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Re-introduction of the golden eagle into the Republic of Ireland

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Abstract

The golden eagle (*Aquila chrysaetos*) became extinct in the Republic of Ireland in about 1912. Historical evidence suggests that, in the early nineteenth century, the population exceeded 50 pairs. It is thought that the extinction was a consequence of persecution and habitat change. Because there seems little chance of natural recolonisation a re-introduction programme has been developed. It is intended to release up to 15 birds per year for 5 years, starting in 2001. Single chicks will be obtained from Scottish nests with twins. The ways in which this project adheres to the six main IUCN re-introduction criteria are addressed. Two simulation models are described. The first, GEPM, demonstrates that the removal of chicks from Scottish nests should not have a detrimental effect on the Scottish population. The second model predicts the probable home range occupancy if only 12 birds are released each year. It is expected that between 3 and 13 ranges will be occupied by 2007. The imprecision in this estimate is a consequence of uncertainty about juvenile survival rates. The rationale behind our reintroduction scheme is outlined to stimulate debate about the development of good practice.

Keywords: IUCN; Population simulation; Donegal; Prey transect

1. Introduction

Re-introductions are often used in species conservation programmes or as a biodiversity enhancement method. The IUCN (1996) defined a re-introduction as "an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct". Cade (2000) catalogued 52 raptor re-introductions since 1986, involving at least 25 species. In a recent review, Fischer and Lindenmayer (2000) raised a number of concerns about re-introductions including failures to justify the re-introduction, lack of clear definitions of success, inadequate monitoring and poor communication of programme methods and outcomes. Whilst echoing some of these concerns, and raising others, Cade (2000) concluded that most raptor re-introductions are highly successful. In this paper, we describe the investigations that preceded the imminent re-introduction of golden eagles (*Aquila chrysaetos*) into the Republic of Ireland and identify how the programme's success will be measured.

Golden eagles are a widespread but rare bird of prey across Europe (Tucker and Heath, 1994), and formerly bred throughout Ireland's mountains and along the coasts. The first signs of a declining population were reported in the nineteenth century and by 1900 the population was reduced to a few pairs in the northwest. Whilde (1993) suggests that the last two breeding pairs were in Glenveagh (1910) and on the North Mayo coast (about 1912). A pair bred on Fair Head, County Antrim (Northern Ireland) from 1953–1960, but the site was deserted by 1962 (Deane, 1962). The golden eagle is one of six raptors [golden eagle, white tailed eagle (*Haliaeetus albicilla*), osprey (*Pandion haliaetus*), red kite (*Milvus milvus*), marsh harrier (*Circus aeruginosus*) and goshawk (*Accipiter gentilis*)] that are known to have become extinct in Ireland in the last 300 years (D'Arcy, 1999). Ireland is the only country from which golden eagles are known to have become extinct since the mid-nineteenth century (Watson, 1997).

There are thought to be two main reasons why golden eagles became extinct in Ireland. First there was widespread habitat change due to the demands of a growing rural population in the late twentieth century. Secondly, golden eagles experienced extensive persecution including

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poisoning, shooting, trapping and egg collecting. Despite the existence of suitable habitat and a widespread decline in persecution, it seems unlikely that natural recolonisation will occur from the closest, but much reduced, population in southwest Scotland. Indeed, only four adult golden eagles have been recorded in Ireland over the last 36 years.

As a signatory of the Rio de Janeiro Convention on Biological Diversity and the European Union's Habitat Directive, the Irish Government is required and encouraged, where appropriate, to re-introduce extinct native species. The golden eagle is also included on Annex 1 of the European Union Directive on the Conservation of Wild Birds (79/409/EEC), requiring member states to avoid any pollution or deterioration of habitats or disturbance. The National Parks and Wildlife Service (NPWS) of Ireland initially assessed the feasibility of re-introducing golden eagles into Glenveagh National Park in 1989–1991. Since 1995 the Irish Raptor Study Group (IRSG) has been examining and planning the re-introduction of golden eagles into northwest Ireland.

A re-introduction proposal has been drawn up that complies with Recommendation Number R (85) 15 of the Council of Europe Committee of Ministers to Member States on the re-introduction of species, adopted in 1985 which states that all responsible re-introductions are expected to meet six criteria (Centre Naturopa, 1996):

1. there should be good historical evidence of former natural occurrence;
2. only species lost through human agency and unlikely to re-colonise naturally should be considered;
3. factors causing extinction should be rectified;
4. there should be suitable habitat of sufficient extent to which the species can be re-introduced;
5. re-introduced individuals should be from a population as genetically close as possible to that of the former native population;
6. their loss should not prejudice the survival of the donor population.

The planned re-introduction also complies with a number of legal constraints including the licencing requirements of the NPWS and the Department of Agriculture. Scottish Natural Heritage have supplied a licence for the removal of wild-bred chicks from nests, subject to conditions that are highlighted in subsequent sections.

