Population estimates, trends and background information for six Irish bat species

ARTICLE 17 REPORTING 2018-2023: SUPPORTING DOCUMENT

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CONTENTS

1. INTRODUCTION

The original detailed methods used to calculate bat populations in Ireland were described in Population Estimates, Trends and Background Information for Six Irish Bat Species: Article 17 Reporting for 2007-2012 Supporting Document by Roche, Aughney and Langton (2013). This document updates those population calculations for the current Article 17 reporting period - 2018-2023. The species assessed in this document are:

Common pipistrelle – *Pipistrellus pipistrellus*

Soprano pipistrelle – *Pipistrellus pygmaeus*

Nathusius' pipistrelle – *Pipistrellus nathusii*

Leisler's bat – *Nyctalus leisleri*

Daubenton's bat – *Myotis daubentonii*

Brown long-eared bat – *Plecotus auritus*

1.1 POPULATION ESTIMATION

1.1.1 PARAMETERS FOR ESTIMATING POPULATIONS

1.1.1.1 PROBABILITY OF OCCURRENCE ESTIMATES

DETECTION AREA

The probability of recording a bat was based on data from Car-based Bat Monitoring Scheme and the All Ireland Daubenton's Bat Waterways Monitoring Scheme (2007-2012). Data from the Republic of Ireland only was included in calculations for the present report. While these estimates are based on data from several years of the surveys and multiple sites, they also include surveys that were carried out relatively soon after sunset, when numbers may be low, as well as surveys in less favourable conditions. Consequently they may not reflect maximum possible levels of bat activity. For common and soprano pipistrelles, there is a proportion of calls every year that cannot be identified to species level. Therefore, these calls are omitted from the present dataset. In addition, any bats flying beyond the range of the detector will not be detected.

PROBABILITIES AND ASSUMPTIONS

Using roadside surveys to calculate national populations comes with a number of caveats. The assumption that bats occur with equal probability along roads as other habitats may not be correct (e.g. presence of white and yellow street lighting attracts Leisler's bats, see Roche *et al*. (2012)). The presence of building roosts may result in bias towards roads whereas vehicular disturbance may result in bias against. Along roadsides, the presence of hedgerows and tree lines may result in higher abundance of bat activity than may be expected over grassland, for example. Further empirical evidence is needed to determine differences between use of roadsides and other habitats.

For Daubenton's bat there is no data available on the extent of usage of lake habitats. For present reporting lake perimeters are taken as having similar likelihood of occurrence of bat activity as river habitats but further evidence is needed to determine more accurately the differences between extent of use of lake and river habitats by Daubenton's bat.

For all species there may be variations in abundance across the country that are not accounted for in this estimation. Stratifying according to geographic information / habitats may improve estimates and with the advent of Taillte Eireann's new National Landcover Map more detailed analyses and new population estimates may be feasible for the next reporting cycle.

1.1.2 ROOST COUNTS AND LANDSCAPE OCCUPANCY

Roost counts have been carried out consistently at brown long-eared bat roosts since 2007. While this yields robust data for trend analysis it does not constitute a complete census of the species since a limited number of roosts are counted every year. In order to extrapolate from roost count information to the wider country, we used a combination of information on average foraging distances (Entwistle *et al*., 1996) and the modelled core area for the species in Ireland (Lundy *et al.*, 2011). Foraging distances may vary in Ireland compared with Scotland or depending on extent/quality of available habitat. Also, the core area for the species may be occupied at varying densities depending on quality of habitat or roost availability.

There are questions surrounding the ratio of male:female in brown long-eared bat roosts. However, since calculated mean and median roost numbers included all recorded brown long-eared bat roosts and not simply the female-dominated maternity roosts included in the yearly surveillance scheme, no adjustments are proposed for a skewed male:female ratio for the present reporting round.

1.2 POPULATION TRENDS

Population trends of six bat species have been assessed yearly, using the three monitoring schemes mentioned above, since 2003 in the case of the Car-based Bat Monitoring Scheme, since 2006 in the case of the All-Ireland Daubenton's Bat Waterways Monitoring Scheme and since 2007 by the Brown Long-eared Bat Roost Monitoring Scheme. Analyses were carried out to determine trends for five species in the Republic of Ireland alone and for all Ireland for one species (Nathusius' pipistrelle). Analysis for the whole island is used instead of Republic of Ireland alone for Nathusius' pipistrelle because there are too few individuals of this species encountered during the car-based bat monitoring survey.

