The fate of plastic leg rings used on geese and swans

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Engraved plastic leg rings have been placed on Barnacle Geese, Bewick's Swans and Whooper Swans to facilitate long-term studies of individual birds within the different populations. The rate of wear for Barnacle Goose rings was 0.23 mg/year which, on average, was less than 1% of the initial weight of the ring. The mean rate of ring loss was just 0.35% per annum for Barnacle Geese, but different groups of swans broke or lost their rings at rates varying from 5.8% for female Bewick's Swans to 27.6% for male Whooper Swans with Vynalast rings during the first two years after ringing. In some cases, the type of material used to make the swan rings affected their lifespan; Vynalast rings proved less durable than Darvic rings on Whooper Swans but there was no significant difference in the rate of ring loss for Darvic and Vynalast rings on Bewick's Swans. Whooper Swans proved more likely to break or lose their leg rings than Bewick's Swans, irrespective of the material used to make the rings. The mean minimum lifespan recorded for rings fitted to Bewick's Swans was significantly shorter for males than females but there was no difference between the sexes regarding the lifespan of Whooper Swan rings. Some individuals (predominantly male) were more likely to break or lose their rings than others. Different factors thought likely to influence the rate of ring loss included the diameter of the ring (larger rings had a lower survival rate), and the size and strength of the birds.

Swans and geese are long-lived species with a maximum life expectancy in excess of 20 years (Owen 1982, Scott 1988). Plastic leg rings, each engraved with a unique letter or number code, have been used for many years to identify individual birds in the field (Ogilvie 1972). Resightings of known individuals have been used to investigate the population dynamics of the different species (Evans 1978, Owen 1984, Black & Rees 1984) and, in Barnacle Geese *Branta leucopsis*, the disppearance of a ring has been taken to indicate the death of the bird (Owen 1982).

The durability of metal rings fitted to seabirds has been considered in detail (Serventy 1970, Coulson 1976, Harris 1980, Spear 1980) and the lifespan of a metal ring is known to vary between species (Hatch & Nisbet 1983a,b, Nisbet & Hatch 1983). The type of material used for making metal rings also affects their longevity (Anderson 1980a, Spear 1980) and the rate of wear or loss may be related to the habitat and behaviour of the birds (Anderson 1980a,b, Hatch & Nisbet 1983a,b). Although plastic rings are invaluable for long-term studies of individual birds within a population, comparatively little is known about the rate at which they wear and become lost. This paper examines the fate of plastic rings used on Barnacle Geese, Bewick's Swans *Cygnus columbianus bewickii* and Whooper Swans *Cygnus cygnus*, and assesses the value of a regular ringing programme for studies of population dynamics of geese and swans.

Materials and Methods

Plastic rings, made of laminated Polyvinyl Chloride (PVC), have been placed on swans and Barnacle Geese for over 25 years. The first material to be used was made by I.C.I. and sold under the trade-name "Darvic", but between 1982 and 1987 a different material, "Vynalast", was used for swan rings. Whereas Darvic was made almost entirely from unplasticised PVC, Vyanalst consisted of a mixture of unplasticised PVC and Achrylonitrile Butidiene Styrene (ABS). Vynalast was developed as an engraving laminate to replace Darvic but it transpired that it became brittle more rapidly than Darvic, particularly when exposed to moisture (I. Davenport pers. comm.). Darvic therefore was again used for making swan rings from 1987 onwards.

