# TA7.2 Golden Eagle Population Model Report

# GLENSHERO WIND FARM

## Golden Eagle Population Model Report

## Technical Appendix 7.2


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# 1 INTRODUCTION

This report has been produced by MacArthur Green and in accordance with Scottish Natural Heritage recommendations during consultation. All staff contributing to this technical appendix have undergraduate and/or postgraduate degrees in relevant subjects, have deep professional ecological impact assessment and ornithology survey experience, and hold professional membership of the Chartered Institute of Ecology and Environmental Management (CIEEM). The report has been reviewed and approved by David MacArthur of MacArthur Green and a copy of his CV is included in Environmental Impact Assessment Report (EIAR) Volume 4: Technical Appendix 1.2.

Population modelling has been used to assess potential impacts for some Scottish wind farm projects where golden eagle has been identified as a sensitive receptor, and has commonly been based on the golden eagle population modelling (GEPM) methods used in Whitfield et al. (2006[1]; 2008[2]); Fielding and Haworth (2010[3]) and Haworth (2014[4]). The GEPM procedure has been used for assessing the potential effects of the proposed Glenshero Wind Farm (the 'proposed development'). The model uses a deterministic matrix formulation and can be used to explore how additional eagle mortality may affect predicted growth rates of the Natural Heritage Zone (NHZ) 10: Central Highlands' golden eagle population. There are four key parameters in the model:

- Number of occupied ranges;
- Mean number of young fledged per pair per year;
- Annual survival rate of young birds; and
- Annual survival rate of adult range-holding birds.

Estimates for the first two are available with a reasonably high degree of confidence at a NHZ 10 level. The latter two are more difficult to estimate at the level of individual NHZ populations and therefore the values for these have been informed by studies conducted on other populations, in combination with regional information, such as trends in the number of occupied ranges, which can be used to modify their values (Haworth, 2014). Only the female half of the population is modelled. Therefore, calculated collision rates were halved, assuming a 1:1 sex ratio and equal activity.

Fielding and Haworth (2010) describe how alternative scenarios can be modelled to obtain predicted rates of population growth over the next 25 years, with or without a proposed wind farm and with varying rates of additional mortality on adults and/or sub-adults. The predicted population growth rate, the expected number of occupied territories after a period of 25 years and the time to reach a

[1] Whitfield, D. P., Fielding, A. H., McLeod, D. R. A., Haworth, P. F. & Watson, J. 2006. A conservation framework for the golden eagle in Scotland: refining condition targets and assessment of constraint influences. Biological Conservation, 130(4), 465-480.

[2] Whitfield, D P, Fielding, A H, McLeod, D R A and Haworth, P F (2008). A conservation framework for golden eagles: implications for their conservation and management in Scotland. Scottish Natural Heritage Commissioned Report No.193 (ROAME No. F05AC306).

[3] Fielding, A. and Haworth, P. (2010). Golden eagles and wind farms: A report created under an SNH Call-of-Contract Arrangement. Haworth Conservation.

[4] Haworth, P. (2014). The Dunmaglass Wind Farm Regional Eagle Conservation Management Plan. Haworth Conservation.

notional population target (e.g. the level associated with the wider concept of "Favourable Conservation Status" outlined below) can be compared whilst varying levels of additional mortality.

The parameter ranges considered in the GEPM for assessing the potential impacts of the proposed development and other wind farms cumulatively were agreed during correspondence with Scottish Natural Heritage (emails dated 19/02/2018) are outlined in turn below in Table 7.2.1, and detailed in the text below. A summary of this and all other relevant consultation responses is presented in EIAR Volume 2: Chapter 7: Ornithology, Table 7.1.