1.3 POPULATION CHANGE FROM 2007-2012 TO 2018-2023

The populations that were calculated based on probability of occurrence 2007-2012, or roost counts, for the 2012 Article 17 reporting round have now been recalculated for this report based on observed population trends in the intervening time period, i.e. original estimate x change in population.

2. METHODS

2.1 POPULATION ESTIMATES: AREAS AND LINEAR FEATURES

Estimations for total land area of the Republic of Ireland vary somewhat but the figure used here is 69879.8km^2.

For the 2007-2012 estimates no figure was available for hedgerow length in Ireland. Since that time, hedgerow length has been calculated based on 2018 data from Tailte Éireann's Landcover map.

The total length of rivers also varies depending on the source. This information is used for estimation of the Daubenton's bat population.

The estimated core area or favourable area of landscape was taken from Lundy *et al.* (2011) for brown long-eared bats.

2.1.1 POPULATION ESTIMATES METHOD A: BASED ON AREA (M^2)

Overall area of Republic of Ireland 69879.8km^2 i.e. 69,879,800,000m^2

Average percentage of 0.32ms snapshots with bats from 2007-2012 car-based bat monitoring data, Republic of Ireland

- Common pipistrelle: 2.17, probability of occurrence 0.0217
- Soprano pipistrelle: 1.015.74, probability of occurrence 0.01015
- Nathusius' pipistrelle: 0.01, probability of occurrence 0.0001
- Leisler's: 0.9117, probability of occurrence 0.009117

Detectable distance either 20-30m for common and soprano pipistrelles; 30-40m for Nathusius', 60-80m for Leisler's

Approximate detectable area is a semicircle $\pi r^2/2$.

For a 20m radius then detectable area approximately 628m^2

For a 30m radius then detectable area approx. 1413m^2

For a 40m radius then detectable area approx. 2512m^2

For Leisler's, a max 60-80m radius may be detectable, approx. 5652 to 10048m^2.

Formula: Number of semicircles that fit within Republic of Ireland x probability of occurrence

2.1.2 POPULATION ESTIMATES METHOD B: BASED ON LENGTH OF FEATURE - WATERWAYS

DAUBENTON'S

Table 2.1: Formula for Daubenton's based on river length + lake perimeter length

Data Source	Lake Perimeter Length (km)	Stream Order Strahler (mean width)	River Length (km)	Effective Length (accounting for increased width of higher orders)
EPA (2013)	9907	2 (1.58m)	18120	18120
		3 (3.8m)	9227	9227
		4 (8.18m)	4909	4909
		5 (16.71)	2080	2080
		6 (35.88)	973	1946
		7 (71.53)	72	216
EPA (2013) totals	**9907**	**-**	**35381**	**36498**
Anon (2005) WFD		**Unknown**	**23118**	**Unknown**

35,381km for Republic of Ireland, stream ordered by Strahler method and from Category 2 (average width 1.58m) upwards or, according to the summary of characterisation of river basins in Ireland 23,118km (Water Framework Directive data, exact widths unknown (Anon 2005)). Assuming detectable area is 20+20m for a surveyor. Number of spots needed to cover rivers in Republic of Ireland:

- Water Framework Directive + Lake Perimeters: (33025x1000/40) = 825,625
- EPA 2013 + EPA Lake Perimeters: (45288x1000)/40=1,132,200.
- EPA 2013 + Adjustment for total length available at wider rivers (length stream order 6 multiplied by 2 and length stream order 7 multiplied by 3) + EPA Lake Perimeters: (46405x1000)/40=1,160,125

To estimate the proportion of spots with bats at any one time, the number of passes per minute is multiplied by approximate pass length (in seconds) and then divided by the number of seconds per survey (240). Average number of passes per 4 minutes is 5.473 (all years 2007-2012). Therefore 5.473*3/(4*60)=0.0684125

Multiply number of spots by probability of encountering a Daubenton's bat at any given spot at any given time:

- 825,625x0.0684125=56,483 (WFD, Anon (2005) + lake perimeters)
- 1,132,200x0.0684125=77,456 (EPA + lake perimeters)
- 1,160,125x0.0684125=79,367 (EPA wider rivers adjusted for effective length + lake perimeter)

2.1.3 POPULATION ESTIMATES METHOD C: BASED ON LENGTH OF FEATURE - HEDGEROWS

New information about length of hedgerows has become available since the 2007-2012 reporting round. This was calculated from the Tailte Éireann (TE) Land Cover data set by extracting the Hedgerow land cover category and then converting the polygon to a centreline polyline. Given the nature of the TE Landcover data and the conversion from polygon to polyline the derived figure will only be approximate, additionally the TE Landcover data is based on 2018 imagery. This resulted in a figure of 474,908.5km of hedgerows in Ireland (Helen Bradley, NPWS, pers. comm.).