The aim of this paper is to identify how the re-introduction proposal satisfies legal requirements and the six release criteria of Recommendation Number R (85) 15. The proposal also overcomes the frequent shortcomings identified by Fischer and Lindenmayer (2000) and Cade (2000) and should contribute to the development of good practice for future release schemes. It is intended that the first birds should be released in 2001.

2. Methods

2.1. Release site selection

Suitable upland sites were assessed and scored according to 12 criteria: historical golden eagle nest sites; abundance of three potential prey species [Irish mountain hare (*Lepus timidus hibernicus*), rabbit (*Oryctolagus cuniculus*) and red grouse (*Lagopus lagopus scoticus*)]; three indicators of intentional disturbance (persecution levels, and raven (*Corvus corax*) and buzzard (*Buteo buteo*) abundances); sheep (*Ovis aries*) and red deer (*Cervus elaphus*) densities and husbandry; expansion potential; human population and local attitudes; logistical support. The largest areas of suitable golden eagle habitat are found in northwest Ireland where eight regions were assessed as candidate locations for initial releases: the Twelve Bens, Maumtrasna, Mweelrea and Partry Mountains in Connemara, Achill and Clare Islands, North Mayo coast, Benbulbin in Sligo, Glencolumbkille peninsula, Blue Stack and Derryveagh Mountains in Donegal.

2.2. Population modelling

Two questions were posed by the donor licencing authority (Scottish Natural Heritage).

1. Will the removal of chicks have a detrimental effect on the Scottish population?
2. Do the planned releases have the potential to produce a self-sustaining Irish population?

In order to provide first approximations towards answering these questions two Monte Carlo models were developed (both models are available on request from AHF).

2.2.1. Golden eagle productivity model (GEPM)

The GEPM model attempts to provide a conservative assessment of the possible effects of removing chicks on the future occupancy of golden eagle ranges within Scotland. It incorporates five important assumptions, most of which are a consequence of the lack of detailed information. The assumptions are:

1. all parameter estimates apply equally to males and females;
2. all adult (at least 4 years old) birds are equally likely to occupy vacant home ranges;
3. birds do not occupy ranges until they are at least 4 years old;
4. the number of occupied ranges cannot rise above 110% of the initial value;
5. there are no regional trends.

GEPM is constructed in an EXCEL spreadsheet. This allows the model to be flexible and accessible. It is a

stochastic model, in that the parameter values (Table 1) are perturbed by the addition of random 'noise' drawn from a normal distribution. The level of perturbation can be varied and may be set to 0 to produce a deterministic model. The default perturbation is obtained by setting the standard deviation to 10% of the mean. The perturbation makes use of random data generators from Poptools (Hood, 2000).

The model tracks the fate of cohorts. The structure of the model is shown in Fig. 1. Individual birds may die or, if they survive to 4 years old, they may occupy a vacant range. The effects of varying the different elements of the model are viewed by following the behaviour of the time course (examples shown in Fig. 3). Because the model is stochastic it should be run many times for any particular combination of model parameters.

2.3. Release model

An intentionally conservative release model was developed to predict the short-term future of the developing golden eagle population. The model uses multiple simulations to derive the expected population structure. It was implemented using two simple MINITAB v12.22 macros and is based on four assumptions.

1. Released birds are a random sample from the host population. There is no guarantee that the released birds will have a 1:1 sex ratio. The simulation deals with this problem by assuming the number of males (m) follows a Binomial distribution: $m \sim \text{Bin}(12, 0.5)$. The number of females is simply $12-m$.
2. All birds that survive to age 4 establish a pair as long as a member of the opposite sex is available.
3. A proportion of released birds die before age four. Survivorship rates (s) do not differ between sexes. Because actual survival rates are unclear three levels are tested: 0.25, 0.50 and 0.75. Survivorship is calculated separately for each sex and the actual value of s is drawn from a normal distribution, i.e. s is assumed to be $N(\mu,\sigma)$, where μ is 0.25, 0.50 or 0.75 and σ is $\mu/5$.
4. At age 4 the number of pairs is equal to whichever is smaller, the number of males or the number of females. For example, if four males and two females survived there would be two pairs. Any unpaired birds (two males in the previous example) have a chance of forming a pair next year. Unpaired 4-year-old birds have a 75% chance of surviving to the next year. They drop out of the population if they are still unsuccessful when 5 years old.

