Morven South

Morven South Offshore Wind Array Project

Habitats Regulations Appraisal

Volume 3, Annex 2.4: Predator Eradication Modelling Report

MVCNS-J1201-RPS-10159
May 2026

B01

SLR TETRA TECH

Document status

Version	Purpose of document	Authored by	Checker	Approved by	Date
FINAL	Application	TTRPSEL	TTRPSEL	MvOWL	May 2026

Prepared by:

TTRPSEL

Prepared for:

Morven Offshore Wind Limited

Table of contents

List of tables

List of figures

1 Modelling the benefits to seabirds from predator eradication on the Island of Muck

1.1.1.1 A key consideration when identifying suitable islands for predator removal is an understanding of the current status of the seabird populations most likely to benefit and to make predictions for how those populations may respond to a rat eradication (Table 1.1).

Table 1.1: Summary of change in colony size (from the Seabird Monitoring Programme database) for each key species on Muck

Species	Population status on Muck
Guillemot (*Uria aalge*)	Declining
Razorbill (*Alca torda*)	Declining
Puffin (*Fratercula arctica*)	Declining
Kittiwake (*Rissa tridactyla*)	Declining

1.2 Approach to estimating benefit

1.2.1.1 The available data was compiled for each species of seabird for which compensation may be required, and which could benefit from rat eradication, from islands in the United Kingdom (UK) where rat eradication has been completed. These data are considered to provide the best available evidence for modelling the likely benefits to seabirds from rat eradication.

1.2.1.2 For each species from each island where there were sufficient data (more than four colony counts in the years after predator eradication) the colony growth rate (lambda) was calculated using the equation:

$$\lambda = \left(\frac{N_{t+y}}{N_t}\right)^{\left(\frac{1}{y}\right)}$$

1.2.1.3 Where:

λ = population growth rate;

N = Seabird colony count;

t = Year of first colony count;

y = Number of years between counts.

1.2.1.4 For each seabird species (with sufficient data) two concurrent population growth rates were obtained, one from the island where the rat eradication was conducted and another from an island in the same geographical region without rats present (in some case there was more than one of the latter available). By subtracting the growth rate observed on existing rat-free islands from that seen on the newly rat-free island the net growth was obtained. This value represents the rate at which the key seabird populations on Muck may grow following the proposed eradication campaign.

1.2.1.5 Data for all islands considered are presented in this report however, on review, some of the locations were not considered suitable for the proposed modelling methods, for example due to highly variable counts between years for which no apparent explanation could be found. These are discussed in the species sections below.

1.3 Species requiring compensation

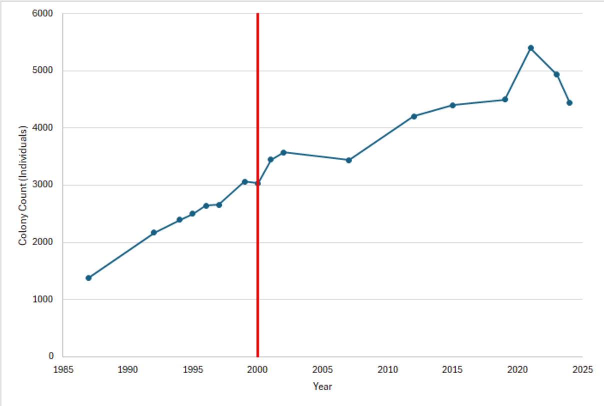
1.3.1.1 The species that are expected to require compensation are guillemot, razorbill, puffin, gannet (*Morus bassanus*) and kittiwake. Of these, the ones expected to benefit most from rat eradication are guillemot, razorbill and puffin. There are no historical records of gannet breeding on Muck and it is not considered likely that this species would colonise the islands. A small number of kittiwake do breed on Muck, and although this species is not typically considered to be one which suffers from rat predation (and no quantitative data on before/after eradication growth rates is available), it is highly likely that some degree of benefit would be experienced.

1.3.2 Guillemot

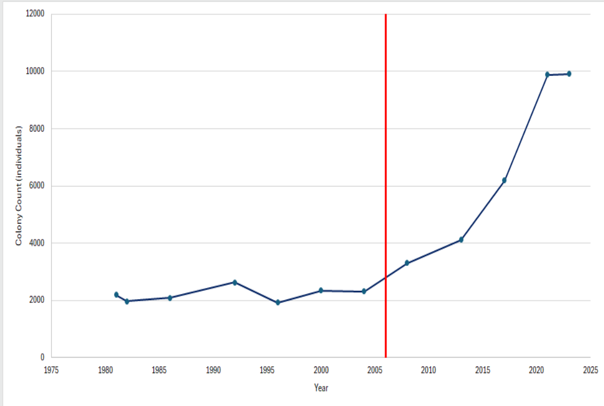
1.3.2.1 On Muck, the guillemot population was approximately stable between 2001 and 2018, with 394 individuals in 2001 to 420 in 2018, but appears to have since declined, with 319 reported in 2021.

1.3.2.2 While Furness *et al*. (2013) noted that, “it is very unlikely that rat eradication would be an effective conservation measure for guillemots” it was also noted that, “brown rats are a factor reducing productivity at a few colonies”. However, Booker *et al*. (2019) attributed the increase in guillemot population size on Lundy to rat eradication.

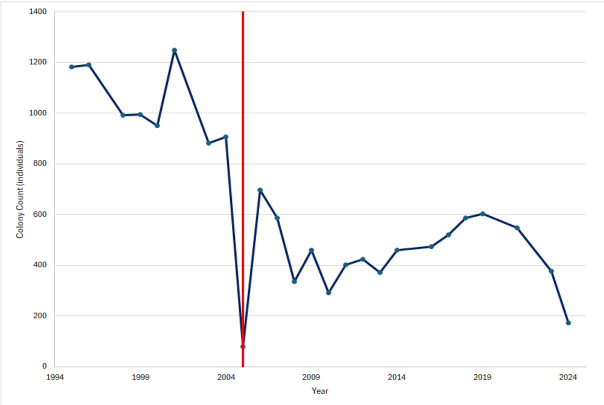
1.3.2.3 The changes in guillemot populations recorded at the colonies where rats have been eradicated (i.e. Ramsey Island, Lundy, and Canna) indicates that guillemot populations have responded positively to the absence of rats in southwest colonies in England and Wales, but not as strongly on the west coast of Scotland (Figure 1.1). While the response was most clear on Lundy, it was also apparent on Ramsey Island.



Ramsey Island



Lundy



Canna

Figure 1.1: Change in guillemot populations in colonies where rats have been eradicated. Red line shows the year rats were eradicated. (Counts from Canna are plot counts and not total colony estimates)

1.3.2.4 While the relationship between abundance and year on Ramsey Island (Figure 1.1) following rat eradication was positive, the growth trend was similarly positive, and possibly steeper, prior to rat eradication. The apparent slowing in the rate of increase following eradication may be due to other pressures or higher quality habitat becoming limited, leaving only less valued habitat.

Evidence from Canna

1.3.2.5 Rats were eradicated from Canna over the 2005-2006 winter, with the last rat trapped in February 2006 (Bell *et al*. 2011). The guillemot colony is challenging to census, hence counts should be considered as indicative only. Although an extremely low count was recorded in 2005 (79 AON) immediately prior to the rat eradication, this was considered to represent an unusual set of circumstances, with elevated levels of early nest failure (due to rat and gull predation; Swann 2013) and is therefore not treated as a reliable estimate of the number of pairs that attempted breeding in that year.

1.3.2.6 Furness *et al*. (2013) noted that Luxmoore *et al*. (2019) “found no evidence of any increase in guillemot breeding numbers at Canna as a consequence of eradication of rats from that island”. However, following rat eradication from Canna severe food shortages affected guillemots on Canna, characterised by low individual return rates (i.e. birds failing to attempting to breed), high nest failure rates and low chick weights (Bob Swann, pers. comm). Subsequently, up to around 2021, it was noted that food availability had improved, with “very high” return rates of adult birds and high levels of productivity resulting in the study colony beginning to recover (Bob Swann pers. comm).

