarly the seasonal peaks for sightings and records of this species are in September and October, coinciding with autumn migratory behaviour so, although in these areas the records are more likely to be of vagrants, it is conceivable that some could be migrants.

Vespertilio murinus is a long-distance migrant normally spending the summer in northern, central and eastern Europe and flying generally in a south-westerly direction to southern Europe to hibernate (Hutterer *et al*., 2005; Stebbings *et al*., 2007). In southern Sweden a few individuals were recorded in the autumn leaving land and flying out over the sea (Ahlén, 1997). There has been an increase in records in the British Isles since 1980, predominantly in the autumn and spring suggesting that migrants are sometimes deflected from continental Europe (Racey *et al*., 2008). This is also possible for records from Shetland and North Sea installations, and maybe also for records from the Faroes. It is possible that the specimen recorded from NE Iceland (Fig. 5) in October 2004, could be a storm-assisted migrant.

Lasiurus cinereus is a fast flying, highly migratory species that has been recorded in Orkney and Iceland in autumn and winter (Stebbings, 1986; Stebbings *et al*., 2007). Three of the specimen records from Iceland were from small, remote locations on the southern coast of Iceland, so ship-assisted passage was considered unlikely (Koopman and Gudmundsson, 1966), while the fourth specimen was from Heimaey Island, Vestmannaeyjar Islands off the southern coast of Iceland. Koopman and Gudmundsson (1966) also mentioned that meteorological records of storm tracks just prior to the October records of 1957 and 1964 indicated winds suitable to carry bats from eastern Canada to south western Iceland. This was further substantiated by a meteorologist (Jakobsson, 1967).

Although Wolley (1849, 1850) was of the opinion that the Orkney record was of a ship-assisted individual, Hill and Yalden (1990) and Yalden (2008) pointed out that at least

two American land-birds were also recorded in western Europe in the autumn of 1847. Furthermore, there were 93 records of American land-birds and over a thousand records of American waders in the British Isles between 1958 and 1972, many of these occurring in October (Hill and Yalden, 1990). It seems highly likely therefore that the Orkney and Iceland records are of bats storm-carried whilst migrating, although, in the case of the Orkney record, at least partial ship-assisted passage may not be excluded.

Myotis lucifugus is a medium-range migrant with movements of more than 300 km to hibernation sites according to Hutson (2008a). The record in August could be of a stray migrant, although Koopman and Gudmundsson (1966) concluded that it was more probable that this immature bat was ship-assisted to Reykjavik harbour.

Frequency of occurrence

The apparent increase in the occurrence of bats, raises the following questions that need to be addressed.

(a) Is there a real increase in records?

The results show that there has been a measurable increase in records for four of the five study areas (Iceland, Faroes, Shetland and Orkney).

(b) Is the increase due to improved communication?

In such isolated regions as most of the study areas, until relatively recently internal communication was limited and communication with the external world restricted, which may have restricted the communication of rare animals like bats to the scientific world. For example in the Faroes in the 1970s, radio was very new, few people had a telephone, there was no television and travel was poor in comparison with the situation today, with modern standards of communication and improvements to the road network. It therefore seems obvious that the dissemination of news may have improved considerably. This does not apply

to the situation in Iceland however, which has had good internal communication for considerably longer and external communication for at least 60 years.

(c) Is there an increased awareness?

There has always been an interest in the news of unusual sightings of animals, witness the early records of bats in Shetland in 1774 (Low, 1879), 1815 (Laing, 1815), and 1904 (Tulloch, 1904), in Orkney in 1847 (Wolley, 1849) and 1908 (Spence, 1909), and in Iceland in the 18th century (Pennant, 1784), circa 1817 (Faber, unpublished) and 1936 (Petersen, 1994). There are no similar early records in the Faroese literature and indeed Degerbøl (1940) makes no mention of them.

It appears that bats have become more and more common over the last decades. For example amateur naturalists have lived on Nólsoy in the Faroe Islands for the last 150 years, yet the first bats were not observed on the island until 1987 and had increased to 25 records in the period from 2000 to 2009. The Orkney records are also interesting, in that the numbers of bats reported have increased dramatically from the few in the 1970s and 1980s to the much greater reports in the 1990s and 2000s. This increase may be due in part to greater awareness and involvement of local naturalists and others inspired by a very keen recorder (Booth, 1979, 1980, 1989, 1992 – 2012), but it is also likely to be a true reflection of the situation since the Orkney Field Club was also flourishing in previous years with publications dating from 1968. Researchers at IINH have taken an interest in recording bats in Iceland, since at least 1940, probably from as early as 1889 when the Icelandic Natural History Society and its natural history museum was established. However the records remained steadily at two per decade from the 1960s to the 1990s, with a marked increase from 2000 to 2012.