The reintroduction sequence was simulated 1000 times for each of 3 years. It was assumed that 12 birds were released each year. Five parameters were retained from each simulation: the numbers of male (M) and

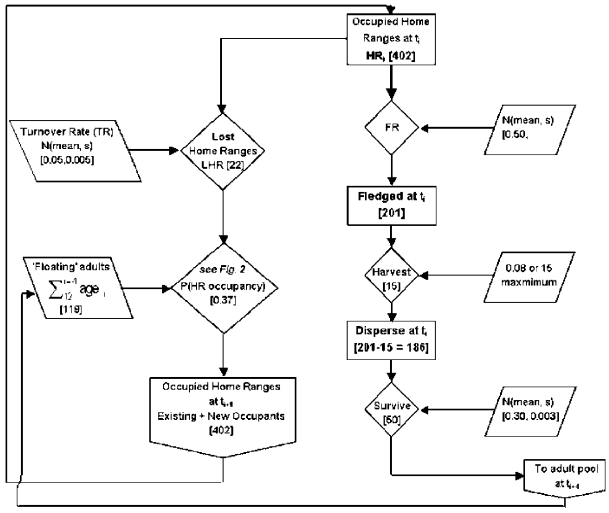

Fig. 1. Flow chart of GEPM model, figures in brackets are sample values from one simulation which had the following starting conditions: 400 Occupied ranges (HR), fledging rate (FR) of 0.50 per range per year, Home range turnover rate (TR) of 0.05 (20 year occupancy), 8% (or a maximum of 15) chicks removed for the re-introduction, age specific survival rates (SR_i) were 0.30, 0.80, 0.90, 0.90, 0.90, 0.75, 0.60, 0.50, 0.00 for ages 4–12, respectively.

Table 1
Golden eagle productivity model parameters (suggested values are shown)

Home range count (HR)	Estimate of the number of occupied home ranges [typically 350–450, 424 in Green (1996)].
Turnover rate (TR)	Proportion of home ranges that become vacant each year, TR^{-1} = average occupancy in years (0.05 is 20 years).
Fledging rate (FR)	Total number of offspring divided by number of occupied home ranges [0.53 mean in Watson (1997)].
Harvest rate (RR)	Proportion of offspring removed for the re-introduction programme (capped at a maximum allowable value of 15).
Age-specific survivorship rates	These rates apply to birds not occupying home ranges.
SR_i	
SR4 (0.40)	Proportion of fledged birds surviving from release to age 4.
SR5 (0.80)	Proportion of year 4 birds surviving to age 5.
etc.	
SR12 0.00	All birds not occupying a home range are 'killed', extending this has little effect on the model.

female (F) released birds, the numbers of males (Male4yr) and females (Fem4yr) surviving for 4 years and the number of pairs formed (Pairs). Results are presented for the number of pairs formed, summed over the 3 years considered in this simulation.

3. Results

3.1. Release site identification

The Glenveagh National Park in the Derryveagh Mountains of County Donegal (Fig. 2) had the highest aggregate score of all of the sites examined. Two independent experts (Mr. R. Dennis and Dr. J. Watson) endorsed the location as a suitable site for the initial release programme. Line transects (O'Keeffe, unpublished) indicated that prey, particularly mountain hare, were sufficiently abundant (46 kg 100 km^{-1}) to support golden eagles. Using historical maps and current land usage, Haine (unpublished) identified a potential 23 home ranges in the surrounding countryside of northwest Ireland.

Fig. 2. The Republic of Ireland (shaded gray) with the release site (Glenveagh National Park) marked by a filled circle.

3.2. Population models

3.2.1. Productivity model

The model was evaluated under 72 parameter permutations, with and without chick removal. Each parameter combination was replicated 100 times. Fig. 3a demonstrates the cyclic behaviour that is seen when occupancy duration is low. In Fig. 3b the population begins to decline rapidly, this is true even if no birds are removed for the reintroduction programme. A rapid home range turnover is expected if ranges experience severe disturbance and persecution. If the model is run under quite conservative conditions there is little evidence that removing birds for re-introduction will have a significant effect on the Scottish donor population, independent of that caused by the simulation conditions. Under most reasonable combinations of the model's parameters the number of occupied ranges remains within 1% of the initial value of 400 (Table 2).

The simulation results suggest that turnover rate and juvenile survival are more critical than fledging rate and that harvesting has an insignificantly small effect (Table 2). An analysis of variance confirms that the mean number of occupied ranges, at year 30 of the simulation, was significantly related to the turnover rate ($P<0.001$), fledging rate ($P=0.001$) and juvenile survival rate ($P<0.001$). Removal of chicks for the re-introduction