1.3.2.7 However, Highly Pathogenic Avian Influenza (HPAI) appears to have negatively affected the guillemot colony on Canna between 2021 and 2023 resulting in a reduction in the colony counts in 2023 and 2024 (Figure 1.1), reductions of 31% (2021 to 2023) and 54% (2023 to 2024). It appears that in the most recent years (e.g. 2025) predation by otters has become a problem for guillemot on Canna (B. Swann, pers. comm). That otters can access breeding guillemots reflects the types of breeding habitat used on Canna (categorised as under boulders on wave-cut platforms), which is much more accessible to otters than the typical cliff ledges used by this species. It is also important to note that guillemot was not a focal species for the rat eradication on Canna, which was much more focussed on creating conditions suitable to permit Manx shearwater numbers to increase.

The evidence from Canna was considered to represent a specific set of circumstances and consequently it was not considered to provide a reliable guide to how the guillemot population on Muck may respond to rat eradication.

Evidence from Lundy

1.3.2.8 Rats were eradicated from Lundy by 2004 (first rat free year). The guillemot colony then grew over the subsequent years increasing from 2,321 individuals in 2004 to 9,912 individuals in 2023 (Table 1.2). This resulted in an annual population growth rate across this period of 1.079 (i.e. ~8% per year).

Table 1.2: Available guillemot colony count data from Lundy, calculated population growth rate (Lambda)

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1981	n/a	2,197	n/a	Pre-eradication
1982	1	1,979	0.901	Pre-eradication
1986	4	2,096	1.014	Pre-eradication
1992	6	2,629	1.038	Pre-eradication
1996	4	1,921	0.925	Pre-eradication
2000	4	2,348	1.051	Pre-eradication
2004	4	2,321	0.997	Post-eradication
2008	4	3,302	1.092	Post-eradication
2013	5	4,114	1.045	Post-eradication
2017	4	6,198	1.108	Post-eradication
2021	4	9,880	1.124	Post-eradication
2023	2	9,912	1.002	Post-eradication
2004 – 2023	19	n/a	1.079	Post-eradication

1.3.2.9 Suitable comparable data in the same region as Lundy were available from Skomer (Table 1.3) and Skokholm (Table 1.4).

Table 1.3: Available guillemot colony count data from Skomer, calculated population growth rate (Lambda). Pre- and post-eradication years from Lundy are highlighted

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1985	n/a	6,118	n/a	Lundy: Pre-eradication
1986	1	5,833	0.953	Lundy: Pre-eradication
1987	1	6,192	1.062	Lundy: Pre-eradication
1988	1	6,532	1.055	Lundy: Pre-eradication
1989	1	5,556	0.851	Lundy: Pre-eradication
1990	1	6,051	1.089	Lundy: Pre-eradication
1991	1	7,516	1.242	Lundy: Pre-eradication
1992	1	8,032	1.069	Lundy: Pre-eradication
1993	1	8,729	1.087	Lundy: Pre-eradication
1994	1	8,427	0.965	Lundy: Pre-eradication
1995	1	9,995	1.186	Lundy: Pre-eradication
1996	1	9,174	0.918	Lundy: Pre-eradication
1997	1	9,721	1.060	Lundy: Pre-eradication
1998	1	10,899	1.121	Lundy: Pre-eradication
1999	1	12,135	1.113	Lundy: Pre-eradication
2000	1	13,852	1.141	Lundy: Pre-eradication
2001	1	14,281	1.031	Lundy: Pre-eradication
2002	1	14,434	1.011	Lundy: Pre-eradication
2003	1	14,676	1.017	Lundy: Pre-eradication
2004	1	14,187	0.967	Lundy: Post-eradication
2005	1	19,711	1.389	Lundy: Post-eradication
2006	1	16,977	0.861	Lundy: Post-eradication
2007	1	17,544	1.033	Lundy: Post-eradication
2008	1	17,088	0.974	Lundy: Post-eradication
2009	1	19,512	1.142	Lundy: Post-eradication
2010	1	19,962	1.023	Lundy: Post-eradication
2011	1	21,688	1.086	Lundy: Post-eradication
2012	1	22,508	1.038	Lundy: Post-eradication
2013	1	20,862	0.927	Lundy: Post-eradication
2014	1	23,493	1.126	Lundy: Post-eradication
2015	1	23,746	1.011	Lundy: Post-eradication
2017	2	24,788	1.022	Lundy: Post-eradication
2021	4	27,057	1.022	Lundy: Post-eradication
2022	1	31,790	1.175	Lundy: Post-eradication

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
2023	1	29,141	0.917	Lundy: Post-eradication
2004 – 2023	**19**	**n/a**	**1.039**	Lundy: Post-eradication

Table 1.4: Available guillemot colony count data from Skokholm, calculated population growth rate (Lambda). Pre- and post-eradication years from Lundy are highlighted

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1987	n/a	6,118	n/a	Lundy: Pre-eradication
1992	5	5,833	0.991	Lundy: Pre-eradication
1993	1	6,192	1.062	Lundy: Pre-eradication
1994	1	6,532	1.055	Lundy: Pre-eradication
1995	1	5,556	0.851	Lundy: Pre-eradication
1996	1	6,051	1.089	Lundy: Pre-eradication
1997	1	7,516	1.242	Lundy: Pre-eradication
1998	1	8,032	1.069	Lundy: Pre-eradication
1999	1	8,729	1.087	Lundy: Pre-eradication
2000	1	8,427	0.965	Lundy: Pre-eradication
2001	1	9,995	1.186	Lundy: Pre-eradication
2002	1	9,174	0.918	Lundy: Pre-eradication
2003	1	9,721	1.060	Lundy: Pre-eradication
2004	1	10,899	1.121	Lundy: Post-eradication
2006	2	12,135	1.055	Lundy: Post-eradication
2007	1	9,777	0.806	Lundy: Post-eradication
2008	1	4,075	0.417	Lundy: Post-eradication
2009	1	14,281	3.505	Lundy: Post-eradication
2010	1	14,434	1.011	Lundy: Post-eradication
2011	1	14,676	1.017	Lundy: Post-eradication
2012	1	14,187	0.967	Lundy: Post-eradication
2013	1	19,711	1.389	Lundy: Post-eradication
2014	1	16,977	0.861	Lundy: Post-eradication
2015	1	17,544	1.033	Lundy: Post-eradication
2016	1	11,579	0.660	Lundy: Post-eradication
2019	3	14,339	1.074	Lundy: Post-eradication
2021	2	15,643	1.044	Lundy: Post-eradication
2022	1	15,064	0.963	Lundy: Post-eradication
2004 – 2022	**18**	**n/a**	**1.018**	Lundy: Post-eradication

1.3.2.10 The available evidence from Lundy showed that applying the population growth rate to the Muck population would result in a rapidly growing population, at approximately 8% pa (Table 1.5). The evidence from Skomer was for a slightly lower population growth rate (c. 4% pa) across the same time period, and slightly lower population growth rate again from Skokholm (c. 2% pa), although the latter two are from islands that have never had rats present. By subtracting the additional birds per annum projected to occur on Skomer and Skokholm (respectively) based on the population growth rate from Lundy, the potential growth in the population that may have occurred anyway was accounted for, leaving the projected annual increase in birds on Muck that would be expected due to rat eradication only. The outputs were provided for years 1 to 5, 19 (the span of Lundy data), 25 and 35 years post-eradication (the latter being the limit of the Morven North Offshore Wind Array Project (hereafter "Morven North") and Morven South Offshore Wind Array Project (hereafter "Morven South").