(d) Is there an increase in shipping traffic?

Shipping traffic into Iceland, especially the use of containers to transport all manner of goods has increased considerably over the last few decades. Air traffic has also increased

and is an important source of goods transport for all study areas. At least ten of the records from Iceland are believed to have been associated with shipping, and one possibly with air transport. In the Faroe Islands only one bat is presumed to have been imported with timber and there are no other Faroese observations to suggest that bats have arrived with either aircraft or ship.

(e) Is the apparent increase due to changes in weather patterns and the effects of climate change?

Unusual weather patterns have been invoked in the past to account for the occurrence of vagrants, such as that of the specimen of *L. cinereus* in Orkney, which coincided with that of North American land birds in western Europe. The relationship between bat occurrences and weather patterns was identified in Iceland in the 1960s (Koopman and Gudmundsson, 1966; Jakobsson, 1967). The 2010 invasion of the Faroes also included birds from the USA, Europe and the Far East, and European Lepidoptera. During the same period, a number of European Lepidoptera reached south east Iceland, borne there on a warm south-easterly wind (Erling Ólafsson, personal communication). It is difficult to reach any conclusions concerning the possibility of changes in environmental factors affecting the situation in the Faroes at this time, for although September and October were amongst the seven months that were warmer than normal that year (Cappelen, 2011) weather maps for the Faroes showed no unusual wind conditions at that time (http://www.dmi.dk/faeroeerne/arkiver/vejrarkiv/).

It is important to distinguish the influence of occasional unusual weather patterns, from an overall trend in climate change. The evidence about long term changes in weather patterns linked to global environmental change is still fragmentary but nevertheless strongly indicated, and evidence to demonstrate the ecological response of species to climate change is accruing in many taxa (Thomas and Lennon, 1999; Parmesan *et al*., 1999; Visser and Holleman, 2001; Walther *et al*., 2002; Parmesan and Yohe, 2003; Sherwin *et al*., 2013). As

far as the study areas are concerned, Cappelen (2011) reported that the decade from 2001-2010 was the warmest in the Faroes since measurements began in 1890.

The status of *Pipistrellus nathusii* in the British Isles has changed over more than four decades from vagrant to that of a resident and winter migrant. This may represent a range extension which could conceivably be linked to climate change, or may just be a question of mistaken identity in the past and an increase since the mid-1980s of skilled recorders (Russ *et al*., 2001). The increase in frequency of recording of *P. nathusii* in the study areas however, suggests that migrating bats are more often in areas where they are more prone to being swept off-course. In a recent study, this species has been used to demonstrate range expansion linked to climate change in the UK (Lundy *et al*., 2010). These authors mapped the change in habitat suitability for this species from 1980 to 2000 based on UK Meteorological Office data and modelled the projected change in habitat suitability from 2020 to 2080. The presence of resident *P. pipistrellus* on Orkney may also be regarded as a range extension, implying that overall conditions have improved sufficiently to support breeding and overwintering bats.

Other recent studies that examined the predicted impact of climate change on bats include Rebelo *et al*. (2010), Prydatko *et al*. (2011) and Sherwin *et al*. (2013). Rebelo *et al*. (2010) modelled the potential distribution of bat diversity for three biogeographic groups: temperate, boreal and Mediterranean. Four of the ten species in their temperate group, included species reported in the current study: *P. nathusii, N. leisleri, E. serotinus* and *P. auritus*, while *N. noctula* was one of four species in their boreal group.

The measurable increased frequency of the occurrence of bats in Iceland, the Faroes, Shetland and Orkney suggests that all the above factors are important but it is difficult to distinguish between them. The importance of different factors appears to be variable depending on the study area. Overall the European migratory species are probably more likely to reach Shetland and Orkney and North Sea installations. The North American bat

species seem more prone to appear in Iceland than in the other study areas. However although further away from sources of bats, whether in Europe or North America, migratory bats may well reach the Faroe Islands and Iceland as do vagrant birds (Pétursson and Skarphéðinsson, 1978) and insects (Kaaber *et al*., 1994; Jensen, 2001).

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Table 1. Summary of records of bats from Iceland, the Faroe Islands, the Orkney Islands, the Shetland Islands, and North Sea installations. The species marked with an * are North American bats.

