Survival and breeding of Greater Flamingos *Phoenicopterus ruber roseus* in the wild after a period of care in captivity

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Of 20-22,000 Greater Flamingos present in southern France in December 1984, 3000 were found dead during a spell of freezing weather in January 1985 and a further 4000 birds are estimated to have died. Of 1000 birds captured in a weakened state during the cold spell and cared for in captivity, 53 adults were marked with plastic rings. About 15% of these birds are estimated to have died shortly after release. Birds that were not seen alive after release tended to have been lighter at release and to have gained less weight during their period in captivity. The subsequent survival and incidence of breeding of birds that were seen alive after release was high.

Greater Flamingos *Phoenicopterus ruber roseus* of the western Mediterranean population breed in commercial salinas and brackish wetlands in southern France and Spain and spend the winter in these areas and also in Portugal, Morocco, Algeria, Tunisia and Sardinia (Johnson 1989). Southern France has a colder winter climate than other parts of the wintering range of the population and there is evidence that flamingos that spend the winter in France suffer higher than average mortality in cold winters (Johnson, Green & Hirons 1990). In the period 2-17 January 1985, an exceptional cold spell occurred during which most of the lagoons along the Mediterranean coast of France froze over. Of 20-22,000 flamingos present in France in December 1984 about 9500 remained after the end of the cold period (Johnson 1985). About 3000 birds were found dead and it is estimated from the survival rates of plastic-ringed birds that approximately 7000 died. A considerable effort was made to feed starving flamingos in the wild by putting out rice grain around areas of open water and about 1000 birds were captured in a weakened state, held in captivity at seven centres and released soon after the weather improved. In this paper we report on the survival and breeding of a small sample of these birds that were marked with plastic rings before release.

Methods

Flamingos weakened by starvation were taken into captivity at seven centres in southern France and maintained on a diet of rice grain and dried dog food soaked in water. Most were captured in the period 8-15 January and released on 23-27 January. Birds were ringed at three centres (Palavas, Beziers and Pont du Gau) with plastic rings engraved with unique combinations of letters that can be read at a distance of up to 200 m with the aid of a telescope. Some birds were weighed and measured when taken to the centre on 13-14 January, some just before release on 23-24 January and some at both times. The measurements used in this paper are wing length (maximum chord) and weight (measured to the nearest 50 g). Because there is a marked sexual dimorphism in size, birds could be reliably sexed according to their wing length (Johnson 1985). Flamingos were approximately aged as first-year, second-year or older according to plumage characteristics (Johnson 1983). Because survival of flamingos is known to vary with age up to three years old and because only small numbers of first and second year birds were ringed, only data on the birds that were in adult plumage are reported here.

Marking flamingo chicks with plastic rings began in 1977 at the breeding colony in the Camargue, southern France and about 600 chicks have been ringed in each year since then. A systematic programme of ring reading is carried out in France, Spain, Sardinia and Tunisia and particularly at the two breeding colonies in the Camargue and Fuente de Piedra, Andalucia, where the birds are observed from hides near the nesting site.

Table 1. Estimates of calendar year-specific survival and resighting rates of released Greater Flamingos by Cormack's (1964) method with 95% confidence intervals in brackets. Also shown are the numbers of birds released or seen in a given period (R), the number of those that were seen again subsequently (r) and the number of birds that were not seen in a given period but were known to be alive from subsequent sightings (z). Survival and resighting rates cannot be separately estimated for 1988.

	R	r	z	Survival	Resighting
Release	53	45	-	-	-
1985	37	35	8	0.858 (0.729-0.931)	0.814 (0.670-0.904)
1986	40	39	3	0.948 (0.806-0.988)	0.929 (0.801-0.977)
1987	41	40	1	0.976 (0.840-0.997)	0.976 (0.846-0.997)
1988	41	-	-	-	-

Observations of rehabilitated flamingos were collected as part of this programme. At breeding colonies records were kept of incubation behaviour and care of the chick, so birds which were proved to have attempted breeding could be identified. However, because breeding attempts could rarely be continuously monitored to completion or failure it is not possible to be definite about the breeding success of individual birds.