**Table 7.2.1: Parameters used in GEPM**

| Parameter | Golden Eagle Conservation Framework Report | Values used in Glenshero GEPM | Rationale |
|---|---|---|---|
| **Number of pairs within NHZ 10** | 12 | 21 | Data provided from the Highland Raptor Study Group showed that there were 21 pairs within NHZ 10 in 2017; up from 12 pairs from the national census in 2003. |
| **Total number of ranges within NHZ 10** | 26 | 28 | Data provided from the Highland Raptor Study Group showed that there were 28 ranges within NHZ 10 in 2017; up from 26 ranges estimated for the national census in 2003. |
| **Favourable Conservation Status of NHZ 10: Occupancy** | 17 | 19 | 66% occupancy rate of total available ranges within NHZ 10 |
| **S1 – survival rate from fledging to age 4 (note this is not the annual rate but the product of 4 annual rates)** | 0.400 | 0.243 – 0.400 | 0.243 for ages 0-4 combined (annual survival of 0.702[4]) is the value extrapolated from the model, based on the best fit of observed population growth from 2003 (12 pairs) to 2017 (21 pairs), using the predicted adult survival (0.9512) and mean productivity (0.750) rates for this period. It is thought that sub-adult survival has historically been the main factor in keeping the population low within this NHZ (see results of satellite tag study by Whitfield & Fielding 2017 for example).<br>0.400 was used by Whitfield *et al.* (2008) and Haworth (2014). This equates to a 40% survival from fledging to adulthood (annual survival of 0.795[4]). This was considered to be the minimal sub-adult survival rate which would predict stability or expansion for any credible measure of productivity which has been identified. |
| **S2 – adult survival (note this is the annual rate)** | 0.9512 | 0.9512 | 0.9512 was used by Whitfield *et al.* (2006; 2008) and Haworth (2014). This is a precautionary estimate which equates to a minimal adult survival rate (20 years of occupation) which predicts stability or expansion for any credible measure of productivity which has been identified. |
| **Mean fledging rate per pair within NHZ 10 (both sexes)** | 0.83 (2003 census) and 0.47 (mean 1982, 1992, 2003 censuses) | 0.47 | Mean productivity from 1982, 1992 and 2003 national censuses, as outlined in the Golden Eagle Conservation Framework. NHZ 10 mean productivity in 1982 and 1992 was low at 0.24 and 0.29 respectively, but higher in 2003 at 0.83. |
| | | 0.53 | Mean of all available results for NHZ population. From 1982, 1992, 2003, 2015-17 monitoring. |
| | | 0.723 | From Highland Raptor Study Group data provided in 2017. Mean of 2015-17 counts:<br>*In 2015, all ranges were checked and 11 were considered vacant. 14 chicks fledged from 17 territorial pairs (0.824 chicks/ terr pr)*<br>*In 2016, all ranges were checked and 9 were considered vacant. 12 chicks fledged from 19 territorial pairs (0.632 chicks/terr pr)*<br>*In 2017, 26 ranges were checked and 5 were considered vacant. 15 chicks fledged from 21 territorial pairs (0.714 chicks/terr pr)* |
| | | 0.75 | Mean of all available results for NHZ population in recent times. From 2003 and 2015-17 monitoring. |
| | | 0.83 | NHZ10 productivity in 2003 national census. This was the highest fledging rate of all NHZs assessed in this year. |

## 2 CONSERVATION STATUS OF NHZ 10: CENTRAL HIGHLANDS

Whitfield et al. (2008) devised three tests that should be applied to a golden eagle population to assess its conservation status. All three Level tests must be passed to achieve a favourable status.

1. Regionally, at least 66% of known territories should be occupied by pairs.
2. Demographic parameter values should allow the maintenance of a stable or expanding population. With limited information available on survival rates, an annual adult survival of 95.12% was adopted as the lower limit for a favourable conservation status classification. This equates to an expected 20 years of territory occupation by an adult. A minimum acceptable rate for sub-adult survival of 40% (across the first four years of life which equates to an annual survival rate of 79.5%) was used. Under these survival rates **an average reproductive rate of about 0.28 fledglings per pair per year** is the minimum required to maintain a stable population (i.e. a growth rate of 1). It follows, however, that if these parameter values varied regionally then lower rates in one parameter could be compensated for, to a degree, by higher rates in another parameter.
3. Compare the predicted population projections from the population model against the observed trends in the number of occupied territories from previous censuses. If the observed population trend failed to match predictions then the survival rates applied in the Level 2 test were probably too high. Hence, for example, if stability or increase was predicted but decline was observed. Under these circumstances it would be assumed that survival was below the lower limit for favourable status and the population would be deemed to have failed the Level 3 test.