Table 1.5: Projected population size increase of guillemots on Muck (from a starting population size of 319 individuals in year 0, not shown) and projected annual increase in pairs as a result of rat eradication based on evidence from Lundy

	Lundy growth rate		Skomer growth rate		Skokholm growth rate		Additional birds per annum	
Years	Projected Muck population size (indiv.)	Additional birds per annum	Projected Muck population size (indiv.)	Additional birds per annum	Projected Muck population size (indiv.)	Additional birds per annum	Lundy - Skomer	Lundy - Skokholm
1	344		331		325			
2	372	27	344	13	331	6	15	21
3	401	30	357	13	337	6	16	24
4	433	32	371	14	343	6	18	26
5	467	34	386	14	349	6	20	28
19	1,362	100	655	24	449	8	76	92
25	2,155	158	822	31	500	9	128	150
35	4,626	340	1,201	45	599	11	296	330

1.3.2.11 The projected benefits from rat eradication can also be compared to the predicted impacts from the Morven North and Morven South projects alone. The predicted impact on guillemots, which may require compensation, is between 123.2 and 480.5 individuals per annum (using the Applicant's precautionary position (low) and NatureScot's position (high), respectively).

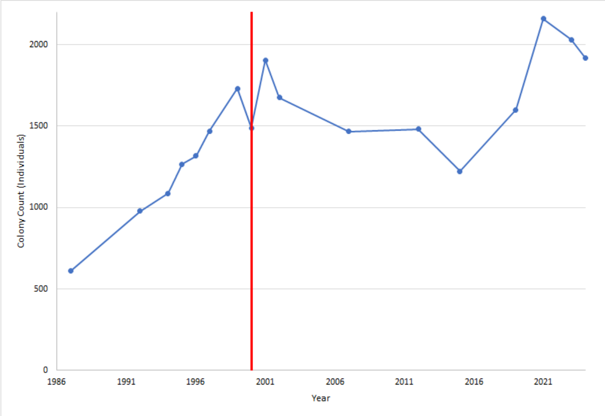
1.3.2.12 While consideration of population growth in terms of the difference between islands with and without removal of rats provides a useful comparative guide, it is also informative to consider the contrast between continuation of a current trend (in the case of Muck a decline) and the anticipated positive growth following rat eradication. Records of the guillemot population on Muck are sporadic, but there appears to have been a significant decline from 1,073 reported guillemot in 1986 (Dobson and Dobson 1986) to 377 in 2001 (SMP), 420 in 2018 (Burnell *et al.* 2023) and 319 in 2021 (Inger et al. 2023). Across the whole period this represents a decline of 3.4%, and just between the last two counts a decline of 8.8%. Compared with these rates of decline, growth at the rate seen on Lundy (7.9%) would mean a comparative 35 year population of between 4,850 and 4,930 (i.e. comparing the decline in the population extrapolated from the current trend with the growth predicted by the Lundy growth rate) and, perhaps more importantly, would be a reversal of the current long-term downward trend.

1.3.3 Razorbill

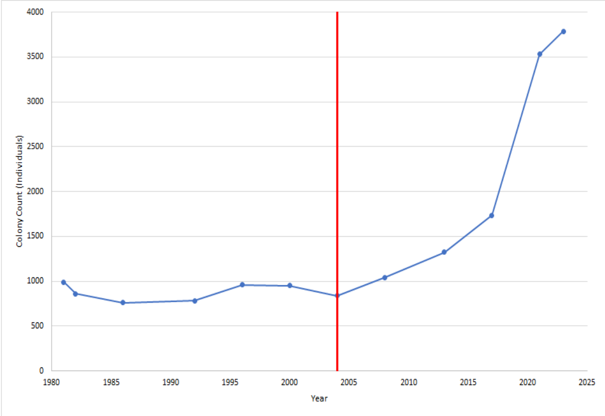
1.3.3.1 On Muck, the razorbill population declined from 136 individuals in 2001 to 100 in 2018 and further still to 51 in 2021.

1.3.3.2 While Furness *et al*. (2013) noted that, "it is very unlikely that rat eradication would be an effective conservation measure for razorbills" it was also noted that, "brown rats are a factor reducing productivity at a few colonies". However, Booker *et al*. (2019) attributed the increase in razorbill population size on Lundy to rat eradication.

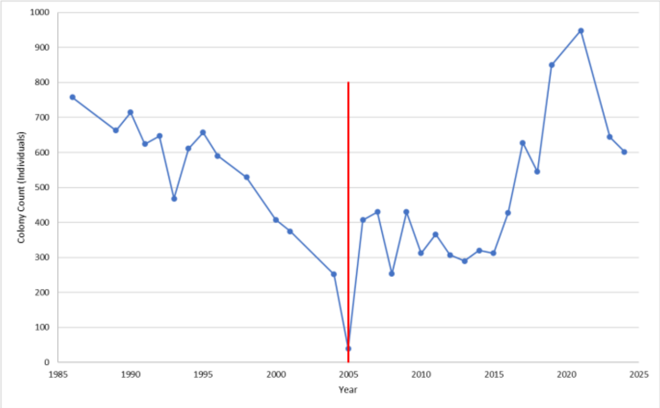
1.3.3.3 The changes in razorbill populations recorded at the colonies where rats have been eradicated (i.e. Ramsey Island, Lundy, and Canna) indicates that razorbill populations have responded positively to the absence of rats (Figure 1.2). While the response was most clear on Lundy, it was also apparent on Ramsey Island. On Canna the population size was declining rapidly prior to rat eradication. Following removal of rats the decline was halted and there have been periods of stability and periods of growth and, although still fluctuating, the population is now approaching similar numbers to those seen in the past.



Ramsey Island



Lundy



Canna

Figure 1.2: Change in razorbill populations in colonies where rats have been eradicated. Red line shows the year rats were eradicated

Evidence from Canna

1.3.3.4 Rats were eradicated from Canna by 2006 (first rat free year). Although an extremely low count was recorded in 2005 (40 AON) immediately prior to the rat eradication, this was considered to represent an unusual set of circumstances, with elevated levels of early nest failure (due to rat and gull predation; Swann 2013) and is therefore not treated as a reliable estimate of the number of pairs that attempted breeding in that year. Hence 2004, the last year prior to the rat eradication, has been used as the starting point for subsequent growth rate calculations. For a period of around 10 years the razorbill counts remained between 300 and 400 AON, before increasing to a peak of 948 in 2021 (Table 1.6). There has been a decline since which coincided with the reports of HPAI in 2022 and 2023, with the population in 2024 reported to be 602 AON. Excluding the known under-estimate in 2005, these counts give annual population growth rate across the whole post-eradication period (2004-2024) of 1.045, although, if the peak prior to HPAI is used (948 in 2021) average growth between 2004 and 2021 was 1.081.

Table 1.6: Available razorbill colony count data from Canna, calculated population growth rate (Lambda)

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1986	n/a	758	n/a	Pre-eradication
1989	3	663	0.956	Pre-eradication
1990	1	715	1.078	Pre-eradication
1991	1	624	0.873	Pre-eradication
1992	1	647	1.037	Pre-eradication
1993	1	468	0.723	Pre-eradication
1994	1	611	1.306	Pre-eradication
1995	1	657	1.075	Pre-eradication
1996	1	590	0.898	Pre-eradication
1998	2	529	0.947	Pre-eradication
2000	2	408	0.878	Pre-eradication
2001	1	375	0.919	Pre-eradication
2004	3	252	0.876	Pre-eradication
2005*	1	40	0.159	Post-eradication
2006	1	407	10.175	Post-eradication
2007	1	430	1.057	Post-eradication
2008	1	253	0.588	Post-eradication
2009	1	430	1.700	Post-eradication
2010	1	312	0.726	Post-eradication
2011	1	366	1.173	Post-eradication
2012	1	307	0.839	Post-eradication
2013	1	290	0.945	Post-eradication
2014	1	320	1.103	Post-eradication
2015	1	312	0.975	Post-eradication
2016	1	428	1.372	Post-eradication
2017	1	628	1.467	Post-eradication
2018	1	545	0.868	Post-eradication
2019	1	850	1.560	Post-eradication
2021	2	948	1.056	Post-eradication
2023	2	644	0.824	Post-eradication
2024	1	602	0.935	Post-eradication
2004 – 2024	**20**	**n/a**	**1.045**	**Post-eradication**
2004 – 2021#	**17**	**n/a**	**1.081**	**Post-eradication**

* this count is considered a known under-estimate (Swann 2005)

this growth rate omits the unreliable 2005 count and the possible HPAI induced declines in 2023 and 2024

1.3.3.5 Comparable count data in the same region as Canna were available from Ceann a Mhara, Tiree (Table 1.7), Mingulay (Table 1.8) and Sanda (Table 1.9). However, with only four counts from Sanda from the post-eradication period on Canna, these data were considered insufficient to support this analysis and were not used further. In addition, on inspection of the counts for Mingulay a considerable degree of inter-annual fluctuation was apparent (Table 1.8), with regular changes from one year to the next of over 3,000 individuals, which in a population typically less than 10,000 represents swings of +/-30-40%. No explanation for these fluctuations has been found, and while these may reflect true population change such between year changes, both positive and negative, are unusual in seabird populations, therefore the most likely explanation is that counts were incomplete in some years. Since the reliability of these data could not be determined, the Mingulay data were not considered in the remainder of the analysis.