Using a very simple analysis based on the number of bat passes per km surveyed by the car-based bat monitoring survey we made the following calculation:

Mean number of bats per km surveyed in Republic of Ireland (2018-2023) x length of hedgerow (km)

This type of population estimate does not take into account differences in detectability between species and it may therefore overestimate or underestimate numbers since probability of detection or detectable range are not taken into account.

2.1.4 POPULATION ESTIMATES METHOD D: BASED ON ROOST NUMBERS

The brown long-eared bat is subject to regular counting at roosts. Data for roost counts was taken from the overall database on the species for the Republic of Ireland, not just monitoring sites, which may have resulted in an overestimation of the population since monitored roosts tend to be somewhat larger than average.

The median roost count (2000-2009) was found to be nine individuals and the mean is 14.2. Entwistle *et al.* (1996) reported that the brown long-eared bat spent 92% foraging time within 1.5km of roost, based on study sites situated in Scotland. Therefore, the potential foraging area for each roost was taken to extend to this radius, covering 7.065km^2.

Assuming that the entire modelled core area (Lundy *et al*., 2011) sustains brown long-eared bat roosts then

$$\left(\frac{\text{Overall Modelled Core Area in RoI}}{\text{Foraging Area}}\right) \times \text{mean or median roost size}$$

i.e. (48431/7.065)x9 (median)

or

(48431/7.065)x14.2 (mean)

2.2 UPDATING POPULATION ESTIMATES FOR 2018-2023 BASED ON TRENDS

Since the population estimates above were calculated based on 2007-2012 data these required updating for the 2018-2023 reporting round. In order to do so, we calculated the difference in population trend indices between the two reporting rounds.

Table below provides an example of the mean change in trend indices for *Pipistrellus pipistrellus* between the two Article 17 reporting rounds.

Table 2.2: trend indices and mean change in trend indices for *Pipistrellus pipistrellus* between the two Article 17 reporting rounds

Year	Index	Year	Index
2007	125.68	2018	171.81
2008	123.23	2019	175.69
2009	118.85	2020	185.63
2010	118.16	2021	199.86
2011	121.93	2022	216.71
2012	129.26	2023	239.83
Mean 2007-2012	122.85	**Mean 2018-2023**	198.26
Total Mean Change Since 2007-2012 reporting period	**+75.41**		

2.2.1 YEARLY TRENDS: CAR-BASED BAT MONITORING

2.2.1.1 CAR-BASED BAT MONITORING: PIPISTRELLES & LEISLER'S BAT

Analysis of the data used a Poisson distribution Generalised Linear Model (GLM) with General Additive Model (GAM) smoothing and bootstrapping, as used for island-wide trends (see Roche *et al.* (2012) for details). Poisson distribution modelling was used for common and soprano pipistrelles and Leisler's bat. However, for Nathusius' pipistrelle, a Binomial model is used due to the high number of surveys where none of these bats are recorded, in addition the trend is all-Ireland due to the low number of encounters. Survey squares (each of which have 15 separate survey transects) have been treated as independent replicates. There are 23 survey squares (30km squares) in the Republic of Ireland and five in Northern Ireland.

Data for Republic of Ireland from 2003 was used. Fewer survey squares were included in the early years, which means that trends from 2003-2004 may not be as reliable. 2003 is set as the base year for interpreting trends although 2006 is the baseline for Nathusius' pipistrelles because this species was not recorded for the first few years of the survey. Trends in populations are not expressed in change of absolute numbers since annual surveillance measures levels of activity along roadsides, rather than numbers of bats. Therefore, annual trend estimates are considered an index of activity that, it is hoped, mirror true population levels. 2003, the base year, is assigned the value of 100 to facilitate easy interpretation. An example of a trend index for one species is shown in Figure 2.1. In this example, the lower confidence limit for 2023 exceeds 100. This means that there has been a significant increase in the population activity index ($P<0.05$) since 2003. For reporting purposes, the confidence intervals are expressed as the final year upper and lower (95%) estimates. If both upper and lower

intervals are less than 100 this indicates a declining trend. Increasing trends will have an upper and lower interval both greater than 100 (see Figure 2.1). Also, the % increase of the upper and lower confidence intervals since 2003 can be calculated by subtracting 100 from the 2023 estimates. In some cases, this results in a negative number for the lower trend where the confidence interval surrounding the smoothed trend encompasses the baseline, but in the example below, the upper estimate indicates an increase of over 280% between 2003 and 2023 while the lower interval indicates an increase of approximately 100% from 2003 to 2023.