The NHZ 10: Central Highlands' golden eagle population was determined by Whitfield et al. (2008) to be in unfavourable conservation status. The population failed the Level 1 test because, in 2003, only 12 ranges out of 25 known at that time were occupied, meaning that another five needed to be reoccupied for the NHZ to pass the Level 1 test.

For the Level 2 test, Whitfield et al. (2008) ran a population model for the NHZ with a starting population set at the 2003 level, and with a capped population set at the number of known territories. The output was the mean predicted number of occupied territories after 21- 30 years averaged over 100 simulated runs using randomly generated parameter values. NHZ 10 passed both Level 2 tests with observed fledging rates of 0.47 (mean for the 1982, 1992 and 2003 national surveys) and 0.83 for the 2003 national survey (i.e. above the minimum mean reproductive rate of 0.28).

The Level 3 test was failed because the relatively high productivity rates (0.83 per pair in 2003, and a long-term mean of 0.47 per pair) would have been expected to permit population expansion, but the trend was for stability.

The two main factors believed to be restricting growth of the NHZ 10 population were persecution and over-grazing by red deer *Cervus elaphus*, which have also been identified as the primary constraining factors in all NHZs in the wider area.

As the level 1 and level 3 tests were failed, the NHZ 10 population was considered to be in Unfavourable Conservation Status in 2008.

# 3 GEPM INPUT PARAMETERS

## 3.1 Level 1 Test: Number of Currently Occupied Ranges

In Whitfield et al. (2008) a target of 66% occupation of known territories was prescribed before each NHZ population could be considered to be in favourable condition. For the NHZ 10 population, this would be 19 out of a possible 28 known territories. It is therefore considered that currently the Level 1 Favourable Conservation Status threshold is met as there were 21 territories occupied in 2017 (estimate provided by Highland Raptor Study Group, 2017).

## 3.2 Level 2 Test: Survival Rates

Survival rates specific to the NHZ 10 population are unknown and so estimated S1 (sub-adult) and S2 (adult) survival rates were used in the model, based on evidence from the following sources:

- **S2 survival:** An S2 adult annual survival rate of 0.9512 was used in Whitfield *et al.* (2008) for various NHZs and for the NHZ 10 population in Haworth (2014). This is defined as the lowest rate for attaining favourable conservation status used in Whitfield et al. (2006), so is a precautionary value.
- **S1 survival:** a four year survival rate of 0.243 for survival from ages 0-4 (equating to annual survival of 0.7434) was derived using the model to match the observed population growth from 2003 (12 pairs) to 2017 (21 pairs), with conservative adult survival (0.9512) and the mean observed productivity rates from 2003 to 2017 (0.750). This is lower than the national mean rate of 0.400 used in the Golden Eagle Conservation Framework model. This is consistent with indications that poor sub-adult survival has historically been the main factor in keeping the population low within NHZ 10 (see results of satellite tag study by Whitfield & Fielding 2017 for example, where the Monadhliath Mountains were identified as a hotspot for final positions for a number of satellite tags of sub-adults).

Using these estimated survival rates in the model, the NHZ population would be expected to reach a carrying capacity of 28 pairs by around 2028; thereafter, all excess individuals would have to be recruited to neighbouring NHZ populations to breed. To simulate this in the GEPM a cap of 28 was placed on the number of pairs. Once this population size was achieved in the model the growth rate becomes 1 (i.e. stable). Consequently, the quoted rates of growth provided below refer to the period until this cap was attained in the model. These were calculated as the average over the period of growth, but omitted the first 3 annual values as these reflect starting conditions in the model and not the stable growth rate (Caswell 2001[5]).

## 3.3 Level 2 Test: Mean Fledging Rate

Mean fledging rates are based on values provided in the last four national censuses, as well as 2016 and 2017 data provided by the Highland Raptor Study Group. A range of fledging rate from 0.47 to 0.83 per pair was therefore investigated, as per Table 7.2.1.

# 4 RESULTS OF THE GEPM

## 4.1 Baseline Scenario

With the more recent data now available, an updated evaluation of the current conservation status of the NHZ 10 population can be made, within the context of the three tests described above.