	Iceland		Faroes		Shetland		Orkney		North Sea		Total
Species	number	%	number	%	number	%	number	%	number	%	
Eptesicus fuscus *	1	3									1
Eptesicus nilsonii			1	1					1	3	2
Eptesicus serotinus			1	1	1	2					2
Lasiurus cinereus *	4	11					1	1			5
Myotis lucifugus *	2	5									2
*Myotis septentrionalis**	2	5									2
Nyctalus leisleri	1	3	1	1	3	5			1	3	6
Nyctalus noctula	1	3			3	5	3	2	2	7	9
Nyctalus sp.					2	4	2	1			4
Pipistrellus nathusii	6	16	17	18	12	21	5	3	20	67	60
Pipistrellus pipistrellus							71	39			71
Pipistrellus sp.	1	3	1	1	14	24	19	11			35
Plecotus auritus					3	5	4	2			7
Vespertilio murinus	2	5	2	2	7	12			6	20	17
Unidentified	18	47	73	76	13	22	75	42			179
Total records	38		96		58		180		30		402
Number of species	8		5		6		5		5		

Table 2. Frequency of occurrences in all study areas from 1960 to 2009, grouped into ten year periods, and for three years from 2010 to 2012. Figures in bold indicate the peak records for each of the study areas.

Area	Records	1960-69	1970-79	1980-89	1990-99	2000-09	2010-12
North Sea	all records	1	0	6	**15**	6	0
	P. nathusii	0	0	4	**14**	2	0
Orkney	all records	0	3	2	60	**74**	37
	P. nathusii	0	0	0	1	**2**	2
	P. pipistrellus	0	0	0	15	**39**	16
Shetland	all records	1	2	**13**	12	11	**13**
	P. nathusii	0	0	4	**7**	0	0
Faroes	all records	0	0	2	10	25	**79**
	P. nathusii	0	0	2	3	**7**	5
Iceland	all records	2	2	2	2	**12**	5
	P. nathusii	0	1	1	0	**3**	1

FIGURES

Fig. 1. Map of the study areas relative to the continental landmasses of Europe, Scandinavia, Canada and North America. Iceland 1; the Faroe Islands 2; the Shetland Islands 3; the Orkney Islands 4; North Sea installations 5.

Fig. 2. Map showing distribution of species of bats recorded from the Faroe Islands. *Pipistrellus nathusii* ■; *Vespertilio murinus* ●; Eptesicus serotinus ▲. The location where both *P. nathusii* and *Nyctalus leisleri* have been recorded is indicated by ▼. The location where *P. nathusii, V. murinus* and *Eptesicus nilsonii* have been recorded is indicated by ✚.

Fig. 3. Map showing distribution of six species of bats recorded from the Shetland Islands. *Pipistrellus nathusii* ■; *Nyctalus leisleri* ●; *Vespertilio murinus* ▲; *Nyctalus noctula* ✚; *Plecotus auritus* ▼. The location where both *P. nathusii* and *Eptesicus serotinus* have been recorded is indicated by ♦; where *P. nathusii* and *Nyctalus noctula* have been recorded is indicated by ✖; where *P. nathusii* and *Vespertilio murinus* have been recorded is indicated by ►; and where *V. murinus* and *Plecotus auritus* have been recorded is indicated by ◄.

Fig. 4. Map showing distribution of species of bats recorded from the Orkney Islands. *Pipistrellus nathusii* ▲; *Pipistrellus pipistrellus* ■; *Plecotus auritus* ●; *Nyctalus noctula* ▼; *Lasiurus cinereus* ✚. The location where both *P. nathusii* and *Plecotus auritus* have been recorded is indicated by ✖.

Fig. 5 Map showing distribution of species of bats recorded from Iceland. *Pipistrellus nathusii* ▼; *Vespertilio murinus* ●; *Lasiurus cinereus* ■. The location where both *P. nathusii* and *Lasiurus cinereus* have been recorded is indicated by ♦. Species found at various

locations in the vicinity of Reykjavik: *Pipistrellus nathusii*, *Myotis septentrionalis, Myotis lucifugus*, *Nyctalus leisleri*, *Nyctalus noctula* and *Eptesicus fuscus* are indicated by ▲.

Fig. 6. Map showing distribution of species of bats recorded from North Sea installations. *Pipistrellus nathusii* ■; *Vespertilio murinus* ●; *Nyctalus noctula* ▲. Location in the North Sea where both *Pipistrellus nathusii* and *Vespertilio murinus* have been recorded is indicated by ♦. Details of the records of species on the Faroes, Shetland and Orkney Islands are shown in Figs. 2 – 4.

Figure 7. Seasonal occurrence of records of *Pipistrellus pipistrellus* from selected localities in Orkney, showing changes in location over the years from 1994 to 2010. The vertical axis represents the number of records for each month from April to September.

Figure 8. Map showing the inundation of bats on the Faroes during September to November 2010.

Figure 9. Comparison of the seasonal occurrence of records of *Pipistrellus nathusii* from the combined study areas, with those of *Pipistrellus pipistrellus* from Orkney. The vertical axis represents the number of records each month.

Figure 10. Comparison of the seasonal occurrence of all records of bats, other than *Pipistrellus*, from the combined study areas. The vertical axis represents the number of records each month.