The leg rings were made by cutting blanks from large sheets of the laminated plastic; the edges were burred and the alphabetical or numerical codes engraved through the top layer to expose a contrasting under layer (Ogilvie 1972). The sheets were usually sawn into strips, either by hand or with a power tool, since experience showed that cutting with shears or a guillotine tended to produce hairline cracks; these cracks may have affected the longevity of a small percentage of the early rings (Ogilvie 1972). The material used for swan rings was originally 1.6 mm thick, consisting of a 0.4 mm upper layer and a 1.2 mm lower layer. From the early 1970s onwards, however, 2 mm thick Darvic was used. This generally consisted of 0.5 mm and 1.5 mm layers respectively for yellow on black laminates, with 0.25 mm and 1.75 mm layers for white on black laminates, although there was some variability between the sheets. The deeper engraving needed to expose the lower layers on the yellow rings may have weakened these rings but, since the electrical engraving machine was operated manually, it is likely that the codes on the white rings were cut to varying depths (M. Ogilvie & C. Mitchell pers. comm.). White rings were allocated to Bewick's Swans which were adult at the date of ringing, whilst yellow rings were used on cygnets and second winter birds. A small number of green rings, made of the thin 1.6 mm laminate, was used on yearling Bewick's Swans between 1968 and 1971. The precise date of the change from 1.6 mm to 2 mm Darvic is not known, but at least 270 Bewick's Swans are known to have been marked with rings made from the thinner material. Darvic rings used on Whooper Swans were all made from 2 mm laminate; Whoopers caught at Caerlaverock were usually marked with yellow rings and Whoopers from Welney with white rings, irrespective of the age of the birds on ringing. The Vynalast rings used on both swan species between 1982 and 1987 were 1.5 mm thick, including an upper layer 0.25 mm thick. Goose rings considered in this study were mostly made from 1.5 mm Darvic, consisting of 0.5 mm and 1.0 mm upper and lower layers respectively; 22 Darvic rings 2 mm thick were also included. The rings were heated to soften the plastic, either in an oven at 105°C or by immersion in boiling water, and then moulded into shape (Ogilvie 1972). The internal diameter of the rings was 24 mm for Bewick's Swans, 26 mm for Whooper Swans and 14 mm for Barnacle Geese. In all cases plastic-ringed birds were also marked with metal (monel) rings, placed on the other leg. The presence of the metal rings permitted identification on recapture or recovery when a plastic ring was lost.

Most ringing of Barnacle Geese took place at the breeding grounds in Spitsbergen (Owen 1982). More than 5000 birds have been marked and most surviving ringed birds are sighted 5-15 times each year in one or more of their wintering, staging and breeding areas. Information from 62 Barnacle Goose rings that were replaced or found on dead birds, and which were not chipped, was available for an analysis of ring wear. Chipped rings were not included in the sample because of the impossibility of calculating wear when the recovered rings were incomplete. Since the initial weights of the recovered rings had not been recorded they were estimated by measuring the dimensions upon recovery, then calculating the initial weights from the weight to surface area ratio obtained for unused rings of the same size. The difference between the estimated initial weight and the weight of the ring upon recovery indicated the extent to which the ring had become worn whilst on the bird. Information from the known history of 5264 rings was used to obtain a mean lifespan for goose rings.

The swans were caught and marked at three of their British wintering sites: Slimbridge, Gloucestershire; Welney, Norfolk; and Caerlaverock, Dumfriesshire. Although the first marking of a Bewick's Swan with a metal ring took place in 1961, a regular ringing programme using plastic leg-rings was not introduced until 1967. Similarly, one Whooper Swan was ringed (at Slimbridge) in 1969, but the species has only been caught and ringed on a regular basis since 1980. Both species visit lakes at Wildfowl and Wetlands Trust centres, where they can be observed at close range. The presence or absence of each bird is recorded daily throughout the winter, and information can therefore be gathered concerning the condition of the ring and the date on which it was last seen. Sightings of rings are also reported by ornithologists from other parts of the birds' migratory range. Since trained observers can identify individual Bewick's and Whooper Swans by the variation in their black and yellow bill patterns, as well as by the artificial markings (Rees 1981, Brazil 1981), swans returning to Trust Centres were frequently recognised even if they had lost their plastic rings. Moreover, the Bewick's Swan is a monogamous species (Scott 1988) and initial results from a Whooper Swan study indicate that these birds also form long-term pair bonds (Black &

Rees 1984). If a swan returns with a new mate, therefore, it is usually indicative of the death of the previous partner.