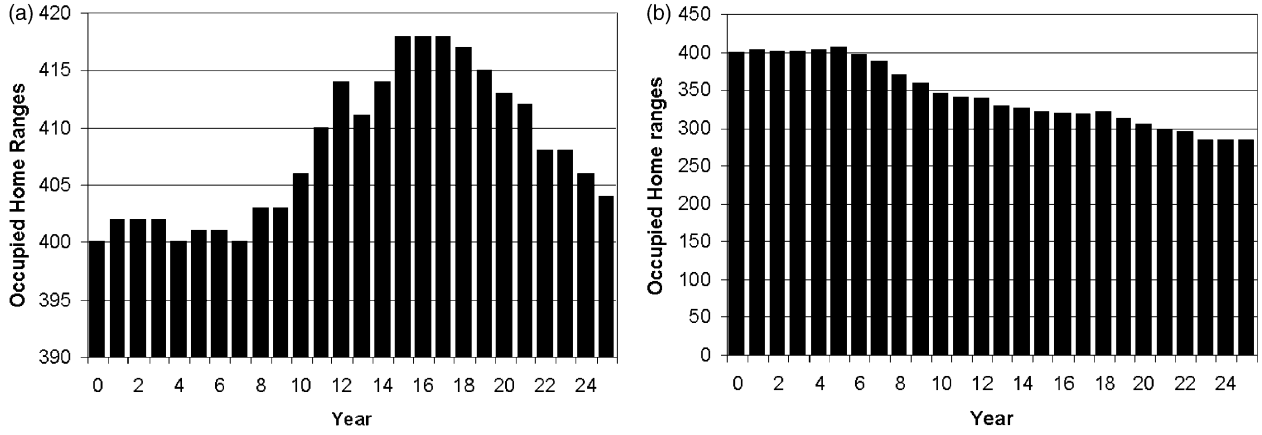

Fig. 3. (a) Example simulation (GEPM) over a 25-year period. The model simulates removal of 8% of chicks during years 6–10 on the number of occupied home ranges. Simulation conditions are identical to those in Fig. 1 except that home range occupancy is 13 years. (b) This simulation uses identical values to those for Fig. 3a, except that home range occupancy has been reduced to 11 years.

programme had no significant effect ($P = 0.864$). The greatest numerical differences in the numbers of surviving juvenile eagles, with and without removals, occurred when productivity and survival were both high. Under these circumstances the pool of adult birds waiting for vacant ranges is very much larger than the supply. Even under the worse case scenario presented in Table 2 (20% survival to age 4, 0.35 fledging rate and 10 year range occupancy) the removal of 15 birds only decreased juvenile eagles surviving to 4 years old from 24 to 21 birds.

3.2.2. Release model

Example results for five simulations of the release model are shown in Table 3. In this example there are no unpaired birds from the previous year. Table 4 summarises the results from 1000 simulations. As expected, increasing juvenile survival rates resulted in more pair formation. Under the worst-case scenario of 25% survival the simulation predicted four occupied ranges by 2007. Table 5 shows the results from the release model simulations in more detail. Estimated probabilities, calculated for a range of outcomes, suggest that between

Table 2
Mean numbers (based on 100 simulations) of occupied ranges in year 30 of the simulations[a]

Chicks removed	Survival to age 4	Home range occupany (years)								Fledging rate
		10	11	12	14	17	20	25	33	
No	0.2	89.6	113.8	144.3	182.9	229.4	288.2	354.4	399.8	0.35
	0.4	204.3	253.0	306.9	364.4	397.7	399.1	399.6	399.2	
	0.6	355.2	386.1	397.7	399.2	398.6	398.0	399.0	400.0	
	All	216.4	251.0	283.0	315.5	341.9	361.8	384.4	399.7	
Yes	0.2	88.1	113.5	142.1	181.0	228.7	284.8	349.3	399.7	
	0.4	198.5	249.6	301.5	355.7	396.9	399.1	399.4	398.9	
	0.6	352.4	381.7	398.9	398.3	400.3	398.7	398.5	399.1	
	All	213.0	248.3	280.8	311.7	342.0	360.9	382.4	399.2	
No	0.2	104.9	133.4	166.9	209.0	260.7	320.2	385.3	398.5	0.40
	0.4	255.5	303.3	362.5	397.0	400.0	401.1	398.4	399.0	
	0.6	392.7	400.6	401.1	397.8	399.4	399.3	398.6	399.8	
	All	251.1	279.1	310.2	334.6	353.4	373.6	394.1	399.1	
Yes	0.2	102.5	130.7	163.6	208.8	255.3	318.9	379.1	399.4	
	0.4	246.3	302.3	356.6	393.8	401.4	399.8	398.5	399.2	
	0.6	391.7	398.8	399.9	399.4	399.4	398.3	400.3	398.9	
	All	246.8	277.3	306.7	334.0	352.0	372.3	392.7	399.1	
No	0.2	136.9	171.1	214.4	263.6	321.7	381.3	400.5	397.9	0.50
	0.4	350.4	390.2	400.6	398.5	398.6	399.2	400.1	399.6	
	0.6	399.4	399.4	399.8	399.0	402.1	400.4	401.7	399.0	
	All	295.5	320.3	338.3	353.7	374.1	393.6	400.8	398.8	
Yes	0.2	136.6	169.3	209.6	261.1	319.6	377.1	400.4	398.8	
	0.4	345.7	385.6	400.0	402.3	399.4	398.9	399.6	399.9	
	0.6	398.1	400.2	397.1	401.7	399.8	401.4	400.8	398.7	
	All	293.5	318.4	335.6	355.0	372.9	392.5	400.3	399.1	

[a] In all simulations the initial number of occupied ranges was 400. 8% or 15 chicks were removed where applicable.

