ON THE LIFE HISTORY OF A REINTRODUCED POPULATION OF EAGLE OWLS *(Bubo bubo)*

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INTRODUCTION

Presumably, the eagle owl *(Bubo bubo)* once occurred nearly everywhere on the European continent. During the last two centuries, however, this species became more restricted to areas where it was less persecuted and disturbed by man. Persecution by man has included indiscriminate shooting, capturing of breeding birds, collecting of eggs, and taking of nestlings to rear in captivity for hunting purposes (Herrlinger 1973). The geographical distributions over time, of nest sites in our study area (Bergerhausen and Radler, unpublished review of reportings) shows a trend of restriction into less accessible areas, i.e. rocky hills or mountains. The species probably disappeared from most parts of the Federal Republic of Germany (FRG) by the 1960's, while a small population continued to decline in the south. During that time, attempts were started in several regions of the country to reintroduce this owl where it had recently disappeared (Herrlinger 1973).

This paper will be concerned with: (1) a brief description of reintroduction projects, (2) the life history of eagle owls in the central part of the FRG during the last decades, (3) types of mortalities, survivorship and nesting success and (4) genetic issues of reintroduction projects in this country.

Since the life history of this eagle owl population, and the factors affecting it, is currently being intensively monitored, we will limit ourselves in this paper to describing the available and relevant information to give an idea of the magnitudes involved.

ORGANIZATION AND METHODS

The first release trials, by the end of the 1950's, were not successful in increasing the numbers of breeding pairs. Therefore, Oswald von Frankenberg organized a cooperation of zoos, wildlife parks, owl breeders and naturalists known as "Aktion zur Wiedereinbür-gerung des Uhus" [translated as "Initiative for Reintroduction of the Eagle Owl (IRE)"]. The objective of the IRE was to release at least 40-60 birds each year to increase the number of nesting pairs. By the middle of the 1970's, this goal was achieved. Since 1979, more than 100 eagle owls were released each year. From 1964 through 1985, the total number of owls released was nearly 1,500 birds.

Program costs have been estimated at about DM 3000 (US $1,500) per released bird (Bergerhausen 1981). These costs include food, material for extra aviaries, and labor (including field observations). Total costs to date amount to almost DM 5,000,000 (US $2,500,000) or about DM 90,000 (US $45,000) per known pair with fledglings. About 10% of these costs was covered by government funds and private donors, while 90% was provided by members of the IRE in both labor and material (including food for the captive owls).

The IRE released only birds propagated in captivity, which were mainly descendents from zoo animals or wild-caught birds from eastern and northern European countries. Four main techniques of release have been successfully applied (Bergerhausen et al. 1981, Bergerhausen 1985): (1) fostering by wild-breeding pairs of fledglings not yet self-supporting, (2) release of juveniles, about 4-5 months old, from transport boxes placed in suitable habitats; most of these birds had been trained in aviaries to handle live prey, (3) release of fledging juveniles directly from the breeding aviary,

Table 1. Releases and recoveries within one year after release for the main release techniques applied (= 98%) during the years 1974-1984.

Technique	Releases Number	Releases %	Recoveries %
(1) Fostering of fledglings by wild-breeding pairs	115	10	32
(2) Release of juveniles from transport box	928	81	34
(3) Release of juveniles from aviary	70	6	31
(4) Release of mates during courtship	37	3	48
Wild-hatched and banded as nestlings	168		18

partly while offering food outside the aviary for several weeks after, and (4) release of mates to wild owls calling during courtship in winter.

Table 1 summarizes the number of owls released and the percent of recoveries within one year after release for each technique. These results, however, may be of only limited use because the critical assumption implied, i.e. equal probability for finding (= reporting) dead birds remains to be evaluated. We consider technique 4 less efficient, because we expect an even lower rate of reporting by the public due to decreased human activity during the most critical first months after release.

The seasonal distribution of release depended on the time of hatching and the release method used. Figure 1 summarizes these relationships for the released birds together with the distribution of recoveries. The main features to recognize in Figure 1 are: (1) time of laying in the captive population varies considerably, being distributed like a normal curve around the middle of April, (2) the majority of birds were released between July and October, and (3) the seasonal distribution of recoveries is fairly even at any time of the year, apart from an increase associated with the release of a greater number of juveniles. This indicates an increased mortality of juveniles shortly after they are released.