The status of each of 2169 plastic swan rings was observed and classified as follows:

1. Intact - (when the bird was last seen).
2. Broken - ring that was last seen to be broken, but still on the bird.
3. Broken and replaced - ring that was previously broken but was replaced on recapture.
4. Lost - ring lost since the immediately preceding sighting of the bird.
5. Dead birds - this category includes both birds found to be dead whose rings were returned and birds assumed dead when their former partners returned with a new mate.
6. Replaced undamaged Vynalast rings - Vynalast rings on birds recaptured after 1987 were replaced routinely with Darvic rings since Darvic appeared to be more durable.

The sex and age of the bird were recorded at the time of ringing of both swans and geese. For the purposes of the ring loss analyses, the birds were classified either as adult (more than one year old) or as juvenile, since Scott (1988) demonstrated that the minimum percentage of Bewick's Swans surviving from one year to the next rose from just over 60% between the first and second winters to consistently over 80% thereafter.

The lifespan of a ring was calculated as the time, in years and fractions of a year, between the ringing date and the last resighting date. Where a bird had lost its ring between two resighting dates or had died, the last date on which the ring was known still to be intact was taken as the final date for that particular ring. This study therefore was based upon the minimum known lifespan of each ring. The data included only those rings placed on birds prior to the 1987-88 winter but resightings were considered until the 1988-89 winter; the most recently fitted rings therefore had a maximum potential lifespan of two years at the time of the analysis. Although rings recovered from dead birds were often undamaged, they were considered separately (code number 5 above) since the ring was not re-used and therefore ceased to be susceptible to relevant loss or wear damage. Similarly, replaced but undamaged Vynalast rings (code 6 above) were considered to be intact on the date upon which they were removed.

Results

Ring loss by Barnacle Geese

There was no significant difference between male and female Barnacle Geese in the rate of ring wear, ring loss, or the lifespan of the rings (all t-values less than 1, $P>0.05$). The data from

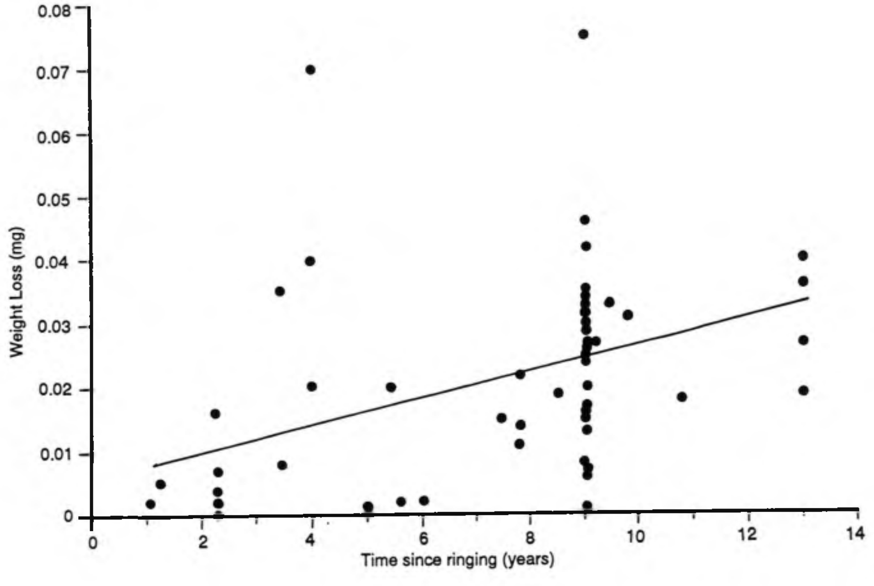

Figure 1. The loss in ring weight recorded for Barnacle Goose rings in relation to the number of years since ringing.

both sexes therefore were combined for the remaining analyses. There was a significant relationship between loss in ring weight and time since ringing, with a mean rate of weight loss of 0.23 mg/yr, although the regression accounted for only 22% of the variation in the data (F-ratio = 16.0, P<0.001 - see Fig. 1). The initial weight of the recovered goose rings was found to vary between 420-460 mg, so the average rate of loss in weight was less than 1% per year.