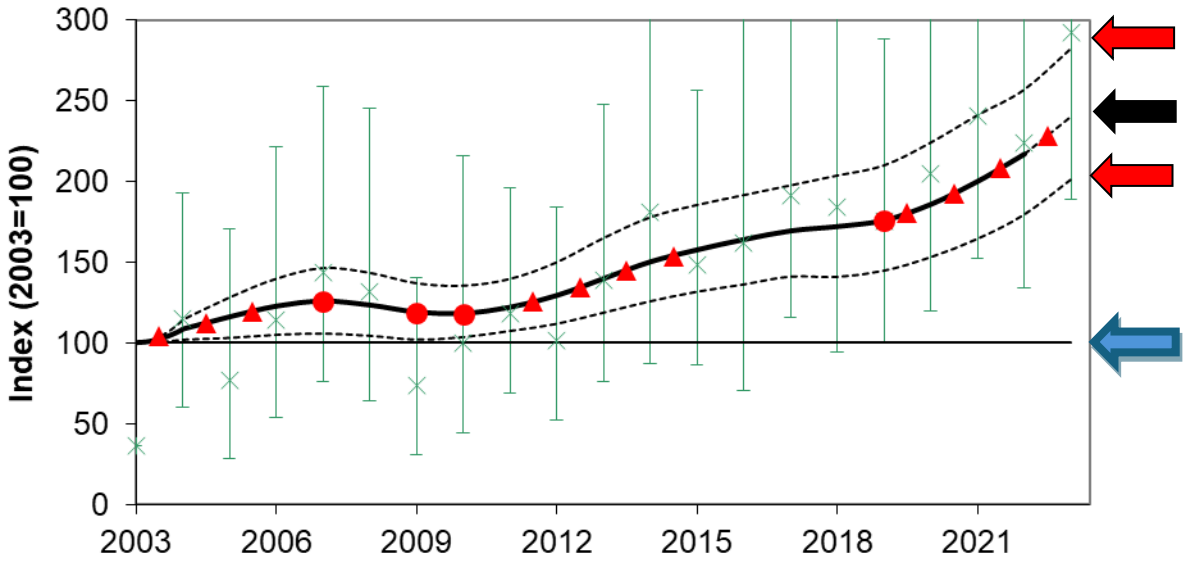

Figure 2.1: An example of a Car-based Bat Monitoring Scheme bat species trend index, shown as an example, with upper and lower confidence intervals indicated with red arrows, the 2003 baseline with blue arrow and the estimated smoothed trend shown with a heavy black line and black arrow.

The yearly annual trend estimate can also be expressed as percentage change per year between the base year (2003) and 2023. Estimates for yearly change are calculated using the following formula:

$$\text{Yearly \% Change} = (\text{Estimate at end of series}/100)^{(1/(\text{no. of years in series}))} - 1$$

2.2.1.2 ALL-IRELAND DAUBENTON'S BAT WATERWAYS SCHEME

Results for waterways surveys carried out in Republic of Ireland were collated and analysed using a Binomial (presence absence) GLM with GAM smoothing. For full details of the survey and analysis method see Aughney *et al.* (2012). Yearly % change, upper and lower confidence intervals of the trend is estimated in the same way as for the above example in section 2.2.1.

2.2.1.3 BROWN LONG-EARED BAT ROOST MONITORING

Results are shown from a GAM model, with the trend expressed as an index and 2008 as the base year. The model uses a poisson distribution. Models are fitted with covariates, for details (see Aughney *et al.*, 2013). Yearly % change, upper and lower confidence intervals of the trend is estimated in the same way as for the above example in section 2.2.1.

3. RESULTS

3.1 POPULATION ESTIMATES

Table 3.1: Bat population estimates for Republic of Ireland, 2012 & 2023. (A) Based on probability of detection from 2007-2012 Car-based Bat Monitoring Scheme data for common, soprano and Nathusius' pipistrelles and Leisler's bat with overall land area and estimated detectable area; (B) Probability of detection from 2007-2012 spot counts for Daubenton's bat with river length and estimated detectable distance; (C) Average number of bats per km times length of hedgerow (2023); (D) Median and mean roost count for brown long-eared bats, estimated foraging area and Max Ent modelled core area for the species in Republic of Ireland. A, B and D are recalculated for 2023 based on trends in the intervening period.