Results

Fifty-three ringed adult flamingos were released in late January 1985. Table 1 shows the numbers of these seen subsequently by calendar year. Cormack's method (Cormack 1964) was used to estimate survival and resighting rates. Only sightings of live birds were used in the analysis. It should be noted that the first survival rate of the series is different from the others because it represents survival from release to some time within 1985. All other rates are annual survival rates between calendar years. Inspection of Table 1 suggests that survival was lower within a year of release than it was in subsequent years and that a smaller proportion of birds that were alive throughout 1985 were resighted than was the case in subsequent years. The similarity of survival and resighting rates for 1986 and 1987 suggested that models might be fitted with fewer parameters that assumed that these rates did not vary within certain sets of years. Models were fitted by maximum-likelihood methods described by Clobert *et al.* (1985). The fit of different models was compared using likelihood-ratio tests. Table 2 compares the fit of four alternative models. The results indicate that Model 2 provides a parsimonious description of the data because it has fewer parameters than if all rates are assumed to be calendar year specific while not being a significantly poorer fit to the data than the fully parameterised Model 1. Model 2 estimates survival to within a year of release as 0.854 (95% C.L. 0.728-0.927) and subsequent annual survival as 0.972 (95% C.L 0.919-0.991).

The difference in survival between the period within a year of release and subsequent years was attributable to the fact that eight of the 53 birds released were never seen alive after release. Five of these birds were found dead within six weeks of release. None of the other 45 birds has been found dead to date. No significant differences in survival were found between the sexes. Of 27 males, 24 were resighted after release compared with 21 of 26 females (Fisher exact test, two-tailed, $P = 0.467$).

Table 3 compares measurements made during their period in captivity for birds that were or were not seen alive after release. The meas-

Table 2. Selection of a simplified model to describe the release-resighting data for Greater Flamingos presented in Table 1. Bracketing together of years indicates that parameter values were assumed to be equal for that set of years. Model 1 corresponds to the fully parameterised model presented in Table 1. The goodness-of-fit of models with a letter in common in the right hand column was not significantly different at the 5% level.

Model	Survival parameters	Resighting parameters	Deviance	Number of parameters
1	'85, '86, '87	'85, '86, '87 plus s X p ('88)	152.6	7 a
2	'85,('86='87='88)	'85,('86='87='88)	156.0	4 a
3	('85='86='87='88)	'85,('86='87='88)	162.5	3 b
4	'85,('86='87='88)	('85='86='87='88)	164.0	3 b

Table 3. Comparison of measurements of Greater Flamingos that were not seen alive after release with those of birds that were seen alive after release. Standard errors and sample sizes are given in parentheses. See text for details of the measurements. Significant differences between the two groups of birds, as assessed by t tests, are denoted by; +, $0.10>P>0.05$; *, $P<0.05$.

Measurement	Males		Females	
	Not seen after release	Seen after release	Not seen after release	Seen after release
WNG (mm)	440 (-;1)	435 (6;11)	405 (5;4)	401 (4;9)
WT1 (g)	2633 (230;3)	2790 (84;18)	2117 (33;3)	2106 (40;20)
WT1/WNG (g)	2595 (-;1)	2774 (198;8)	2045 (50;2)	2054 (50;9)
WT2 (g)	3000 (-;1)	3158 (95;12)	2338 (52;4) +	2510 (42;10)
WT2/WNG (g)	2942 (-;1)	3166 (131;11)	2282 (37;4) *	2501 (54;9)
GAIN (g)	350 (-;1)	406 (78;9)	225 (25;2) *	458 (34;10)

Key to measurements: WNG = wing length; WT1 = weight on 13 or 14 January; WT2 = weight on 23 or 24 January; WT1/WNG and WT2/WNG = weights corrected for the effect of wing length (see text); GAIN = weight gain between the first and second weighings.

urements used were wing length (WNG), weight upon being captured on 13 or 14 January (WT1), weight shortly before release on 23 or 24 January (WT2), weight at either of these times corrected for the effect of wing length (WT1/WNG and WT2/WNG) and weight gain over the period of about ten days between weighings (GAIN). Correction for the effect of wing length was performed by fitting separate linear regressions of weight on wing length for WT1 and WT2, but with results for males and females pooled. The regressions are;

$$WT1 = 11.065WNG - 2232.2$$
and
$$WT2 = 11.609WNG - 2062.6$$

Weights of females were adjusted using these regression coefficients to that expected for a bird with a wing length of 400 mm and those for males were corrected to 435 mm.

Birds that were not seen alive after release tended to have been lighter at release and to have gained less weight in captivity than those known to have survived the period immediately after release. This difference was present for both sexes but statistically significant only for females.