Information on the fate of Barnacle Goose rings examined on retrapped birds confirmed that there was no sexual difference in the number of rings lost; of the 18 birds that had lost their rings eight (44%) were female (P = 0.4, Binomial Test). The mean lifespan (to date) of all the rings re-examined was 4.9 years, compared with 5.2 years for the rings that were known to be lost (Table 1), suggesting that the likelihood of a ring becoming lost in any given year is independent of its age.

Table 1. The fate of the Barnacle Goose rings, assessed when the birds were recaptured.

Status of the rings	*n*	Mean lifespan (yrs)	S.E.
Intact	632	4.61	±0.107
Worn and removed	151	6.05	±0.285
Lost*	18	5.22	±0.777
Total	801	4.90	±0.103

*For lost rings the lifespan was calculated as the time of ringing to the time when the bird was last seen in the field with the ring intact (a minimum lifespan).

The fate of rings examined on birds recaptured in the summer of 1986 is shown in Table 2. A higher proportion of the rings fitted before 1977-78 were found to be broken or lost than was the case for those fitted after 1977-78 (χ^2 = 26.1, P<0.001); only two (15%) of the 13 rings used in 1973 were still intact in 1986. Since only small numbers of birds were caught in certain years, however, it was not possible in this analysis to determine further whether the probability of a ring surviving from one year to the next was correlated with the age of the ring; the high proportion of early rings lost could simply be attributed to the number of years between ringing and recapture. A total of 5074 ring-years was recorded for rings known to be still intact, compared with just 18 rings found to have been lost; the mean number of rings lost each year between 1973 and 1986 therefore was 0.35% of the rings used during this period.

Only a small number of birds was observed carrying damaged rings in the field. Of 48 broken rings recorded, seven (15%) were lost subsequently. The mean interval between ringing and breakage was 5.73 years and that between breakage and loss was 2.95 years. Several rings survived for at least five years after first being recorded as broken.

Ring loss by Bewick's and Whooper Swans

A total of 1736 rings was used on Bewick's Swans and 433 rings on Whooper Swans. The analysis of ring lifespan for the two swan species was complicated by the use of a thinner Darvic laminate for the early rings and by the use of Vynalast between 1982 and 1987. The effect of using thinner laminate was assessed by comparing the number of years from ringing to the date on which each ring was last seen to be intact for a sample of 25 male and 25 female Bewick's Swans allocated 1.6 mm Darvic rings but otherwise selected at random with the minimum ring lifespan recorded for a similar sample of 50 swans allocated 2 mm Darvic rings. There was no significant difference between the two groups in the number of years between ringing and the last sighting of the intact ring (U = 1182, P = 0.64, Mann-Whitney U test). The Darvic ring data obtained for the two different laminates were combined, therefore, for the remaining analyses.

The mean known lifespan for all Darvic and Vynalast rings fitted to Bewick's and Whooper Swans was determined by calculating the number of years from ringing to the date on which the ring was last seen to be intact, then dividing the total number of ring-years recorded by the number of rings used (Table 3). These figures represented the minimum lifespan of the rings since most rings were still intact when they were last checked. The mean minimum lifespan of the rings could not be used directly to compare rates of ring loss between swan species since Bewick's Swans had been ringed for 13 years before the Whooper Swan ringing programme was introduced. A comparison of the mean minimum lifespans recorded for rings placed on male and female birds indicated that female Bewick's Swans are more likely to retain their rings for longer periods than males (t = 3.53 for Darvic rings and t = 2.82 for Vynalast rings, P<0.001 in each case). There was no difference between the sexes regarding the lifespan of Whooper Swan rings (Table 3). The results were not affected significantly by changes in the distribution of individual swans in winter since males and females are equally likely to be

Table 2. The status of Barnacle Goose rings on birds recaptured in 1986.

