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BAND WEAR IN THE FULMAR

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The loss of bands from long-lived birds can bias the results of survival studies. This paper examines the rate of weight loss in different kinds of metal bands on Fulmars (*Fulmarus glacialis*) and the causes of wear and band loss.

The Aberdeen University study of breeding Fulmars in Orkney, begun in 1950, continues on the basis of short annual visits to the island of Eynhallow. In order to calculate survival rates for the Fulmar, which has an average adult life expectancy of 33.92 years in the males and 35.47 years in females (Dunnet and Ollason, 1978), it is necessary to make positive identification of individual banded birds over a long period of time. This requires that numbered metal bands be both durable and dependable. The period of adolescence in the Fulmar is long (mean 9.2 years: Ollason and Dunnet, 1978), and this also highlights the need for long-lasting bands.

Band wear and band loss have been the subject of several papers: Herring Gull (*Larus argentatus*), Poulding (1954); Dominican Gull (*L. dominicanus*), Fordham (1967); Caspian Tern (*Sterna caspia*) and Ring-billed Gull (*Larus delawarensis*), Ludwig (1967); Herring Gull and Lesser Black-backed gulls (*L. fuscus*), Coulson (1976). The causes are considered in the discussion section.

METHODS

Since 1950, 590 adult and 6,793 pulli Fulmars were banded in Orkney. Aluminum bands were used in the earlier years, but since 1958, 9.0-mm monel bands have been used exclusively. The earliest aluminum bands, with six-digit numbers, were made of commercially pure aluminum and the later, seven-digit ones, of magnesium-aluminum (i.e., 3% magnesium, 0.5% manganese). The monel bands are of nickel-copper alloy (Spencer, 1972).

Bands from recaptured birds were separated into seven groups according to type of metal and similarity of manufacture (Table 1). They were flattened, length and breadth were measured to 0.1 mm thickness to 0.01 mm by point micrometer and weighed to 0.001 g. Measurements of inner and outer surface wear of 10 aluminum bands were compared with measurements of 20 new bands (Fig. 1).

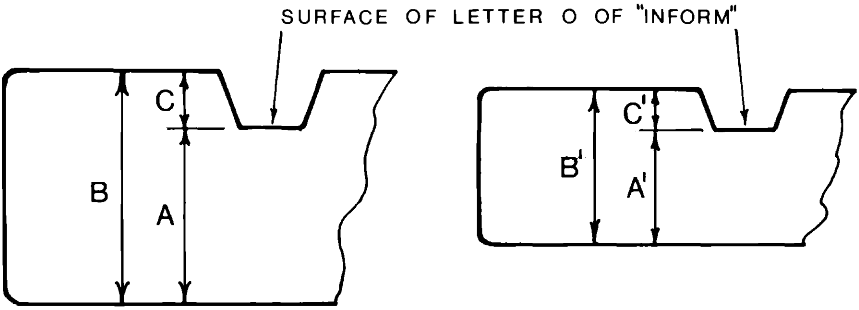

FIGURE 1. Diagrammatic section through new band (left) and worn band (right). Letters refer to dimensions in Table 2.

RESULTS

Aluminum Bands

Surface Wear.—Surface wear is reportedly greater on the inner surface of bands in several species (e.g., Coulson, 1976). The relatively rapid wear that occurs with aluminum gave measurable thickness-loss within eight years of banding. Table 2 indicates that greatest wear occurs on the inner surface of bands; on the average, 26% of the original thickness is lost on the inside by abrasion against the tarsal scutes and only 3% on the inscribed surface due to contact with the ground. Any corrosion by seawater would presumably affect both surfaces equally.

Recovered 9-mm dia. aluminum bands from different series were varied in their length and width. This variability in dimensions was also found in unused series, which showed differences in average weights in two unused series, 315901 (n = 13) and 362751 (n = 27); the mean weights were respectively, 0.712 g and 0.690 g ($P < .001$). Within-series weights of these new bands were more uniform, with coefficients of

TABLE 1.
Annual weight-loss of metal bands from Fulmars.

Type	Series	n	Mean annual wt. loss (g)	% Mean annual wt. loss	Correlation (*r*)	*P*
Aluminum	383401	48	0.032	4.76	0.927	<.001
Aluminum	3011751	38	0.037	5.26	0.934	<.001
Aluminum (Double-ended)	AT45301	42	0.048	3.64	0.972	<.001
Monel	3054651	12	0.009	0.54	0.553	<.1
Monel	SS00401	32	0.004	0.26	0.153	N.S.
Monel	FS05001	11	0.014	0.91	0.399	N.S.
Monel	AT66701	6	0.015	0.90	0.698	N.S.

TABLE 2.

Inner and outer wear on 10 aluminum bands 6 to 8 years old. Mean thicknesses (mm) are compared with those of 20 new bands. Refer to Fig. 1.

New band, thickness			Worn band, thickness			Wear	
A	B	C	A′	B′	C′	Inner A-A′	Outer C-C′
0.823	0.998	0.175	0.568	0.714	0.146	0.255	0.029
SD = 0.046	SD = 0.012	SD = 0.047	SD = 0.042	SD = 0.057	SD = 0.030		

variation of 0.56% and 1.45%. Similar results were obtained from two other series of unused bands.

A group of 19 recovered bands in the series 322501–371550 from the earliest years of the study were so variable in quality that they were not used in weight-loss analysis. Variation in the embossing depth, probably due more to the stamping method than to the softness of metal, could have affected their chances of being successfully identified upon recovery. Five bands recovered from the series 333651 were so lightly stamped that inscriptions were poor by the fourth or fifth years, whereas 353358, heavily stamped, was more legible in its ninth year. Weights of the five bands were similar to weights of worn ones of the same age from different series, hence the poor inscriptions could not be ascribed to wear. Excessively heavy stamping distorted some sets, noticeably increasing band width, but apparently not damaging the band.