Species	A Probability of Detection, Detectable Radius and Land Area (2012),					B Prob. of Detection, No of Survey Spots and River Length (2012)	C Average no. bats per km (2018-2023) x number km of hedgerows (2018)	D Roost Count, Foraging Radius & Modelled Core Area (2012)
	20m	30m	40m	60m	80m	20m+20m		
P. pipistrellus 2012	2,416,500	1,074,000						
P. pipistrellus 2023 (+75.4%)	**4,229,800**	**1,872,500**					**2,331,400**	
P. pygmaeus 2012	1,129,400	502,000						
P. pygmaeus 2023 (+140.2%)	**2,709,600**	**1,204,800**					**1,443,100**	
P. nathusii 2012		*4,900*	*2,800*					
P. nathusii 2023 (+37.33)		***6,900***	***4,100***				***22,200***	
N. leisleri 2012				112,700	63,400			
N. leisleri 2023 (+49.92%)				**202,300**	**112,800**			
M. daubentonii 2012						56,500-79,400		
M. daubentonii 2023 (-1.24%)						**55,200-76,500**		
Plec. auritus bat 2012								61,700-97,300
Plec. auritus 2023 (+5.18%)								**65,200-102,000**

4. SPECIES ACCOUNTS

4.1 COMMON PIPISTRELLE *PIPISTRELLUS PIPISTRELLUS* (SCHREBER, 1774)

Estimated Population

1,872,500-4,229,800 estimated from probability etc. & trend recalculation

or

2,331,400 estimated from occurrence per km and length of hedgerow

Population estimates for the present reporting period are extrapolated from the probability of encountering a common pipistrelle bat in any given area (based on the rate it was encountered during the Car-based Bat Monitoring Scheme 2007-2012) and adjusted for mean changes to its trend between 2007-2012 and 2018-2023. Such population estimates are based on a range of assumptions which are only approximately correct. This analysis suggests that there is a common pipistrelle population of approximately 1.9-4.2 million in the Republic of Ireland. An additional figure of 2,331,400 is derived from the average number of bats detected per km of roadside surveys and estimates of the total length of hedgerows in Ireland.

The common pipistrelle has increased over the period that the car-based bat monitoring scheme has been running in Ireland, from 2003 to present.

Table 4.1: Per annum changes in roadside common pipistrelle levels, 2003 (baseline year) to 2023, Republic of Ireland.

	Change p.a.	lower 95%	upper 95%	Total Change
20 years (2003-2023)	4.47%	3.55%	5.32%	139.83%
12 years (2011-2023)	5.8%			117.9%

4.2 SOPRANO PIPISTRELLE *PIPISTRELLUS PYGMAEUS* (LEACH, 1825)

Estimated Population

1,204,800-2,709,600 estimated from probability etc. & trend recalculation

or

1,443,100 estimated from occurrence per km and length of hedgerow

Population estimates for the present reporting period are extrapolated from the probability of encountering a soprano pipistrelle bat in any given area (based on the rate it was encountered during the Car-based Bat Monitoring Scheme 2007-2012) and adjusted for mean changes to its trend between 2007-2012 and 2018-2023. Such population estimates are based on a range of assumptions which are only approximately correct. This analysis suggests that there is a soprano pipistrelle population of approximately 1.2-2.7 million in Republic

of Ireland. Trends for soprano pipistrelle have shown a significant increase since the inception of the Car-based Bat Monitoring Scheme in 2003.

An additional figure of 1,443,100 is derived from the average number of bats detected per km of roadside surveys and estimates of the total length of hedgerows in Ireland.

Table 4.2: Per annum changes in roadside soprano pipistrelle levels, 2003 (baseline year) to 2023, Republic of Ireland.