Year in which ring was fitted	Intact n	Intact %	Replaced n	Replaced %	Lost n	Lost %	Total n
1973 Summer	2	15	8	62	3	23	13
1975-76 Winter	3	75	1	25	0	0	4
1976-77 Winter	4	67	2	33	0	0	6
1977 Summer	84	62	44	33	7	5	135
1977-78 Winter	17	77	5	23	0	0	22
1978-79 Winter	4	50	4	50	0	0	8
1979 Summer	0	0	2	100	0	0	2
1979-80 Winter	20	100	0	0	0	0	20
1981 Summer	83	88	7	8	4	4	94
1982-83 Winter	6	75	1	13	1	13	8
Pre-Winter 1977	93	59	55	35	10	6	158
Post-Winter 1977	130	85	19	12	5	3	154
Total	223	71	74	24	13	5	321

Table 3. Comparison of the mean lifespan recorded for rings placed on male and female swans.

Species	Ring Material	Males *n*	Males Lifespan (Years)	Males SD	Females *n*	Females Lifespan (Years)	Females SD	t	*P*
Bewick's	(Darvic)	836	2.96	3.11	733	3.49	3.53	3.53	<0.001
Bewick's	(Vynalast)	98	1.35	1.86	69	1.70	2.82	2.82	<0.001
Whooper	(Darvic)	101	2.08	2.04	108	2.18	2.01	0.36	N.S.
Whooper	(Vynalast)	116	0.66	1.04	108	0.75	1.01	0.64	N.S.

Note: N.S. = Not Significant.

resighted in the wintering range (Rees 1988).

The fate of all Darvic and Vynalast rings fitted to Bewick's and Whooper Swans is illustrated in Figure 2. At the time of the analysis less than 50% of Bewick's Swans and 40% of Whooper Swans had been identified three or more years after ringing. On average, however, over 70% of the rings worn by resighted birds were last recorded as being intact, irrespective of the age of the ring and the material from which it was made (Fig. 2). A comparison of the number of birds recorded with intact Darvic rings with the number that had broken or lost their Darvic rings for rings aged 0 - 5 years, 6 - 10 years and 11+ years found no evidence to suggest that the older rings are more likely to become broken or lost (Table 4). One female Bewick's Swan still retained an intact Darvic ring 17 years after ringing, whilst the longest lasting ring on males had survived for 15 years.

A comparison was made between the number of Darvic and Vynalast rings that were recorded as being broken or lost during the first two years after ringing to determine whether the material used to make the ring affected its longevity. Results showed that 27.6% of 116 Vynalast rings used on male Whooper Swans were lost or broken during the two year period, compared

Table 4. The proportion of Darvic rings broken and lost from the different age groups of swans.

Ring Age (Years)	Male Bewick's *n*	Male Bewick's Broken (%)	Male Bewick's Lost (%)	Female Bewick's *n*	Female Bewick's Broken (%)	Female Bewick's Lost (%)	Male Whooper *n*	Male Whooper Broken (%)	Male Whooper Lost (%)	Female Whooper *n*	Female Whooper Broken (%)	Female Whooper Lost (%)
0 - 5	617	11.7	15.7	506	6.9	6.5	90	24.4	10.0	88	10.2	12.5
6 - 10	133	13.5	7.5	137	2.9	8.0	4	25.0	0.0	16	12.5	0.0
10+	22	9.1	9.1	36	11.1	0.0		-			-	
X^2		3.36			0.97			0.0			1.72	
df		2			2			1			1	
P		NS			NS			NS			NS	

Note: *n* = Number of ring-years recorded for rings within each age category.
Data from dead birds were excluded from the analyses.