Table 3
Example results from five release model simulations (50% survival from release to 4 years old)[a]

M	F	Male4yr	Fem4yr	Pairs
8	4	4	2	2
4	8	2	3	2
5	7	3	4	3
8	4	4	2	2
6	6	4	4	4

[a] M and F are the numbers of released males and females. Male4yr and Fem4yr are the number of birds that survive for 4 years. Pairs is the number of pairs that become established in that simulation.

Table 4
Expected numbers of pairs (mean, median and standard deviation) in 2007 (based on 1000 simulations of the release model)[a]

Survival rate	Mean	Median	*s*
0.25	3.74	4	0.68
0.50	7.73	8	1.01
0.75	11.14	11	1.94

[a] Survival rate is the proportion of released birds that survive to age 4.

Table 5
Probabilities that x pairs will become established (based on 1000 simulations of the release model) assuming that 12 birds are released each year, 2001–2003[a]

Survival rate to age 4	Pairs	2005	2006	2007	Total in 2007
0.25	0	0.02	0.01	0.00	0.00
	1	0.68	0.87	0.66	0.00
	2	0.29	0.12	0.32	0.01
	3	0.01	0.00	0.02	0.37
	4	0.00	0.00	0.00	0.50
	5				0.12
	6				0.01
0.50	0	0.00	0.00	0.00	0.00
	1	0.04	0.00	0.02	0.00
	2	0.51	0.30	0.46	0.00
	3	0.36	0.66	0.50	0.00
	4	0.08	0.04	0.02	0.00
	5	0.00	0.00	0.00	0.01
	6	0.00	0.00	0.00	0.08
	7				0.34
	8				0.36
	9				0.17
	10				0.04
0.75	0	0.00	0.00	0.00	0.00
	1	0.12	0.00	0.00	0.00
	2	0.31	0.06	0.07	0.00
	3	0.19	0.28	0.30	0.00
	4	0.18	0.34	0.34	0.00
	5	0.12	0.21	0.20	0.00
	6	0.07	0.08	0.07	0.00
	7	0.02	0.02	0.02	0.02
	8	0.00	0.00	0.00	0.04
	9	0.00	0.00	0.00	0.13
	10	0.00	0.00	0.00	0.20
	11				0.19
	12				0.17
	13				0.13
	14+				0.11

[a] Probabilities are given for new pairs becoming established each year (2005, 2006, and 2007), and the final total in 2007.

three and 13 golden eagle ranges should be occupied by pairs following 3 years of re-introductions of 12 birds per year. The imprecision is a consequence of uncertainty about the survival rate. If 50% survival is used we expect seven or eight pairs by 2007. The model, and its predictions, can be adjusted as data become available from released birds.

4. Discussion

4.1. Other re-introductions

The planned release of wild-born golden eagles into Ireland will be its first re-introduction into a country from which it was exterminated. The only other re-introduction of golden eagles known to the authors was by Lindberg (1998, cited by Cade, 2000), who released 25 captive bred eaglets into southern Sweden. Consequently, the Irish programme should provide useful information for other raptor releases in the same way we have built on experience obtained from other successful raptor re-introduction programmes in neighbouring countries. In particular, the white tailed eagle (Evans et al., 1994) and red kite (McGrady et al., 1994) Scottish release programmes provided valuable practical assistance.

We are also keen to set these re-introductions into the context of the IUCN guidelines for reintroductions, and to develop a protocol of good practice that might have relevance elsewhere.

4.2. The IUCN assumptions

4.2.1. Historical evidence

Implicit in the re-introduction philosophy is that species must have been a recent member of the local flora or fauna. Ireland is the only country from which golden eagles are known to have been exterminated in recent times. Haine (unpublished) identified a minimum of 57 historical Irish golden eagle nests from R.J. Ussher's notes. Since these notes pertained to the period from 1850 to the loss of the last pair they are likely to underestimate earlier numbers.

4.2.2. Anthropogenic extinction and natural recolonisation

There is little doubt that golden eagles were directly and indirectly exterminated by human activities. Contemporary documentary evidence cited by D'Arcy (1999) shows that eagles were subjected to intentional and accidental poisoning, shooting and trapping. Records from egg collections and taxidermists also provide evidence for additional pressures. During the early nineteenth century the Irish human population expanded, reaching a maximum of eight million prior to the disastrous famine of 1845–1847. Inevitably increasing human population was associated with significant changes in land use. The current population is under six million (CIA, 2000).