Flamingos begin to lay eggs in the Camargue in April, approximately three months after the release of the rehabilitated birds. In Table 4 the proportion of these birds that were proved to attempt breeding of those known to be alive is compared with that for eight-year-old birds ringed as chicks that were not held in captivity during the cold spell. For example, in 1985 the proportion of rehabilitated birds known to breed was compared with results birds from the 1977

Table 4. The proportion of ringed Greater Flamingos proved to breed of those known to be alive in each of the calendar years 1985-88. Results for rehabilitated flamingos are compared with those for eight-year-old birds ringed as chicks that were not cared for in captivity.

	Rehabilitated birds			Eight-year-old birds		
	Proved breeding	Known alive	%	Proved breeding	Known alive	%
1985	10	45	22	55	257	21
1986	26	43	61	88	270	33
1987	25	42	60	61	283	22
1988	13	41	32	71	236	30

cohort of chicks while in 1986 the comparison was with birds of the 1978 cohort and so on. Note that the breeding sites in France and Spain were both monitored and the results include birds nesting at both places. Of the 74 recorded bird-years of breeding by rehabilitated birds, 68 occurred in the Camargue and six at Fuente de Piedra (1 bird in 1986, 2 in 1987, 3 in 1988). A single age class was selected for comparison with the rehabilitated birds because the tendency to attempt to breed is known to increase with age up to at least ten years old (Green & Hirons 1985). Eight-year-old birds were selected because that is the oldest class for which data were available for 1985. The proportion of rehabilitated birds proved to breed was lowest in 1985, soon after release. This result is not likely to be caused by variation in the effort made to observe birds breeding because both colonies were monitored in a similar way in all years. However, it is unlikely the low proportion of rehabilitated birds that bred in 1985 was directly attributable to the effects of starvation and their period in captivity because the proportion of eight-year-old birds had not been taken into captivity that bred was also low in 1985. The proportion of rehabilitated birds that bred was higher than that for eight-year-olds in every year. The most likely reason for this is that the rehabilitated birds were, on average, older than eight years because flamingos are long-lived.

The measurements taken in captivity of rehabilitated flamingos that were proved to breed in 1985 were compared with those for birds known to be alive in 1985 but not proved to breed. There were no significant differences, but birds that bred tended to have gained more weight in captivity than those that were not known to have done so for both males and females (Table 5.)

Discussion

The estimates of survival for rehabilitated flamingos indicate that about 15% of the released birds died within a few weeks, but that subsequent survival was good. Survival of flamingos three or more years old wintering in France in years without prolonged cold spells averaged 0.951 compared with 0.972 for rehabilitated birds (Johnson, Green & Hirons 1990). The reduced survival immediately after release was due to the disappearance of birds that gained less weight than average during their period in captivity. These birds were not significantly lighter at capture than long-term survivors, nor did they have shorter wings. It seems possible that they might have survived if they had been held in captivity for longer or given better quality food to increase their release weight. However, they may have had diseases that both prevented rapid weight gain in captivity and caused death after release.

There was no clear evidence that the period of starvation and care in captivity had a strong effect on the proportion of birds that attempted to breed, even in the breeding season (1985) that started a few months after the cold spell. The

Table 5. Comparison of measurements of released Greater Flamingos known to be alive in the breeding season of 1985, but which were not known to breed with those of birds that were observed breeding in 1985. Standard errors and sample sizes are given in parentheses. Conventions as for Table 3.

	Males		Females	
Measurement	Not breeding	Breeding	Not breeding	Breeding
WNG (mm)	434 (7;9)	440 (5;2)	402 (5;7)	398 (13;2)
WT1 (g)	2767 (107;12)	2838 (146;6)	2120 (41;16)	2050 (124;4)
WT1/WNG (g)	2892 (247;6)	2420 (120;2)	2055 (59;7)	2053 (136;2)
WT2 (g)	3200 (103;10)	2950 (250;2)	2521 (56;7)	2483 (101;3)
WT2/WNG (g)	3227 (151;9)	2892 (192;2)	2500 (70;7)	2504 (30;2)
GAIN (g)	386 (100;7)	475 (75;2)	446 (42;7)	483 (67;3)

proportion of birds that were recorded as having attempted to breed in that year was low for both rehabilitated birds and eight-year-old ringed birds that had not been taken into captivity. This suggests that the cold spell might have suppressed the proportion of birds that were not taken into captivity that bred in 1985. However there was no indication that the total breeding population of Greater Flamingos in the western Mediterranean region was lower in 1985 than in previous or subsequent years (22,400 *v* 22,100 in 1984 and 27,426 in 1986). There was only weak evidence that the weight gain in captivity affected the likelihood of breeding in the first year after release.

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