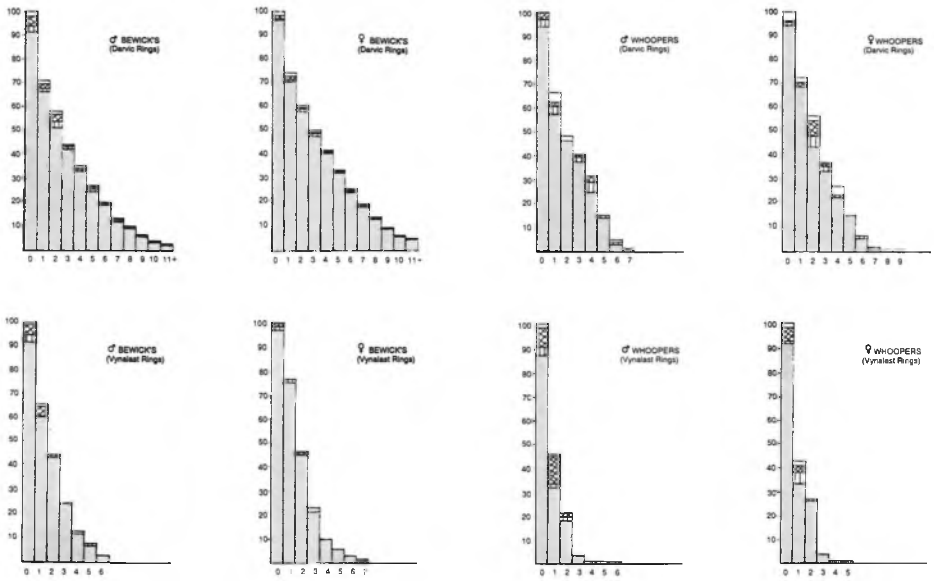

Figure 2. The percentage of Darvic and Vynalast rings placed on Bewick's and Whooper Swans that were resighted for up to 11 years after ringing. The percentage of rings that were:

(i) intact (ii) broken

(iii) lost (iv) recovered from a dead bird

are given for each age category.

The total number of rings considered were:

(A) Bewick's Swans

Males with Darvic rings -	836
Females with Darvic rings -	733
Males with Vynalast rings -	98
Females with Vynalast rings -	69

(B) Whooper Swans

Males with Darvic rings -	101
Females with Darvic rings -	108
Males with Vynalast rings -	116
Females with Vynalast rings -	108

with 10.9% of 101 Darvic rings ($\chi^2 = 6.51$, $P<0.02$), but there was no significant difference between the Darvic and Vynalast rings for Bewick's Swans or for female Whoopers (Table 5). Female Whooper Swans lost a high proportion of their Darvic rings between the first and second years after ringing, however, and further analysis found that a significantly higher proportion of Vynalast than Darvic rings were lost by female Whoopers during the first year after ringing ($\chi^2 = 7.04$ $P<0.01$, see Fig. 2).

Differences between the two swan species regarding the breakage and loss of the plastic leg rings was also assessed by considering the number of rings broken or lost during the first two years after ringing. Of 98 male Bewick's Swans with Vynalast rings, 12.2% broke or lost their rings during the two year period, compared with the figure of 27.6% for male Whoopers quoted above ($\chi^2 = 6.51$, $P<0.02$). Female Whooper Swans also proved more likely to break or lose their leg rings than female Bewick's Swans, irrespective of the type of ring material used, but there was no significant difference beween male birds with Darvic rings (see Table 5).

The mean lifespan recorded for Darvic rings fitted to adult and juvenile swans did not differ significantly for either species. It seems, therefore, that the deeper engraving employed on the yellow rings placed on juvenile Bewick's Swans did not reduce their longevity markedly. Similarly there was no apparent difference in durability of Vynalast rings fitted to adult and juvenile Whooper Swans, but adult Bewick's Swans of either sex retained their Vynalast rings for longer periods than juveniles of the same species (mean ring lifespan for 112 adults was 2.3 years; 48 juveniles 1.3 years; t = 3.66, $P<0.001$). This was not due to age differences in mortality rate since dead birds were excluded from the sample, but it may perhaps reflect the greater tendency shown by young swans to use other wintering sites (Rees 1988), which would reduce the likelihood of birds marked as juveniles being reported in subsequent years.

Some individual swans showed a greater tendency to lose or break their rings than others. The Whooper Swan ring data are complicated by a total of 8% of the Vynalast rings being removed from 1987 onwards, but it was possible to analyse the Bewick's Swan data in some detail. Of all the birds ringed, 176 (10.2%) Bewick's Swans lost or broke at least one ring and 30 of these (17%) lost at least one of their replacement rings. Of the 176 birds that lost their first ring, 67% were male and 33% were female. Of the 30 replacement rings lost, 80% were lost by male birds; one male managed to break six rings in 13 years. Not only do a greater proportion of males than females lose (or manage to remove) their rings, therefore, but some individuals are more likely than others to do so, and the great majority of these are males.