All data relevant to the reintroduction project, including data concerning the established population and ecological genetics re-

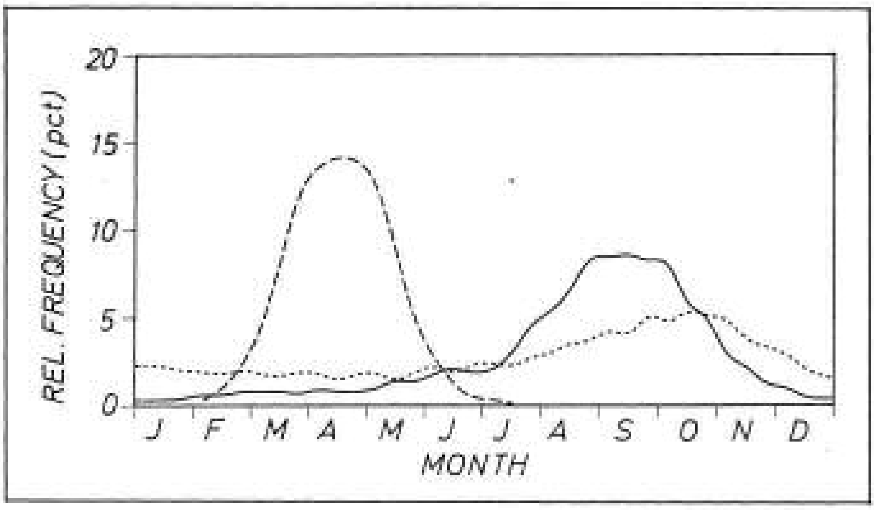

Figure 1. Distribution of time of hatching (dashed), release (solid), and recoveries (dotted) for released birds; curves were smoothed by a moving average procedure.

search, are stored in a computer data base managed via the database-software SIR/DBMS (Robinson et al. 1980). This data base management system is especially suited to fulfill our two main objectives: (1) improve efficiency by storing all relevant information in an easily accessible manner, and (2) to compile data for studies of population dynamics and genetics. The principal design of this data base has been described in more detail elsewhere (Radler et al. 1984).

RESULTS AND DISCUSSION

Types of Mortality

Table 2 summarizes the main types of mortality for recoveries of released and wild-hatched birds. Among the released group, 25% of the mortality was due to collision with power lines and 25% to traffic (road and railway). Among the wild-hatched birds, the first type of mortality causes the same percentage of loss as among the released group, while the latter type of mortality tends to be lower. Among the various other causes, shooting is presumably underestimated by our data. Even though shooting of eagle owls is illegal

Table 2. Frequencies of types of mortality among recoveries of released and wild-hatched eagle owls.

Type of Mortality	Total		Released		Wild-Hatched	
	Number	%	Number	%	Number	%
Electric Power Lines	161	25	150	25	11	24
Traffic (road, railway)	163	25	156	26	7	15
Various other causes	325	50	297	49	28	61
—wires, fences	52	8				
—shooting	17	3				
—sickness	32	5				
—poor condition	31	5				
—recapture	33	5				
—unknown	117	18				
TOTAL	649	100	603	100	46	100

in Germany, among hunters there is still a belief that this predator does substantial harm to populations of small game species (e.g hare, partridge, and pheasant).

Types of mortality are summarized by sex in Table 3. Total mortality rate, as well as mortality due to traffic and various other causes, is balanced among the sexes. However, the proportion of deaths caused by electric power lines is skewed nearly two to one towards females. While the reason for this remains to be investigated, we assume that females, with their wider wing span, have a higher probability of touching the electric wires, or they use power poles more often for perching because of territorial dominance.

Survival and Reproduction

The population dynamics of every species is basically governed by the ratio of survival to reproduction. In species with overlapping generations, population dynamics also depends on the age distribution, which has a state of equilibrium uniquely defined by age-specific rates of survival and fecundity (e.g. Poole 1974). Reliable estimates of these vital statistics are hard to obtain due to difficulties in collecting suitable data.

Table 3. Cross-tabulation of type of mortality among recoveries by sex (released and wild-hatched birds combined). The deviation from homogeneity is significant and mainly due to uneven sexual distribution among deaths caused by power lines (a^2 = 11.719 with 2 d.f.; P<0.01).