[5] Caswell, H. (2001) Matrix Population Models. Sinauer Associates, Inc., Sunderland, MA.

1. Occupancy: 21 out of a possible 28 territories were occupied within NHZ 10 in 2017, resulting in an occupancy rate of 75% (Highland Raptor Study Group data), thereby exceeding the minimum 66% occupancy rate: **Favourable Conservation Status**
2. The mean productivity per pair in recent years, since the 2003 census (2003-17) was 0.750 (0.375 females per pair). Using survival rates described above (S1 = 0.243; s2 = 0.9512), an annual growth rate of around 3% is predicted, leading to 100% territory occupancy within 11 years. If the minimum S1 survival rate considered in Whitfield *et al.* (2008) is used (0.4), population growth is increased to 6% per year (100% occupancy within 6 years): **Favourable Conservation Status**
3. The predicted growth rates correspond to the observed growth between 2003 and 2015 censuses (3%), or between 2003 and 2017 (4%), with 12 active territories in 2003, 17 in 2015, and 21 in 2017: **Favourable Conservation Status**

This means that despite ongoing limiting factors on the population (persecution, grazing), on the basis of the most recent data, the NHZ 10 population is in **Favourable Conservation Status**.

Under the baseline scenario (without additional mortality due to predicted collisions at the proposed development) this population growth would permit the carrying capacity of the NHZ 10 (28 pairs) to be reached, even under the most precautionary estimates of S1 survival and productivity rates (see Table 7.2.2.).

**Table 7.2.2: Growth rate predictions of NHZ 10 Golden Eagle Population under Baseline Scenario. Growth rates above 1 indicate population increase, rates below 1 indicate decline. A rate of 1.05 indicates 5% annual growth. Note that these growth rates only apply until the population attains the carrying capacity.**

| | | Mean fledging rate | | | | |
|---|---|---|---|---|---|---|
| S1 survival rate | | ***0.47*** | ***0.53*** | ***0.723*** | ***0.75*** | ***0.83*** |
| | ***0.243*** | 1.005 | 1.010 | 1.023 | 1.026 | 1.034 |
| | ***0.250*** | 1.006 | 1.011 | 1.026 | 1.029 | 1.035 |
| | ***0.300*** | 1.014 | 1.021 | 1.037 | 1.038 | 1.046 |
| | ***0.350*** | 1.021 | 1.031 | 1.044 | 1.052 | 1.055 |
| | ***0.400*** | 1.032 | 1.039 | 1.051 | 1.061 | 1.068 |

Once all territories are occupied it is reasonable to suppose that individuals unable to acquire territories would emigrate to other NHZs.

### 4.2 With Glenshero Annual Collision Rate

Based on the current, preliminary turbine layout, a worst-case annual collision rate of 0.513 adult birds per year was included in the GEPM as an additional source of mortality to the NHZ 10 population. Using the 2003-17 mean productivity rate per pair within NHZ 10 (0.75), sub-adult 0-4 year survival of 0.243 and adult survival of 0.9512, the population limit of 28 pairs would be reached after 15 years at an annual growth rate of 1.9% (Table 7.2.3).

**Table 7.2.3: Growth rate predictions of NHZ 10 Golden Eagle Population when including predicted Glenshero Wind Farm collision rate (0.513/yr.). Note that these growth rates only apply until the population attains the carrying capacity.**

| | | Mean fledging rate | | | | |
|---|---|---|---|---|---|---|
| S1 survival rate | | *0.47* | *0.53* | *0.723* | *0.75* | *0.83* |
| | *0.243* | 0.995 | 1.001 | 1.018 | 1.020 | 1.026 |
| | *0.250* | 0.996 | 1.003 | 1.020 | 1.021 | 1.027 |
| | *0.300* | 1.006 | 1.013 | 1.030 | 1.034 | 1.040 |
| | *0.350* | 1.015 | 1.022 | 1.039 | 1.040 | 1.048 |
| | *0.400* | 1.022 | 1.028 | 1.046 | 1.054 | 1.057 |

The model predicts growth to carrying capacity in the majority of modelled scenarios, with the exception of the combination of most precautionary fledging (0.47) and S1 survival rates (0.243 and 0.250). Using the more realistic S1 survival rate of 0.4 (and mean fledging rate of 0.75), the carrying capacity would be reached after 6 years at an average annual growth of 5.4%.