Table 1.7: Available razorbill colony count data from Ceann a Mhara, calculated population growth rate (Lambda). Pre- and post-eradication years from Canna are highlighted

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1987	n/a	350	n/a	Canna: Pre-eradication
1988	1	289	0.826	Canna: Pre-eradication
1989	1	296	1.024	Canna: Pre-eradication
1990	1	263	0.889	Canna: Pre-eradication
1992	2	340	1.137	Canna: Pre-eradication
1999	7	384	1.018	Canna: Pre-eradication
2004	5	561	1.079	Canna: Pre-eradication
2005	1	417	0.743	Canna: Post-eradication
2006	1	367	0.880	Canna: Post-eradication
2007	1	530	1.444	Canna: Post-eradication
2008	1	454	0.857	Canna: Post-eradication
2009	1	418	0.921	Canna: Post-eradication
2010	1	350	0.837	Canna: Post-eradication
2011	1	412	1.177	Canna: Post-eradication
2012	1	333	0.808	Canna: Post-eradication
2013	1	376	1.129	Canna: Post-eradication
2014	1	279	0.742	Canna: Post-eradication
2015	1	236	0.846	Canna: Post-eradication
2016	1	197	0.835	Canna: Post-eradication
2017	1	252	1.279	Canna: Post-eradication
2018	1	372	1.476	Canna: Post-eradication
2019	1	289	0.777	Canna: Post-eradication
2020	1	384	1.329	Canna: Post-eradication
2021	1	266	0.693	Canna: Post-eradication

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
2022	1	326	1.226	Canna: Post-eradication
2023	1	298	0.914	Canna: Post-eradication
2024	1	246	0.826	Canna: Post-eradication
2004 – 2024	**19**	**n/a**	**0.933**	**Canna: Post-eradication**

Table 1.8: Available razorbill colony count data from Mingulay, calculated population growth rate (Lambda). Pre- and post-eradication years from Canna are highlighted

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1985	n/a	5,000	n/a	Canna: Pre-eradication
1994	9	7,110	1.040	Canna: Pre-eradication
1998	4	6,387	0.974	Canna: Pre-eradication
2003	5	14,201	1.173	Canna: Pre-eradication
2009	6	3,237	0.782	Canna: Post-eradication
2010	1	2,237	0.691	Canna: Post-eradication
2011	1	5,691	2.544	Canna: Post-eradication
2012	1	4,715	0.829	Canna: Post-eradication
2013	1	5,017	1.064	Canna: Post-eradication
2014	1	8,233	1.641	Canna: Post-eradication
2015	1	11,366	1.381	Canna: Post-eradication
2016	1	8,668	0.763	Canna: Post-eradication
2017	1	11,453	1.321	Canna: Post-eradication
2021	4	8,284	0.922	Canna: Post-eradication
2022	1	4,772	0.576	Canna: Post-eradication
2023	1	3,275	0.091	Canna: Post-eradication
2009 – 2023	14	n/a	1.001	Canna: Post-eradication

Table 1.9: Available razorbill colony count data from Sanda, calculated population growth rate (Lambda). Pre- and post-eradication years from Canna are highlighted

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1986	n/a	900	n/a	Canna: Pre-eradication
1987	1	750	0.833	Canna: Pre-eradication
1988	1	1,050	1.400	Canna: Pre-eradication
1989	1	1,000	0.952	Canna: Pre-eradication
1990	1	1,200	1.200	Canna: Pre-eradication

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1991	1	1,250	1.042	Canna: Pre-eradication
1992	1	1,050	0.840	Canna: Pre-eradication
1993	1	2,700	2.571	Canna: Pre-eradication
1994	1	3,067	1.136	Canna: Pre-eradication
1995	1	2,950	0.962	Canna: Pre-eradication
1996	1	3,050	1.034	Canna: Pre-eradication
1997	1	3,050	1.000	Canna: Pre-eradication
1998	1	3,050	1.000	Canna: Pre-eradication
1999	1	2,944	0.965	Canna: Pre-eradication
2000	1	2,910	0.988	Canna: Pre-eradication
2001	1	3,000	1.031	Canna: Pre-eradication
2002	1	3,500	1.167	Canna: Pre-eradication
2003	1	3,500	1.000	Canna: Pre-eradication
2004	1	3,750	1.071	Canna: Pre-eradication
2005	1	4,500	1.200	Canna: Post-eradication
2006	1	4,000	0.889	Canna: Post-eradication
2010	4	4,000	1.000	Canna: Post-eradication
2019	9	430	0.781	Canna: Post-eradication
2004 – 2019	14	n/a	0.846	Canna: Post-eradication

1.3.3.6 The available evidence from Canna showed that applying the population growth rate to the Muck population would result in modest population growth (Table 1.10). The evidence from Ceann a Mhara was for a population decline across the same time period (Table 1.7). By subtracting the additional birds per annum projected to occur on Ceann a Mhara based on the population growth rate from Canna, the expected growth in the population that may have occurred anyway was removed. Thus, the projected annual increase in birds on Muck is what would be expected due to rat eradication only. The outputs were provided for years 1 to 5, 13 (the span of the evidence from Canna), 25 and 35 (the limit of the proposed Morven North and Morven South projects).

1.3.3.7 The projected growth rates from Canna showed a steady growth rate when applied to the Muck razorbill population (Table 1.10), albeit starting from only 51 individuals even at an 8.1% growth rate, the population will take several years to grow at more than a few individuals per year. Subtracting the growth rate from Ceann a Mhara from the growth rate from Canna resulted in a quicker net population growth, due to the negative growth (lambda value less than one) from Ceann a Mhara.

Table 1.10: Projected population size increase of razorbill on Muck (from a starting population size of 51 individuals in year 0, not shown) and projected annual increase in pairs as a result of rat eradication based on evidence from Canna

	Canna growth rate		Ceann a Mhara growth rate		Additional birds per annum
Years	Projected Muck population size (indiv.)	Additional birds per annum	Projected Muck population size (indiv.)	Additional birds per annum	Canna growth minus Ceann a Mhara growth
1	55	4	48	-3	8
2	60	4	44	-3	8
3	64	5	41	-3	8
4	70	5	39	-3	8
5	75	6	36	-3	8
13	140	11	21	-1	12
25	358	27	9	-1	27
35	780	59	5	0	59

1.3.3.8 The projected benefits from rat eradication can also be compared to the predicted impacts from the Morven North and Morven South projects alone. The predicted impact on razorbill, which may require compensation, is between 5.9 and 23.1 individuals per annum (using the Applicant's precautionary position (low) and NatureScot's position (high), respectively).

Evidence from Lundy

1.3.3.9 Rats were eradicated from Lundy by 2004 (first rat free year). The razorbill colony then increased from a low of 841 individuals in 2004 to 3,785 individuals by 2023 (Table 1.11). This resulted in an annual population growth rate across this period of 1.082.