Type of Mortality	Number	%	**SEX** Female %	Male %
Electric Power Lines	142	26	64	36
Traffic (road, railway)	141	26	49	51
Various other causes	261	48	47	53
TOTAL	**544**	**100**	**52**	**48**

Table 4. Recovery frequencies R (i,j) for released cohorts (i = year of release) by age (j = year of life; starting with median date of birth, i.e. April 15). Only juveniles released by technique 2 or 3 of Table 1 are included.

Releases		Recoveries [R (i,j)] By Age [j]											
Year	Number	j=l	(%)	2	3	4	5	6	7	8	9	10	11
1974	39	**10**	(26)	4	2	0	2	2	1	0	0	0	0
1975	34	**17**	(50)	2	1	1	1	0	0	0	0	0	
1976	50	**19**	(38)	2	2	1	1	0	0	0	0		
1977	38	**12**	(32)	2	1	0	0	0	0	0			
1978	52	**14**	(27)	5	3	1	2	1	0				
1979	69	**18**	(26)	5	3	4	0	1					
1980	115	**29**	(25)	7	3	1	1						
1981	116	**26**	(22)	11	1	1							
1982	133	**37**	(28)	7	0								
1983	146	**41**	(28)	12									
1984	147	**55**	(37)										

TOTAL N = 939 **R = 278** (30)

Table 4 gives the frequencies of owls released as juveniles from 1974 through 1984 by techniques two or three (see Table 1) and recovered through April 1985. Although this type of table has been widely used for estimating age-specific survival rates, this approach is essentially based on a model whose assumptions and implications have been extensively analysed and questioned in a series of recent papers (see Anderson et al. 1985 for a review). A thorough evaluation of those assumptions is essential before inferred estimates of vital statistics can be of any value, or before further management considerations can be based upon them. This type of detailed analysis is beyond the scope of this paper, apart from the fact that additional data is necessary in order to get any "trustworthy" estimate from this model (see Lakhani and Newton 1983, Anderson et al. 1985). For these reasons we do not present survival estimates here.

However, Table 4 clearly shows that survival in our population depends mainly on first-year mortality. Therefore, the assumption of no time-specific variation among recoveries within the first year of life appears to be most crucial in this context. This assumption implies the question of environmentally independent first-year recoveries, which can be readily tested, based on frequencies given in Table 4: The test statistic

$$\chi^2_{k-1} = N^2 \sum_{i=1}^{k} \frac{(R_{i1} - N_i \frac{R}{N})^2}{N_i R \; (N-R)}$$

is distributed as chi-square with k-1 degrees of freedom under the null hypothesis that the products of first-year mortalities and reporting rate are constant (Anderson et al. 1985).

Contrary to the general trend in other unhunted species (Anderson et al. 1981), rejection of this hypothesis is not indicated here (x^2 = 17.983 with 10 D.F.; P<0.10). This is possibly due to management efforts to seek optimal age and environmental conditions for time of release as well as exclusion of owls which are not likely to be suited for release.

The overall rate of recovery within the first year of life was 30% among released birds, while the corresponding value for wild-hatched birds (Table 1) was only 18%. Since it does not seem unlikely that reporting rates are twice as high in released birds, we do not consider this a convincing demonstration that survival is considerably better in wild-hatched juveniles, as concluded by other authors (Bezzel and Schopf 1986).

The dynamics of total numbers of pairs with fledglings of the reintroduced population between 1973 and 1984 is depicted in Figure 2. The over proportional increase in the last two years is possibly a time-lagged reaction to the substantially higher numbers released since 1979.