This demonstrates that the NHZ 10 golden eagle population would be expected to continue to expand despite the additional mortality predicted to be associated with collisions with turbines at the proposed development.

### 4.3 With NHZ 10 Cumulative Annual Collision Rate

A worst-case cumulative annual collision rate for all installed, constructed, consented or application stage wind farm projects within NHZ 10 was estimated to be 1.0036 collisions per year (assuming all collisions are attributable to NHZ 10 adult birds).

Using the 2003-17 mean productivity rate per pair within NHZ 10 (0.75), sub-adult 0-4 year survival of 0.243 and adult survival of 0.9512, a positive growth rate of 1.3% would result (Table 7.2.4). At this rate of growth the carrying capacity of 28 pairs would be achieved by year 24.

**Table 7.2.4: Growth rate predictions of NHZ 10 Golden Eagle Population when including predicted cumulative collision rate (1.0036/yr.). Note that these growth rates only apply until the population attains the carrying capacity.**

| | | Mean fledging rate | | | | |
|---|---|---|---|---|---|---|
| S1 survival rate | | *0.47* | *0.53* | *0.723* | *0.75* | *0.83* |
| | *0.243* | 0.982 | 0.990 | 1.010 | 1.013 | 1.019 |
| | *0.250* | 0.984 | 0.992 | 1.012 | 1.014 | 1.020 |
| | *0.300* | 0.996 | 1.004 | 1.024 | 1.026 | 1.033 |
| | *0.350* | 1.007 | 1.014 | 1.035 | 1.036 | 1.043 |
| | *0.400* | 1.015 | 1.023 | 1.041 | 1.047 | 1.051 |

The model predicts continued growth in the majority of modelled scenarios, with the exception of the most precautionary combinations of fledging rates (0.47 and 0.53) and S1 survival rates (0.243 to 0.300). Using the more realistic S1 survival rate of 0.4, and mean fledging rates of 0.723 to 0.75, the carrying capacity of the NHZ (28 territories) would be reached after 7 years at an average annual growth of 4.1-4.7%.

This suggests that the NHZ 10 golden eagle population is likely to be able to continue to expand, despite the additional mortality predicted to be associated with collisions with turbines at the

proposed development and other projects within NHZ 10. The main limiting factor of the expansion of the NHZ 10 population, persecution, is likely to be reduced as a result of the ongoing Regional Eagle Conservation Management Plan (Haworth, 2014) which means that during the operation period of the proposed development, sub-adult survival rates in particular are likely to be higher than the conservative values considered above.

## 5 SUMMARY AND CONCLUSIONS

Based on the increase in number of occupied territories between 2003 and 2017, and relatively high productivity rates, the NHZ 10 golden eagle population is likely to be in favourable conservation status. The results of the GEPM suggest that:

- Under a baseline scenario (zero collisions) growth would continue until the NHZ's carrying capacity of 28 pairs is reached. Population growth is predicted when even the most precautionary survival and reproductive values are used in the GEPM.
- When additional mortality associated with collisions with turbines at the proposed development (0.513 per year) is taken into consideration, population growth would still likely take place, until the carrying capacity is met, albeit at a lower growth rate. Only when using the most precautionary survival and reproductive rates combined would a decline in population result. Based on the observed population trends, these values are considered to be unrealistic.
- When considering additional collision mortality from the proposed development and all other wind farm projects within NHZ 10 (1.0036 per year), population growth is on balance, still likely to occur. Again most scenarios modelled in the GEPM predict continued growth (albeit at lower levels compared to the above), with only combined precautionary survival and reproductive rates predicting a decline. Again, these combinations of low survival and productivity are considered to be unrealistic.

With stable or continued growth predicted over the long-term, despite additional mortality associated with collisions due to the proposed development and other projects, it is predicted that Favourable Conservation Status would still be achieved, and that no significant effects would occur on the NHZ 10 population as a result of additional mortality associated with collisions.