Table 1.11: Available razorbill colony count data from Lundy, calculated population growth rate (Lambda)

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1981	n/a	991	n/a	Pre-eradication
1982	1	861	0.869	Pre-eradication
1986	4	761	0.970	Pre-eradication
1992	6	785	1.005	Pre-eradication
1996	4	959	1.051	Pre-eradication
2000	4	950	0.998	Pre-eradication
2004	4	841	0.970	Post-eradication
2008	4	1,045	1.056	Post-eradication
2013	5	1,324	1.048	Post-eradication
2017	4	1,735	1.070	Post-eradication
2021	4	3,533	1.195	Post-eradication
2023	2	3,785	1.035	Post-eradication
2004 – 2023	**19**	**n/a**	**1.082**	**Post-eradication**

1.3.3.10 Suitable comparable data in the same region as Lundy were available from Skomer (Table 1.12) and Skokholm Table 1.13).

Table 1.12: Available razorbill colony count data from Skomer, calculated population growth rate (Lambda). Pre- and post-eradication years from Lundy are highlighted

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1985	n/a	3,578	n/a	Lundy: Pre-eradication
1986	1	3,069	0.858	Lundy: Pre-eradication
1987	1	2,938	0.957	Lundy: Pre-eradication
1988	1	2,907	0.989	Lundy: Pre-eradication
1989	1	2,731	0.939	Lundy: Pre-eradication
1990	1	2,626	0.962	Lundy: Pre-eradication
1991	1	2,989	1.138	Lundy: Pre-eradication
1992	1	3,135	1.049	Lundy: Pre-eradication
1993	1	3,676	1.173	Lundy: Pre-eradication
1994	1	3,085	0.839	Lundy: Pre-eradication
1995	1	3,393	1.100	Lundy: Pre-eradication
1996	1	2,934	0.865	Lundy: Pre-eradication
1997	1	2,932	0.999	Lundy: Pre-eradication
1998	1	3,337	1.138	Lundy: Pre-eradication
1999	1	2,938	0.880	Lundy: Pre-eradication
2000	1	3,898	1.327	Lundy: Pre-eradication
2001	1	4,772	1.224	Lundy: Pre-eradication
2002	1	5,095	1.068	Lundy: Pre-eradication
2003	1	4,242	0.833	Lundy: Pre-eradication
2004	1	4,546	1.072	Lundy: Post-eradication
2005	1	5,759	1.267	Lundy: Post-eradication
2006	1	4,561	0.792	Lundy: Post-eradication
2007	1	4,847	1.063	Lundy: Post-eradication
2008	1	4,973	1.026	Lundy: Post-eradication
2009	1	5,262	1.058	Lundy: Post-eradication
2010	1	5,391	1.025	Lundy: Post-eradication
2011	1	5,118	0.949	Lundy: Post-eradication
2012	1	4,971	0.971	Lundy: Post-eradication
2013	1	6,663	1.340	Lundy: Post-eradication
2014	1	6,541	0.982	Lundy: Post-eradication
2015	1	7,489	1.145	Lundy: Post-eradication
2016	1	7,250	0.968	Lundy: Post-eradication
2018	2	7,529	1.019	Lundy: Post-eradication
2021	3	8,168	1.028	Lundy: Post-eradication

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
2022	1	10,192	1.248	Lundy: Post-eradication
2023	1	10,080	0.989	Lundy: Post-eradication
2024	1	10,639	1.055	Lundy: Post-eradication
2004 – 2023	**19**	**n/a**	**1.043**	**Lundy: Post-eradication**

Table 1.13: Available razorbill colony count data from Skokholm, calculated population growth rate (Lambda). Pre- and post-eradication years from Lundy are highlighted

Year	Years between counts	Colony counts (individuals)	Lambda	Pre- or post-eradication?
1986	n/a	395	n/a	Lundy: Pre-eradication
1987	1	702	1.777	Lundy: Pre-eradication
1989	2	382	0.738	Lundy: Pre-eradication
1990	1	380	0.995	Lundy: Pre-eradication
1992	2	731	1.387	Lundy: Pre-eradication
1993	1	804	1.100	Lundy: Pre-eradication
1994	1	818	1.017	Lundy: Pre-eradication
1995	1	891	1.089	Lundy: Pre-eradication
1996	1	941	1.056	Lundy: Pre-eradication
1997	1	1,073	1.140	Lundy: Pre-eradication
1998	1	1,011	0.942	Lundy: Pre-eradication
1999	1	1,180	1.167	Lundy: Pre-eradication
2000	1	1,246	1.056	Lundy: Pre-eradication
2001	1	1,218	0.978	Lundy: Pre-eradication
2002	1	1,285	1.055	Lundy: Pre-eradication
2003	1	1,103	0.858	Lundy: Pre-eradication
2004	1	1,192	1.081	Lundy: Post-eradication
2005	1	992	0.832	Lundy: Post-eradication
2006	1	937	0.945	Lundy: Post-eradication
2007	1	812	0.867	Lundy: Post-eradication
2008	1	946	1.165	Lundy: Post-eradication
2009	1	950	1.004	Lundy: Post-eradication
2010	1	1,140	1.200	Lundy: Post-eradication
2011	1	1,486	1.304	Lundy: Post-eradication
2012	1	1,463	0.985	Lundy: Post-eradication
2013	1	2,294	1.568	Lundy: Post-eradication

Year	Years between counts	Colony counts (individuals)	Lambda	Pre- or post-eradication?
2014	1	2,052	0.895	Lundy: Post-eradication
2015	1	2,382	1.161	Lundy: Post-eradication
2016	1	2,242	0.941	Lundy: Post-eradication
2017	1	2,491	1.111	Lundy: Post-eradication
2018	1	2,585	1.038	Lundy: Post-eradication
2019	1	2,755	1.066	Lundy: Post-eradication
2020	1	3,517	1.277	Lundy: Post-eradication
2021	1	3,356	0.954	Lundy: Post-eradication
2022	1	3,965	1.181	Lundy: Post-eradication
2023	1	3,552	0.896	Lundy: Post-eradication
2004 – 2023	**19**	**n/a**	**1.059**	**Lundy: Post-eradication**

Table 1.14: Projected population size increase of razorbill on Muck (from a starting population size of 51 individuals in year 0, not shown) and projected annual increase in pairs as a result of rat eradication based on evidence from Lundy

	Lundy growth rate		Skomer growth rate		Skokholm growth rate		Additional birds per annum	
Years	**Projected Muck population size (indiv.)**	**Additional birds per annum**	**Projected Muck population size (indiv.)**	**Additional birds per annum**	**Projected Muck population size (indiv.)**	**Additional birds per annum**	**Lundy - Skomer**	**Lundy - Skokholm**
1	55	n/a	53	n/a	54	n/a	n/a	n/a
2	60	5	55	2	57	3	2	1
3	65	5	58	2	61	3	3	2
4	70	5	60	2	64	4	3	2
5	76	6	63	3	68	4	3	2
19	230	17	113	5	152	8	13	9
25	369	28	145	6	215	12	22	16
35	815	62	221	9	381	21	53	41

1.3.3.11 The available evidence from Lundy showed that applying the population growth rate to the Muck population would result in a strong growth rate of 8% (Table 1.14). The evidence from Skomer was for a slightly smaller population growth rate across the same time period, and a slightly larger population growth rate again from Skokholm, which was still less than from Lundy alone (Table 1.12 and Table 1.13 respectively). By subtracting the additional birds per annum projected to occur on Skomer and Skokholm (respectively) based on the population growth rate from Lundy, the expected growth in the population that may have occurred anyway was removed. Thus, the projected annual increase in birds on Muck is what would be expected by rat eradication only. The outputs were provided for the first five years post-eradication, at 19 years (the span of the evidence from Lundy), 25 years and 35 years (the limit of the proposed Morven North and Morven South projects).

1.3.3.12 The projected benefits to rat eradication can also be compared to the predicted impacts from the Morven North and Morven South projects alone. The predicted impact on razorbill is between 5.9 and 23.1 individuals per annum (using the Applicant's precautionary position (low) and NatureScot's position (high), respectively).