The mean number of fledglings from 112 successful (i.e. with at least one nestling of more than 4 weeks of age) pairs was 1.83 (standard deviation = 0.83). This value is well within the range of published figures from other populations in Europe (Table 5). However, simple comparisons are probably misleading because of different field methods and efforts applied in obtaining those estimates. A correlation between persons involved in field work and the number

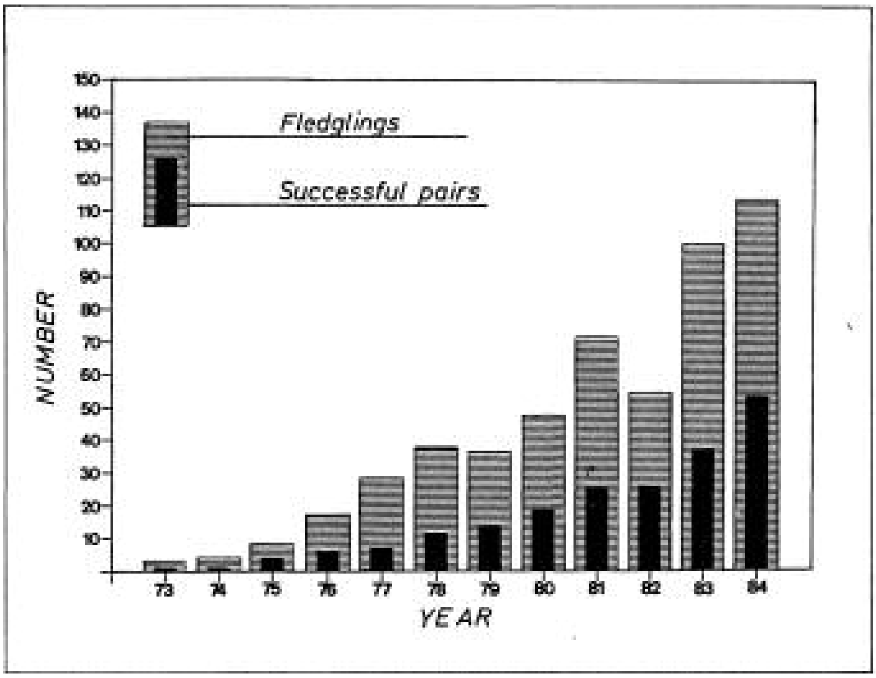

Figure 2: Dynamics of total number of successful (i.e. with fledged young) pairs and fledglings for the reestablished population from 1973 through 1984.

Table 5. Average brood success of eagle owl populations in Europe in terms of fledglings per successful (i.e. with at least one nestling) pair. N = number of broods (years combined).

Country/Area	Brood Success	N	Source
FRG/central	1.83	112	this paper
FRG/southeast	1.81	261	Wickl 1979
Austria	1.90	28	Frey 1973
Czechoslovakia	1.80	51	Suchy 1978
Sweden	1.55	399	Olsson 1986

of reported breeding pairs has been convincingly demonstrated (Bezzel and Schöpf 1986), and could bias the estimate of average breeding success.

We do not consider comparisons of overall breeding success among populations a valuable approach, because, in evaluating the status of a population, only suitable comparisons of survival and fecundity can give helpful information. Due to the tentative character of this study, we prefer not to detail our analysis until data currently being collected is analyzed.

Genetic Issues

Reintroduction is necessarily associated with a severe demographic and genetic bottleneck. As both theory and controlled experiments predict, genetic variability may be lost due to sampling founders for captive propagation and, subsequently, loss of genetic diversity due to a small effective breeding population (Hedrick 1985). These processes are associated with an increase in the mean coefficient of inbreeding in isolated populations. With respect to wild species (especially vertebrates), little is known concerning these processes (Schonewald-Cox et al. 1983).

An important question arises in this context as to whether eagle owls exhibit inbreeding depression with respect to fitness parameters, e.g. fledging success. In a recent paper on this issue, Radler (1986a) showed that consanguineous captive pairs of eagle owls had a lower average brood success; however, this remains to be confirmed in a more detailed analysis. Its implications are being investigated with genetic markers (Radler 1986b), together with an intensive monitoring of the reestablished population, to assess the importance of genetic variability in reintroduced populations.

CONCLUDING REMARKS

The question we find most crucial, and the ultimate criterion in evaluating the success of a reintroduction project remains: Will this extensive and expensive effort eventually result in a stable population of eagle owls in Germany? This question is being approached by intensively monitoring the reintroduced population. Genetic aspects, which are far from negligible for the ultimate success of a reintroduction (Radler, in preparation), will likewise be monitored.

Since the population of concern has limited accessibility, assessment of the influencing factors is not a straightforward task and calls for careful analysis.

We do not feel that reintroduction of animals can be judged to be a promising approach to conservation until a few intensive studies of this magnitude have been carried out.

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