It seems unlikely that Ireland will experience natural recolonisation. Only four of 25 golden eagle recordings in the last 36 years are known to be adults (eight sightings are unaged) and there is no evidence for an increasing number of sightings (1970s four records; 1980s 11 records; 1990s 10 records). The nearest Scottish population has declined because of afforestation, and their productivity is poor (Watson, 1997). If natural recolonisation is to occur birds would need to fly considerable distances over water where soaring conditions will be poor (McGrady, 1997). Although there is evidence from Scottish ringing studies that immature birds

have a relatively wide ranging excursive phase most appear to move eastwards before returning to their natal area (Grant and McGrady, 1999). Finally, Watson (1997) suggests that most juvenile birds are attracted to vacant ranges in the southern and eastern highlands and parts of the southern uplands and northern England. Unfortunately, because of persecution and poisoning, these regions act as a sink that contributes to a shortage of potential Irish colonisers.

4.2.3. Rectification of the extinction causes

As the IUCN (1996) guidelines indicate, it makes little sense to attempt a re-introduction unless the original causes of extermination have been removed. The level of raptor persecution, especially poisoning, has decreased significantly since the banning of strychnine in 1991. Continuing use of other poisons in Ireland is mostly by gun clubs and farmers who target foxes (*Vulpes vulpes*) and hooded crows (*Corvus corone cornix*). However, the National Association of Rifle and Gun Clubs recently suggested that poisoning is an unacceptable means of killing crows. Perhaps the strongest evidence for the removal of persecution comes from recent increases in raven and buzzard numbers in regions with putative golden eagle ranges. Irish raven populations increased by 53% between the 1972 and 1992 atlases. There have been similar increases in buzzard populations, with a rise from 59 pairs in Donegal in 1997 to 100+ pairs in 1999 (McLaughlann, Byrne and Cromie, personal communication). The increase in buzzards has arisen despite the absence of moles (*Talpa europea*) and voles (*Microtus agrestis*) from Ireland. It may also be that the distribution of rabbit, woodpigeon (*Columba palumbus*) and pheasant (*Phasianus colchicus*) are limiting the spread of buzzards (Swann and Etheridge, 1995). Apart from accidental poisoning, intentional persecution may arise if there is a perceived threat to gamebirds or lambs. There are few remaining commercial grouse moors in the Republic of Ireland. It is thought that between 0.15 and 2.40% of the Scottish annual lamb crop is killed by golden eagles (Watson, 1997). Leitch's (1986) study of a Scottish glen with a high sheep stocking density, high golden eagle density and little live prey found that golden eagles killed approximately 2% of the lambs, whilst the total lamb mortality was 26%. It seems that they take lambs up to 2–3 weeks old, that are lambed on the hill. However, in Donegal the majority of lambing takes place indoors or off the hill and they are not returned to the hill until they are 4–8 weeks old. It is anticipated that sub-optimal ranges, with less abundant live prey, will be unoccupied during the first 15–20 years. Therefore, problems with lamb predation are unlikely in the immediate future. The intervening period can be used for a period of liaison with local farmers. It will be interesting to note their reactions if golden eagles are shown to prey on perceived problem species such as foxes, crows and mink (*Mustela vison*). The release programme also incorporates proactive measures to reduce the potential for persecution. Radio-tracking of released birds will help to locate them and enable liaison with landowners and potential poisoners. Food dumps will help to ensure that most birds eat safe carrion during their first winter. If any birds are poisoned this can be used to push for additional changes in legislation and attitudes.

4.2.4. Suitable habitat

It would appear that the topography, land use and current prey base of many historical ranges makes them capable of supporting golden eagles again. The release site is within the Glenveagh and Cloghernagore Special Area of Conservation (SAC, 29 443 ha). All predicted golden eagle home ranges in Glenveagh and the surrounding regions of Donegal are inside SACs and significant parts of these uplands are owned by the State. Although these areas contain numerous commages, where hill farmers have shared land ownership, we expect an increase in the live prey base due to the imminent onset of the widespread Commage Destocking Framework Plan, which is being introduced by the Department of Agriculture, Food and Rural Development and Dúchas (the Republic of Ireland's Heritage Service).