1.3.3.13 While consideration of population growth in terms of the difference between islands with and without removal of rats provides a useful comparative guide, it is also informative to consider the contrast between continuation of a current trend (in the case of Muck a decline) and the anticipated positive growth following rat eradication. Records of the razorbill population on Muck are sporadic, but there appears to have been a significant decline from 246 reported in 1986 (Dobson and Dobson 1986) to 136 in 2001 (SMP), 40 in 2018 (Burnell et al. 2023) and 51 in 2021 (Inger et al. 2023). Across the whole period this represents a decline of 4.4%. Compared with these rates of decline, growth at the rate seen on Lundy (8.2%) would mean a comparative 35 year population of 855 (i.e. comparing the decline in population extrapolated from the current trend with the growth predicted by the Lundy growth rate) and, perhaps more importantly, would be a reversal of the current long-term downward trend.

1.3.4 Puffin

1.3.4.1 Furness *et al*. (2013) stated that, "Eradication of invasive alien rats could allow puffin productivity to increase at colonies where this predator is present" and Furness (2021) concluded that, "There is…clear evidence that eradication of rats can be highly beneficial for puffin populations". Puffin counts at breeding colonies are difficult to complete accurately. While the preferred count is of Apparently Occupied Burrows (AOB) this can be very difficult to achieve, particularly where the puffin burrows could be compromised by those undertaking the count. In all the counts available from colonies where rats were eradicated, no counts of AOB were available, so only counts of individuals were used. It is important to note that counts of individuals are only considered by the SMP manual to be representative of the breeding population within an order of magnitude. However, these counts are likely to be comparable between years and, therefore, able to show change in a population. Comparing the population size of puffins in colonies where rats were eradicated (i.e. Ramsey Island, Lundy, Isles of Scilly and Canna) does indicate that puffins would be expected to increase on islands where rats are eradicated (Figure 1.3). Note however that counting puffin on Canna is very challenging and these estimates are not considered to provide a robust guide to numbers there.

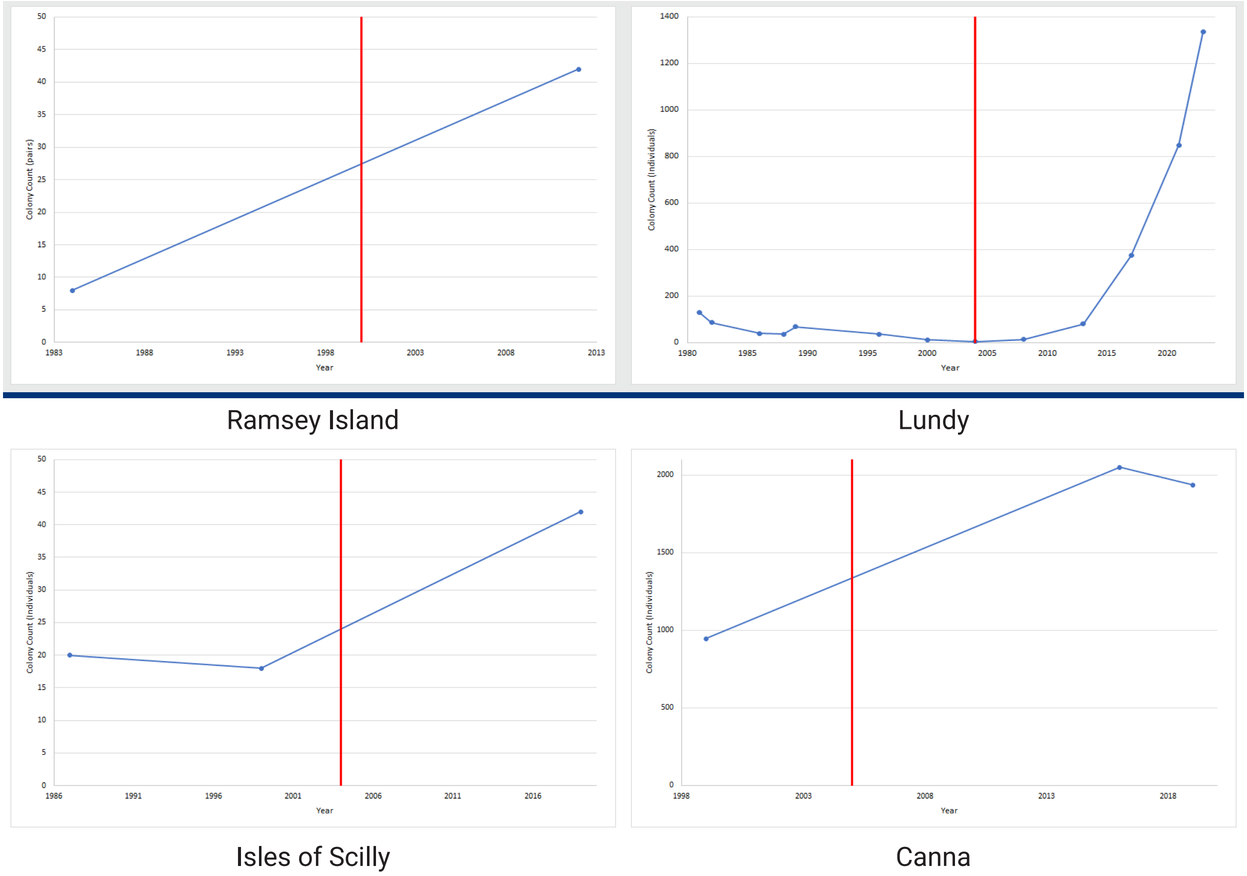


Figure 1.3: Change in puffin populations in colonies where rats have been eradicated. Red line shows the year rats were eradicated.

1.3.4.2 On Muck there was a record of 111 puffins on the sea in 2001 (SMP database), which is not a particularly strong indication of breeding birds being present. However, there were 50 individuals reported on land in 2018 but only 19 in 2021.

Evidence from Lundy

1.3.4.3 Rats were eradicated from Lundy by 2004 (first rat free year). The puffin colony then grew over the subsequent years increasing from 5 individuals in 2004 to 1,335 individuals in 2023 (Table 1.15). This resulted in an annual population growth rate across this period of 1.342.

1.3.4.4 Note that puffin cannot be reliably counted on Canna so it is not possible to consider that population.

Table 1.15: Available puffin colony count data from Lundy, calculated population growth rate (Lambda)

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1981	n/a	129	n/a	Pre-eradication
1982	1	87	0.674	Pre-eradication
1986	4	39	0.818	Pre-eradication
1988	2	37	0.974	Pre-eradication
1989	1	69	1.865	Pre-eradication
1996	7	37	0.915	Pre-eradication
2000	4	13	0.770	Pre-eradication
2004	4	5	0.788	Post-eradication
2008	4	14	1.294	Post-eradication
2013	5	80	1.417	Post-eradication
2017	4	375	1.471	Post-eradication
2021	4	848	1.226	Post-eradication
2023	2	1,335	1.255	Post-eradication
2004 – 2023	**19**	**n/a**	**1.342**	**Post-eradication**

1.3.4.5 Suitable comparable data in the same region as Lundy were available from Skomer (Table 1.16) and Skokholm (Table 1.17).