Discussion

A sample of 62 Barnacle Goose plastic leg rings that was recovered and where the rings were not chipped was used to calculate the rate of wear. Because it had not proved possible to catch consistently large numbers of Barnacle Geese each year, it was not possible to obtain a good predictive model for the rate of wear. Overall, however, wear was calculated at less than 1% per year. The figure was lower than the 3-6% found for metal rings (Anderson 1980a, Spear 1980, Hatch & Nisbet 1983a,b, Nisbet & Hatch 1983), and 3% for celluloid rings (Anderson 1980b), although it is similar to 0.57% for metal rings on Sooty Terns *Sterna fuscata*. The more rapid rate of wear recorded for metal rings fitted to seabirds may have been influenced by the corosive effect of salt water. Although Barnacle Geese have a maximum recorded lifespan of 24 years (Owen & Black 1989), therefore, it seems unlikely that the rings will actually wear through. Anderson (1980b) came to the same conclusion for Darvic rings fitted on Fulmars *Fulmaris glacialis*. The variability in the goose data may be partly attributable to the imprecise method used to estimate the original weight of the ring but may also be due to a real difference in the rate of ring wear by individual birds.

The rate of ring loss recorded for geese and swans appeared to be inversely associated with the birds' body size and weight; adult Whooper Swans on average weigh between 9-11 kg, whereas Bewick's Swans weigh 5.5-7.5 kg and Barnacle Geese 1.5-2.3 kg. The heavier birds may be more likely to damage their rings by rubbing them against other objects. Ring diameter, which increases with the size of the bird, may also influence the rate of ring breakage and loss since it is easier for humans to break the larger swan rings by hand. Ring size, may have an effect particularly if the rings are shattered by gunshot. All three species receive legal protection from hunting throughout their migratory range but are still subjected to considerable shooting pressure (Evans *et al.* 1973, Wildfowl and Wetlands Trust unpubl. data on the incidence of lead pellets in bird tissues).

The shorter lifespan recorded for both Darvic and Vynalast rings placed on male Bewick's Swans, compared with rings of the same mate-

Table 5. Comparison of the number of rings found to be broken or lost within the first two years after ringing of Bewick's and Whooper Swans marked with Darvic and Vynalast rings.

	Bewick's Swans			Whooper Swans				
	n	% Rings seen after 2 years	% Known to be Broken/Lost	*n*	% Rings seen after 2 years	% Known to be Broken/lost	χ^2	*P*
Darvic (Males)	836	58.1	14.7	101	48.3	10.9	1.9	NS
Vynalast (Males)	98	44.9	12.2	116	21.6	27.6	7.7	<0.01
χ^2			0.55			6.51		
P			NS			<0.02		
Darvic (Females)	733	60.6	6.0	108	56.5	14.8	13.8	<0.00
Vynalast (Females)	69	46.4	5.8	108	26.9	14.8	3.7	<0.1
χ^2			0.04			0.00		
P			NS			NS		

Note: The number of rings broken and lost given above is a percentage of the total number of rings used.

rial placed on females, can be attributed to differences in the behaviour patterns of the two sexes since all rings used on Bewick's Swans were of a similar size. Male swans are involved more frequently in physical combat than females (Scott 1978) and may perhaps shatter their rings during these encounters. Male swans are also generally larger than their mates (Evans & Kear 1978) so may be better able to break their rings. Differences in the strength of the birds would also account for the high rate of ring loss by Whooper Swans and explain why certain individual birds proved more likely to lose their rings than others. Studies of Western Gulls *Larus occidentalis* similarly found that some individuals can break their rings (Spear 1980). Although both swans and geese have been observed preening around their rings, however, none of the birds was seen to break or remove these markings.