The estimated 23 ranges in northwestern Ireland is probably conservative (Halley, 1999) and assumes the wide range separation that occurs when there is little winter carrion. Many traditional eyrie ledges are still available and there appears to be no shortage of suitable sites for ravens. Live prey transects (O'Keeffe, unpublished) indicate that Donegal is equivalent to the better Scottish regions (Watson et al., 1992). The main potential prey item would appear to be the Irish hare. Although this is larger than the Scottish mountain hare it is smaller than the Scandinavian subspecies. The island of Mull, which has one Scotland's densest golden eagle populations (Watson et al., 2001), also supports the introduced Irish hare and it is known to be an important prey item for some pairs (Madders and Marquiss, 2001; Haworth, unpublished observation). Comparisons with Scottish mountain hare studies need to be treated with caution because Irish hares are adapted to eat grass and are abundant at all altitudes (Tangney et al., 1995; Wolfe et al., 1996). Although the total amounts of carrion in Donegal are unquantified, the large numbers of foxes, ravens and crows suggest that sheep and deer carrion is at least locally abundant. Although sheep densities have been greatly reduced in Donegal there are still high sheep densities in Mayo and Galway that could provide a good supply of carrion. Some historical ranges, such as the Nephin Beg range, have almost certainly been lost to forestry. The remaining 23 historical ranges all have less than 20% of their

area under trees. Because of recent changes in Forestry grants and Natural Heritage Area designations there should be little extra upland afforestation. Watson et al. (2001) have shown that golden eagle productivity in western Scotland is at least partly dependent on spring weather. The climate of northwestern Ireland suggests that productivity should not be constrained by weather.

4.2.5. Relationships with donor population

Very little seems to be known about the genetic structure of golden eagle populations. Extinct Irish birds were almost certainly from the nominate race *Aquila chrysaetos chrysaetos* which breeds from Scotland through into Russia and as far south as the Mediterranean. The European golden eagle population is further sub-divided into five Biogeographic regions and the Northwest Mountains region would have included the Scandinavian, Scottish and extinct Irish populations (Watson, 1991 in Watson, 1997). The Irish and Scottish golden eagle populations were likely to have been almost contiguous several hundred years ago. Therefore, the proposed Scottish donor population is undoubtedly the closest surviving population to the extinct Irish population. There is little doubt that Irish and Scottish populations were once closely linked. Indeed, the Antrim Fair Head pair are said to have hunted across the Northern Channel in Kintyre (Deane, 1962). One side effect of the planned releases is that tissue samples from released birds will provide genetic information about the Scottish donor stock and baseline information for the future Irish population.

4.2.6. Effects on the donor population

Two of the biggest concerns facing the programme are chick availability and welfare. Potential donor sites are restricted in three ways. Firstly, chicks can only be removed if the landowner has given permission. Secondly, some nests are in locations that create unacceptable safety risks for field workers or the chicks (e.g. falling rocks). Chicks will not be removed until they are old enough to thermoregulate and eat without parental assistance (see also Section 4.3.2). Finally, licence conditions limit the source of chicks to nests with twins. Although it is known that twin frequency varies between regions and years, reliable data are patchy. On Mull, where reasonably comprehensive data are available, the average proportion of successful ranges that fledged twins (1982–1999) was 11% (range 0–25%). However, there is some evidence that the twin proportion has declined since 1987 and that this trend may be related to changes in May and June weather (Watson et al., 2001).

The productivity and release models suggest that the planned re-introduction will have little impact on the donor population, whilst resulting in a reasonable number of occupied ranges. The greatest numerical differences in the numbers of surviving juvenile eagles, with and without removals, are predicted when productivity and survival are both high. However, this is unlikely to have a detrimental effect on the donor population because the pool of surplus adult birds waiting for vacant ranges would be much larger than the supply of vacant ranges. Indeed, under these conditions it is possible that eagles without ranges would begin to exert detrimental density-dependent effects on resident pairs. Even under the worse case scenario presented in Table 2 the removal of 15 birds only decreased the surviving eagles from 24 to 21 birds. If the Scottish population ever experienced such conditions for more than 2–3 years there would be a detrimental effect, even in the absence of any removals. The release simulations suggest around eight occupied ranges by 2007. If juvenile survival of the re-introduced birds approaches the 73% recorded in Scotland for the re-introduced white tailed eagles (Green et al., 1996) this would rise to 10 ranges. This level of occupancy would certainly be considered a success and would compare favourably with the 20 occupied Scottish white-tailed eagle ranges in 2000 (Evans et al., 2001).

4.3. Development of good practice

4.3.1. Communication and publicity

Prior to the first releases considerable emphasis was placed on widescale consultation with potential stakeholders and raising bird of prey awareness, especially in County Donegal. Because large birds of prey have been largely absent from Ireland during the twentieth century there are few widely accepted views on raptors. The attitudes of local communities towards golden eagles are likely to have a significant influence on the project's outcome. Four key local audiences were identified: hill sheep farmers; tourist interests; the Gaeltacht (Irish speaking) community and the Donegal general public. The first three are directly represented on the project Steering Group.

Apart from some productive agricultural land in eastern Donegal, the majority of farm holdings in Donegal are of limited extent and livestock numbers are generally small. The Irish Farmers Association (Ireland's biggest farming union) was consulted widely. After consultations with farming colleagues in Scotland, IFA accepted that there was a minimal threat to Donegal lambs and they are happy for the project to proceed.