Table 1.16: Available puffin colony count data from Skomer, calculated population growth rate (Lambda). Pre- and post-eradication years from Lundy are highlighted

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1988	n/a	6,700	n/a	Lundy: Pre-eradication
1989	1	8,573	1.280	Lundy: Pre-eradication
1990	1	8,500	0.991	Lundy: Pre-eradication
1991	1	9,645	1.135	Lundy: Pre-eradication
1992	1	8,000	0.829	Lundy: Pre-eradication
1993	1	10,791	1.349	Lundy: Pre-eradication
1994	1	10,465	0.970	Lundy: Pre-eradication
1995	1	10,473	1.001	Lundy: Pre-eradication
1996	1	9,141	0.873	Lundy: Pre-eradication
1997	1	9,049	0.990	Lundy: Pre-eradication
1998	1	9,235	1.021	Lundy: Pre-eradication
1999	1	9,213	0.998	Lundy: Pre-eradication
2000	1	10,614	1.152	Lundy: Pre-eradication

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
2001	1	7,854	0.740	Lundy: Pre-eradication
2002	1	10,338	1.316	Lundy: Pre-eradication
2003	1	8,537	0.826	Lundy: Pre-eradication
2004	1	10,688	1.252	Lundy: Post-eradication
2005	1	10,717	1.003	Lundy: Post-eradication
2006	1	10,876	1.015	Lundy: Post-eradication
2007	1	11,821	1.087	Lundy: Post-eradication
2008	1	10,487	0.887	Lundy: Post-eradication
2009	1	13,508	1.288	Lundy: Post-eradication
2010	1	12,577	0.931	Lundy: Post-eradication
2012	2	11,497	0.956	Lundy: Post-eradication
2013	1	19,280	1.677	Lundy: Post-eradication
2014	1	18,237	0.946	Lundy: Post-eradication
2015	1	21,349	1.171	Lundy: Post-eradication
2016	1	22,539	1.056	Lundy: Post-eradication
2017	1	25,227	1.119	Lundy: Post-eradication
2018	1	30,895	1.225	Lundy: Post-eradication
2021	3	21,697	0.889	Lundy: Post-eradication
2022	1	19,960	0.920	Lundy: Post-eradication
2023	1	19,742	0.989	Lundy: Post-eradication
2024	1	14,315	0.725	Lundy: Post-eradication
2004 – 2023	**19**	**n/a**	**1.033**	**Lundy: Post-eradication**

Table 1.17: Available puffin colony count data from Skokholm, calculated population growth rate (Lambda). Pre- and post-eradication years from Lundy are highlighted

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1986	n/a	3,354	n/a	Lundy: Pre-eradication
1987	1	3,582	1.068	Lundy: Pre-eradication
1988	1	4,650	1.298	Lundy: Pre-eradication
1989	1	4,010	0.862	Lundy: Pre-eradication
1990	1	3,710	0.925	Lundy: Pre-eradication
1991	1	4,432	1.195	Lundy: Pre-eradication
1992	1	2,505	0.565	Lundy: Pre-eradication
1993	1	2,145	0.856	Lundy: Pre-eradication
1994	1	3,320	1.548	Lundy: Pre-eradication

Year	Years between counts	Colony count (individuals)	Lambda	Pre- or post-eradication?
1995	1	2,667	0.803	Lundy: Pre-eradication
1996	1	3,332	1.249	Lundy: Pre-eradication
1997	1	3,250	0.975	Lundy: Pre-eradication
1998	1	2,774	0.854	Lundy: Pre-eradication
1999	1	3,083	1.111	Lundy: Pre-eradication
2000	1	3,092	1.003	Lundy: Pre-eradication
2002	2	4,115	1.154	Lundy: Pre-eradication
2003	1	4,169	1.013	Lundy: Pre-eradication
2004	1	4,308	1.033	Lundy: Post -eradication
2005	1	4,510	1.047	Lundy: Post -eradication
2006	1	4,802	1.065	Lundy: Post -eradication
2007	1	4,900	1.020	Lundy: Post -eradication
2012	5	4,637	0.989	Lundy: Post-eradication
2013	1	4,834	1.042	Lundy: Post-eradication
2014	1	5,070	1.049	Lundy: Post-eradication
2015	1	6,665	1.315	Lundy: Post-eradication
2016	1	6,692	1.004	Lundy: Post-eradication
2017	1	7,800	1.166	Lundy: Post-eradication
2018	1	8,762	1.123	Lundy: Post-eradication
2019	1	7,447	0.850	Lundy: Post-eradication
2004 – 2019	**15**	**n/a**	**1.037**	**Lundy: Post-eradication**

1.3.4.6 The available evidence from Lundy showed that applying the population growth rate to the Muck population would result in a rapidly growing population (Table 1.18). The evidence from Skomer was for a slightly smaller population growth rate across the same time period, and a slightly larger population growth rate again from Skokholm, which was still less than from Lundy alone (Table 1.16 and Table 1.17 respectively). By subtracting the additional birds per annum projected to occur on Skomer and Skokholm (respectively) based on the population growth rate from Lundy, the expected growth in the population that may have occurred anyway was removed. Thus, the projected annual increase in birds on Muck is what would be expected as a result of a rat eradication only. The outputs provided for years 1 to 5, 15 (the span of the evidence from Lundy), 25 and 35 (the limit of the proposed Morven North and Morven South projects).

1.3.4.7 The projected growth rates from Lundy showed a rapid growth rate when applied to the Muck puffin population (Table 1.18). Subtracting the growth rate from Skomer from the growth rate from Lundy resulted in a slower population growth. Subtracting the growth rate from Skokholm reduced the predicted benefit on Muck from rat eradication by a larger amount than from Skomer.

Table 1.18: Projected population size increase of puffins on Muck (from a starting population size of 19 individuals) and projected annual increase in pairs as a result of rat eradication based on evidence from Lundy

	Lundy growth rate		Skomer growth rate		Skokholm growth rate		Additional birds per annum	
Years	Projected Muck population size (indiv.)	Additional birds per annum	Projected Muck population size (indiv.)	Additional birds per annum	Projected Muck population size (indiv.)	Additional birds per annum	Lundy - Skomer	Lundy - Skokholm
1	25	n/a	20	n/a	20	n/a	n/a	n/a
2	34	9	20	1	20	1	8	8
3	46	12	21	1	21	1	11	11
4	62	16	22	1	22	1	15	15
5	83	21	22	1	23	1	20	20
15	1,565	399	31	1	33	1	398	397
19	5,073	1,292	35	1	38	1	1,291	1,291
25	29,616	7,545	43	1	47	2	7,544	7,544
35	560,587	142,822	59	2	68	2	142,820	142,820

1.3.4.8 The projected benefit from rat eradication can also be compared to the predicted impacts from the Morven North and Morven South projects alone. The predicted impact on puffins, likely to require compensation, is between 3.2 and 13.3 individuals per annum (using the Applicant's precautionary position (low) and NatureScot's position (high), respectively).

1.4 Species not requiring compensation that would benefit

1.4.1.1 In addition to benefitting the species requiring compensation, other species are highly likely to benefit from eradication of rats from offshore islands. These other species are briefly considered below.

1.4.2 Other species benefits

1.4.2.1 As well as the species discussed in detail above, there are other species of seabirds that are known to be limited by the presence of rats on offshore islands (Furness *et al*. 2013, Furness 2022):

- Manx shearwater (*Puffinus puffinus*)
- European storm-petrel (*Hydrobates pelagicus)*;
- Leach's petrel (*Oceanodroma leucorhoa*);
- Lesser black-backed gull (*Larus fuscus*);
- Herring gull (*Larus argentatus*);
- Great black-backed gull (*Larus marinus*);
- Common gull (*Larus canus*);
- Black guillemot (*Cepphus grille*);
- Shag (*Phalacrocorax aristotelis*);
- Arctic tern (*Sterna paradisaea*);
- Common tern (*Sterna hirundo*);
- Sandwich tern (*Sterna sandvicensis*).

1.4.2.2 Among these, the Seabird Monitoring Programme (SMP) database has records of eight species on Muck, as shown in Table 1.19.

Table 1.19: Additional species that may benefit from rat eradication on Muck

Species	Muck
Manx shearwater	N
European storm-petrel	N
Leach's petrel	N
Lesser black-backed gull	Y
Herring gull	Y
Great black-backed gull	Y
Common gull	Y
Black guillemot	Y
European shag	Y
Arctic tern	Y
Common tern	N
Sandwich tern	Y

1.4.2.3 Among these, the absence of European storm petrel and Leach's petrel in the SMP database may not necessarily mean that these species cannot occur, or have not been recorded, on the short-listed islands. These species are known to be negatively impacted by the presence of rats (Furness *et al*. 2013). Removal of rats from Muck may result in opportunities for these species to colonise of their own accord, although this is by no means guaranteed.

1.4.2.4 One of the species that would likely benefit from rat eradication is black guillemots. However, as this species is not part of the UK Special Protection Area network, it would not represent any benefit as part of a derogation case but would represent a net gain from rat eradication.