The comparison of the rate of ring loss recorded for rings made from 1.6 mm Darvic, 2 mm Darvic and 1.5 mm Vynalast found that the thickness of the Darvic laminate did not have a significant effect upon the minimum lifespans recorded for swan rings, but Whooper Swans proved more likely to lose Vynalast than Darvic rings shortly after ringing. There was some variability in the depth to which the rings were engraved, both because the thickness of the laminate across a sheet was not always uniform and also because the engraver may have set the drill at differing levels. There was no marked difference, however, in the mean minimum lifespan recorded for yellow Darvic rings used on juvenile birds, which generally needed deeper engraving, in comparison with the white Darvic rings usually put on adult swans. It was not possible to control for further variability in constructing the rings, such as differences in the time between heating and moulding the rings or the ambient temperature at the time of ringing but, although these factors may have affected the durability of individual rings, there is no reason to believe that this biased the comparison of rates of ring loss between and within species. Polyvinyl Chloride becomes brittle if subjected to high temperatures for a prolonged period, or if exposed to temperatures below freezing, but Darvic and Vynalast are not reputed to differ in their susceptibility to high and low temperatures (I. Davenport pers. comm.).

Differences in climatic conditions and other habitat variables in the breeding and wintering grounds of the three species are not considered in detail but could also influence the rate of ring loss. The anti-erosion concrete around the edge of ponds used by Bewick's Swans at Slimbridge and Whooper Swans at Caerlaverock, for instance, may damage the swan rings, whilst rocky terrain and coarse or thick vegetation may abrade swan and goose rings in other parts of the migratory range. Further studies may determine whether the tendency for PVC to become brittle at temperatures below freezing is reflected in an annual fluctuation in the number of rings lost attributable to climatic severity. This paper found no direct evidence to suggest that the likelihood of a ring becoming lost in any given year increases with its age. An earlier study of Barnacle Geese found that the mean annual rate of ring loss during the first five years after ringing was 0.14% per annum (Owen 1982), compared with a mean loss rate of 0.35% rings per annum reported here; the higher rate of loss could have been due to the inclusion of older goose rings in the present study. The mean minimum lifespan recorded for goose rings known to have been lost, however, proved similar to the lifespan for all rings re-examined. The analysis of Darvic rings used on Bewick's Swans similarly found that there was no significant difference in the proportion of rings aged 0-5 years reported as broken or lost, compared with rings aged 6-10 years and 11+ years.

Individual marking schemes are being used to enhance an increasing number of long-term studies of wild Anatidae populations and the rate of ring loss may be an important factor in estimating the lifespan of individual birds. In Barnacle Geese, for instance, where it is difficult to identify individual birds by their natural markings, the low rate of ring loss has been used to indicate the death of a bird (Owen 1982). The higher rate of ring loss recorded for both Bewick's and Whooper Swans means that estimates of mortality for these species must be based upon rings recovered from dead birds or the disappearance of one member of an established pair. Since a large proportion of the older resighted swan rings were still found to be intact, however, the swan marking programme is still valuable for recording survival rates for individual birds, as well as for monitoring the movements of ringed swans between migratory and wintering sites.

The information on the fate of rings was collected by a large number of observers; we mention here all those who have made a major contribution, but thank all those that are not mentioned. The main observers were: J.M. Black, C.R.G. Campbell, D. Campbell, C. Clunies-Ross, A.R. Cook, H. Eggers, M.E. Evans, T. Haitjema, C. and R. Hesketh, H. Liber, O. Merne, M.J. Nugent, M.A. Ogilvie, M. Ounsted, C. Prentice, D. Revett, J. Revett, D.K. Scott, B. Sears, P. Shimmings, C. Tomlinson, R.L. Wells, R. White-Robinson, E. Wojtowych and G.A. Wright. J. Bowler helped with the statistical analyses. I. Davenport gave invaluable technical advice on the differences between Darvic and Vynalast. S. Baillie, R.H.J. Graham, C. Mitchell and M.A. Ogilvie made constructive criticisms on a draft of the text.

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Whooper Swan ringed with a plastic leg ring in Iceland, 1988. *Photo: Eileen Rees*