Tourism is the main source of income and employment in Donegal. Donegal Tourism and north west Tourism are anxious to see the project progress. They believe golden eagles will become an attraction, especially in the quieter shoulder seasons (spring and autumn), and can be used to promote Donegal in a wider sense.

Donegal has a large area classified as Gaeltacht, where Gaelic is the predominant language and the

Gaelic culture is still vibrant. As many potential golden eagle home ranges are in Gaeltacht areas, it is important that the project is promoted in Gaelic. The project manager is a competent Gaelic speaker and Údarás na Gaeltachta, the local development agency with responsibility for job creation and enhancing Gaelic culture, were approached and are backing the project financially. They will assist in Gaelic translations and media work.

Unemployment, and resultant emigration, has been a traditional social problem in County Donegal, particularly near those remote mountainous areas considered suitable golden eagle habitat. Communities here are consequently eager to see job opportunities develop locally and are conscious that they too must have a say in shaping their environment. There have been consultations with individuals and the wider community through high profile radio and print media coverage in English and Irish. The project team will continue to meet local elected representatives, interest groups, schools and parish councils and development groups throughout the course of the project. There is a growing view within the county that the project will have economic, cultural, aesthetic and educational benefits alongside its conservation enhancement.

The project has been part funded by the Ireland's National Millennium Committee. Therefore, there is a unique opportunity to promote golden eagles as part of a national and inclusive celebration of Ireland's natural heritage. Through the work of the National Millennium Committee, the project has been given a very high profile on television, radio and the print media. Possibly due to the dearth of other large raptors in Ireland, this project has generated a very positive public reaction to date.

4.3.2. Rearing and release techniques

During the time that it takes to collect a maximum of 15 eaglets they will be housed in Strathspey, the Black Isle, Tayside or Stirlingshire, where they will be fed corvids and rabbits. Human contact will be kept to a minimum. All birds will be examined and certified by authorised Scottish Veterinary staff and again by the Department of Agriculture once the birds arrive in the Republic of Ireland. We are unaware of any serious or contagious pathogens found on Scottish golden eagles and we do not believe the released birds will encounter any serious pathogens in Ireland. The eaglets will be transported by van and ferry to Donegal within a single day[1]. It may be necessary to make two trips depending of the ages of suitable donor stock. Birds will be fed during the journey and as they are placed in release cages where they will be held for about 5–6 weeks or until they are a week past flying age. The release cages are situated in a secure location which has good post-release perching and loafing areas. These cages are modelled on standard bird of prey cages designed for raptor release projects in Europe. They are 4×4×3 m tall mesh cages, with strand board walls to the back and sides. An artificial nest is placed in a back corner and food is delivered through a sleeve and hatch to the nest. This prevents sight of humans and helps to reduce 'imprinting'. Before release all individuals will be fitted with PVC wing tags to enable long-term visual identification of individual birds and radio backpacks for shorter-term radio tracking of the immature birds. DNA blood samples will be collected from each imported bird. Both the individual markings and the blood sampling require a licence from Dúchas.

Because young birds are dependent on their parents for food for about 3 months after fledging, food will be placed next to, or on, the cage roofs for several weeks before establishing long-term food dumps in the general vicinity.

4.4. Measuring success

It will be many years before we can assess the programme's long-term success; for example, it may be 2011 before the first Irish-born birds begin to breed. More immediate performance indicators will become available as released birds begin to prospect for ranges. It is difficult to set the standards against which the survival of released birds should be judged because there is a paucity of empirical data from wild populations. Predictions from the productivity model indicate that golden eagle population levels are more sensitive to juvenile survival and range turnover than they are to offspring production. The release simulation results suggest that even poor juvenile survival could result in five or six occupied ranges by 2006. Therefore, the first measure of success will be a minimum 25% survival from release to age 4, hopefully leading to four occupied ranges by 2007. The ultimate measure of success will be the establishment of a stable breeding population of between 20 and 40 pairs by 2050. Although this is a much lower population than the 420 pairs of Scotland (Green, 1996) it is larger than the stable population of 12 pairs on Crete and the 20 breeding pairs of the isolated population on the Baltic island of Gotland (Hedgren, 1996 cited in Halley, 1999). However, once all of the Irish ranges are occupied excess productivity may provide birds capable of supplementing golden eagle populations in southern Scotland and northern England. As Watson (1997) stated, once golden eagles are restored to Ireland, perhaps they could be eventually restored to the mountains of Wales and northern England.

[1] The manuscript was completed before the first planned collection date in 2001. The United Kingdom experienced a severe outbreak of foot-and-mouth disease in its sheep and cattle in 2001. If the re-introduction is still able to begin in 2001 it is planned to fly the eaglets from northern Scotland to the Republic of Ireland and thus avoid traveling through any infected regions.

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