2 Discussion

2.1.1.1 The response of particular seabird colonies proposed for compensation to removal of predators from offshore islands is challenging to enumerate robustly. The approach taken here makes several important assumptions and these need to be kept in mind when considering the likely accuracy of the predicted benefits to seabirds.

2.1.1.2 It is apparent that there can be important differences between seabird populations on islands where rats have been eradicated. The reasons for these differences are likely multi-factorial. Even when rats are causing population limitations, (e.g. through reduced adult survival, reduced productivity or reduced nesting habitat availability). When these limitations are lifted the population can only increase if other sources of population limitation allow. Other limitations may include food availability, birds available to recruit into the breeding population and other sources of limitation to nesting habitat (e.g. habitat change since locations were abandoned as breeding sites).

2.1.1.3 The approach taken here using population growth rate is biologically realistic but could result in an exponential growth rate with no upper limit. Thus, the benefit to seabirds will increase each year and this increases with time. In reality, growth will be ultimately limited by available nesting habitat on the island or prey resources. So, exponential population increase would only continue until one or more of these factors becomes limiting. The capacity of the available nesting habitat on each island has been informed by surveys undertaken by the Applicant in June 2025 (see Volume 3, Annex 2.6: Pre-eradication Field Study Report: Muck and Volume 3, Chapter 3: Outline Compensation Implementation, Monitoring and Adaptive Management Plan, of the Morven North and Morven South HRA Report).

2.2 Summary

2.2.1.1 The minimum and maximum projected benefit to populations of each seabird species based on the methods described above are summarised in Table 2.1. It is apparent that the proposed compensation measures are highly likely to provide a large benefit to all the seabirds assessed with little risk that colonies will not increase, and these are compared with relatively precautionary impact levels. Based on the comparative observations made at Lundy, Skomer and Skokholm, the benefits to guillemot and razorbill of rat eradication on Muck indicated that the increases calculated may not be sufficient when growth on comparable islands is subtracted. For razorbill, comparative growth projections from other locations (e.g. Canna) suggest a relatively rapid achievement of the compensation target, and the same applied to puffin.

2.2.1.2 However, the actual increase in guillemot numbers on Muck, if a similar trend to that seen on Lundy were to occur, would result in the population doubling in size within 10 years which would represent a substantial conservation gain in its own right. Indeed, against the background of broad trends in auk populations in the west of Scotland over the last 20 years, efforts to reduce sources of mortality and reverse declines are clearly merited and in this context the benefits of rat eradication on Muck extend beyond the compensation requirements of Morven North and Morven South.

2.2.1.3 It is also important to note that these calculated benefits are relatively precautionary, having taken into account the increases in similar nearby populations. While these inter-island comparisons are expected to account for temporal and environmental conditions during the same period which would be expected to influence post-eradication growth rates, it is also illuminating to consider the counterfactual outcomes for a specific island, comparing predicted growth with and without the removal of rats. For example, counts of guillemot on Muck indicate the number of breeding birds has declined from 1,073 in 1986, to 397 in 2000, 420 in 2018, 319 in 2021 and most recently 179 in 2025 (Dobson and Dobson 1986, Mitchell *et al*. 2004, Inger *et al*. 2022, Volume 3, Annex 2.5: Island Screening Report: Muck). Across this period this represents an average annual decline of 4.5%. If a post-eradication growth of 7.9% (as seen on Lundy) is achieved this could result in a counterfactual outcome on Muck of 12.4%. On this basis the Muck guillemot population would achieve the compensation target within the lifetime of the Morven North and Morven South wind farms. But furthermore, the auk populations on Muck would be safeguarded against possible extirpation if rats are left uncontrolled. If this should happen before rats are removed, the considerably greater challenge of encouraging recolonisation would be encountered.

Table 2.1: Summary of benefits to seabirds on Muck from the eradication of rats

Species	Predicted impact (individuals; low to high)	Source	Years from eradication	Minimum (individuals)	Maximum (individuals)
Guillemot	123.3 – 480.5	Lundy	2	15	21
			3	16	24
			4	18	26
			5	20	28
			19	76	92
			25	128	150
			35	296	330
Razorbill	5.9 – 23.1	Canna*	2	-	8
			3	-	8
			4	-	8
			5	-	8
			13	-	12
			25	-	27
			35	-	59
		Lundy	2	1	2
			3	2	3
			4	2	3
			5	2	3
			19	9	13
			25	16	22
			35	41	53

Species	Predicted impact (individuals; low to high)	Source	Years from eradication	Minimum (individuals)	Maximum (individuals)
Puffin	3.2 – 13.3	Lundy	2	8	8
			3	11	11
			4	15	15
			5	20	20
			19	1,291	1,291
			25	7,544	7,544
			35	142,820	142,820

* Note that for Razorbill at Canna there is only one island comparison hence only a maximum comparison is presented.

3 References

Bell, E., Boyle, D., Floyd, K., Garner-Richards, P., Swann, B., Luxmoore, R., Patterson, A., and Thomas, R. (2011). The ground-based eradication of Norway rats (Rattus norvegicus) from the Isle of Canna, Inner Hebrides, Scotland. In: C.R. Veitch, M.N. Clout and D.R. Towns (eds.) Island invasives: eradication and management, pp. 269–274. Occassional Paper SSC no. 42. Gland, Switzerland: IUCN and Auckland, New Zealand: CBB.

Booker, H., Price, D., Slader, P., Frayling, F., Williams, T. and Bolton, M., (2019). Seabird recovery on Lundy. Population change in Manx shearwaters and other seabirds in response to the eradication of rats. British Birds, 112: 217-230.

Dobson, R.H., & Dobson, R.M. (1986). The natural history of the Muck Islands, North Ebudes: 3. Seabirds and wildfowl. Glasgow Naturalist, 21, 183–199.

Furness R.W. (1997). Survey of the Rum Manx Shearwater population S.N.H. Research, Survey and Monitoring Report No 73. Scottish Natural Heritage, Perth

Furness, R.W., MacArthur, D., Trinder, M. and MacArthur, K. (2013). Evidence review to support the identification of potential conservation measures for selected species of seabirds. Report to Defra.

Horswill, C. & Robinson R. A. (2015). Review of seabird demographic rates and density dependence. JNCC Report No. 552. Joint Nature Conservation Committee, Peterborough

Inger, R., Sherley, R., Lennon, J., Winn, N., Scriven, N., Ozsanlav-Harris, L. and Bearhop, S. (2022). Surveys of breeding cliff-nesting seabirds, ground-nesting seabirds and burrow nesting seabirds in Western Scotland. Marine Protected Area Management and Monitoring. Final report to Agri-food & Biosciences Institute.

Lambert, M., Carlisle, S., Cain, I., Douse, A. and Watt, L., (2021). Unexpected involvement of a second rodent species makes impacts of introduced rats more difficult to detect. Scientific Reports, 11: p.19805.

Luxmoore, R., Swann, R. and Bell, E. (2019). Canna seabird recovery project: 10 years on. In: C.R. Veitch, M.N. Clout, A.R. Martin, J.C. Russell and C.J. West, eds. Island Invasives: Scaling up to meet the challenge, 576–579. IUCN, Gland, Switzerland. Gland, Switzerland: IUCN.

Matthiopoulos, J. & Furness, R.W. (2024). Developing a population model for Rum Manx Shearwaters for assessing offshore wind farm impacts and conservation measures. MacArthur Green Report to Scottish Government.

Mitchell, P.I., Newton, S.F., Ratcliffe, N. & Dunn, T.E. (2004). Seabird Populations of Britain and Ireland. : results of the Seabird 2000 census (1998-2002). Published by T and A.D. Poyser, London.

Morvern Offshore Wind (2025). Island Screening Report Isle of Muck Seabird Survey & Habitat Assessment, report by HAR

Murray, S., Shewry, M.C., Mudge, G.P. and Spray, S., (2003). A survey of Manx shearwaters *Puffinus puffinus* on Rum, Inner Hebrides in 2001. Atlantic Seabirds, 5: 89-100.

Swann, R.L. (2013) Canna seabird studies 2005 JNCC Report, No. 474b