	Change p.a.	lower 95%	upper 95%	Total Change
20 years (2003-2023)	6.88%	4.63%	8.96%	278.5%
12 years (2011-2023)	7.62%			221.6%

4.3 NATHUSIUS' PIPISTRELLE *PIPISTRELLUS NATHUSII* (KEYSERLING & BLASIUS, 1839).

Estimated Population

4,100-6,900 estimated from probability etc. & trend recalculation

or

22,200 estimated from occurrence per km and length of hedgerow

Population estimates for the present reporting period are extrapolated from the probability of encountering a Nathusius' pipistrelle bat in any given area (based on the rate it was encountered during the Car-based Bat Monitoring Scheme 2007-2012) and adjusted for mean changes to its trend between 2007-2012 and 2018-2023. Such population estimates are based on a range of assumptions which are only approximately correct. Nathusius' pipistrelle is rarely encountered during the survey, but it may be locally frequent in suitable areas and easily missed by a survey such as this. Trends for Nathusius' pipistrelle have very wide error bars and are provided on an All-Ireland basis due to very low encounter rates. In addition, the baseline year for Nathusius' pipistrelle trends is 2006 since none were recorded prior to that year.

An additional, much higher figure of 22,200 is derived from the average number of bats detected per km of roadside surveys and estimates of the total length of hedgerows in Ireland.

Table 4.3: Per annum changes in roadside Nathusius' pipistrelle levels, 2006 (baseline year) to 2023 All Ireland.

	Change p.a.	lower 95%	upper 95%	Total Change
17 years (2006-2023)	1.25%	-2.62%	5.96%	23.5%
12 years (2011-2023)	0.14%			0.41%

4.4 LEISLER'S BAT *NYCTALUS LEISLERI* (KUHL, 1818).

Estimated Population

112,800-202,300

Population estimates for the present reporting period are extrapolated from the probability of encountering a Leisler's bat in any given area (based on the rate it was encountered during the car-based bat monitoring scheme 2007-2012) and adjusted for mean changes to its trend between 2007-2012 and 2018-2023. Such population estimates are based on a range of assumptions which are only approximately correct. This analysis suggests that there is a Leisler's bat population of approximately 112,800-202,300 in the Republic of Ireland.

Trends for Leisler's bat have shown a significant increase since the inception of the car-based bat monitoring scheme in 2003.

Table 4.4: Per annum changes in roadside Leisler's bat levels, 2003 (baseline year) to 2023, Republic of Ireland.

	Change p.a.	**lower 95%**	**upper 95%**	**Total Change**
20 years (2003-2023)	5.82%	3.65%	7.75%	210.01%
12 years (2011-2023)	4.05%			117.5%

4.5 DAUBENTON'S BAT *MYOTIS DAUBENTONII* (KUHL, 1819).

Estimated Population

55,200-76,500

Population estimates for the present reporting period are extrapolated from the probability of encountering a Daubenton's bat along any given stretch of waterway (based on the rate it was encountered during the All Ireland Daubenton's Bat Waterways Monitoring Scheme 2007-2012) and adjusted for mean changes to its trend between 2007-2012 and 2018-2023. Such population estimates are based on a range of assumptions which are only approximately correct. This analysis suggests that there is a Daubenton's bat population of approximately 55,000-77,000 individuals in the Republic of Ireland which is a slight but not significant decline compared with the 2007-2012 reporting period. Trends for Daubenton's bat have been, overall, reasonably stable.

Table 4.5: Per annum changes in Daubenton's bat levels, 2006 (baseline year) to 2023, Republic of Ireland.

	Change p.a.	**lower 95%**	**upper 95%**	**Total Change**
17 years (2006-2023)	-0.23%	-1.39%	0.95%	-3.84%
12 years (2011-2023)	-0.69%			-8.34%

4.6 BROWN LONG-EARED BAT *PLECOTUS AURITUS* (LINNAEUS, 1758).

Estimated Population

65,200-102,000

Population estimates for the present reporting period are extrapolated from the mean and median roost counts from 2007-2012, along with the mean foraging distance from a published study, and the modelled core area for the species in the Republic of Ireland. The estimate from the 2007-2012 was then adjusted according to the difference between mean trend for the species 2007-2012 and 2018-2023. Such population estimates are based on a range of assumptions which are only approximately correct. This analysis suggests that there is a brown long-eared bat population of approximately 65,000-102,000 individuals in the Republic of Ireland. Modelled population trend indicates that the species has increased annually by 1.5% since the inception of the Brown Long-eared Bat Roost Monitoring Scheme in 2007, although this increase has not been significant.

Table 4.6: Per annum changes in brown long-eared bat levels, 2007 (baseline year) to 2023, Republic of Ireland.

	Change p.a.	**lower 95%**	**upper 95%**	**Total Change**
16 years (2007-2023)	1.5%	-0.07%	2.6%	26.86%
12 years (2011-2023)	-0.63%			-9.92%

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