Thirty-one bands from the series 322501 were significantly ($P < .05$) shorter ($\bar{x} = 30.1$ mm, SD = 0.447) than 30 from the series 3011751 ($\bar{x} = 30.4$ mm, SD = 0.316). Therefore, smaller bands tended to be oval-shaped on the flat tarsi of fulmars, thus preventing the bands from revolving on the leg and leading to a high incidence of abraded single digits from serial numbers. This became apparent within four years and serious in eight years. Wear, thus concentrated, weakened the band at that point.

Weight Loss.—The "pure" aluminum series 383401 was treated separately from magnesium aluminum series 3011751 (Fig. 2). The latter were differently inscribed, ring dimensions were less variable, and they were slightly heavier. The mean annual rate of weight loss was apparently constant and similar in both series at 0.032 g or 4.76% ($r = 0.927$, $P < .001$) and 0.037 g or 5.26% ($r = 0.934$, $P < .001$).

None were recovered beyond their eighth year, by which time about 40% of their original weight was lost. Addresses became difficult to read in the seventh year and serial numbers in the eighth.

In the mid-1950's, 150 "double-ended" aluminum bands, the AT45301 series, were used and 42 were recovered and examined. These were nearly twice the length of normal bands with a duplicated set of

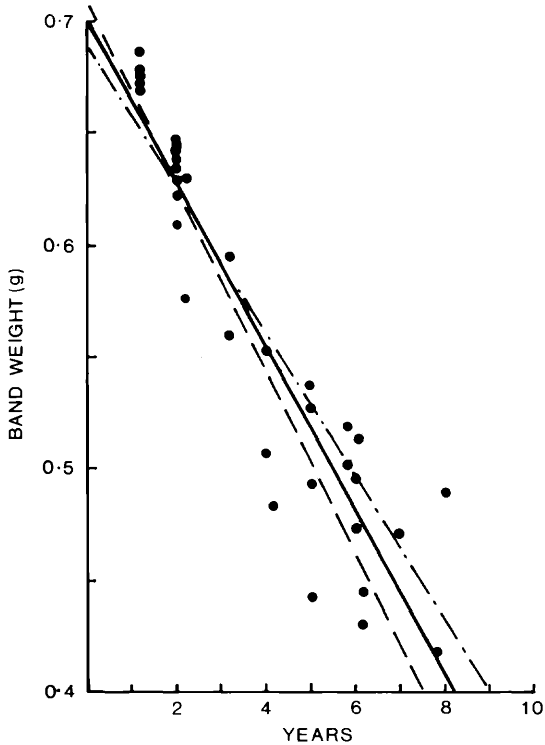

FIGURE 2. Adult Fulmar band-wear. Magnesium-aluminum series 3011751. Females — — —, Males —.—.—, Combined ———. For all bands combined, y = .703 − .037x.

inscriptions at either end so that one set was protected within the outer, overlapping layer of metal. They are prone to experience concentrated wear on one small area, mainly at the middle where the outer overlap stops, creating a weak point where the band would eventually break. Such localized wear frequently affected one or more symbols as early as one year after banding and was severe in the fourth year. Nearly total obliteration of information on the outer half was evident in the ninth year, but one such band survived for 11 years with its duplicate information completely legible, protected by the now thin outer half. Mean annual weight loss was 0.048 g or 3.64% (r = 0.972, P < .001) (Fig. 4). None have been recovered beyond their 11th year; by their 12th year they would have lost 44% of their original weight.

Nestling Bands.—Of the 372 Fulmar pulli that were banded in various parts of Orkney with butt-ended aluminum bands, five were recovered away from Eynhallow in their first year and three in the second year

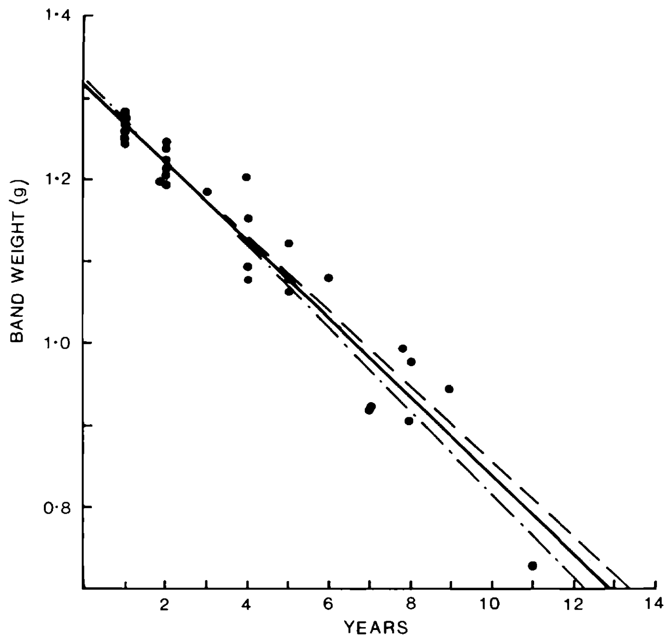

FIGURE 3. Adult Fulmar band-wear. Aluminum double-ended series AT45301. Females — — —, Males —.—.—, Combined ———. For all bands combined, y = 1.318 − .048x.

(2.2% recovery rate). One pullus with a double-ended band (of the 99 used on pulli) was recovered in its third year, but three other double-ended bands survived until the wearers returned to breed on Eynhallow, probably for the first time, 7, 8, and 9 years after fledging. By using monel bands, we are now aware that Fulmars do not breed until 6 to 13 years old ($\bar{x}$ = 9.2 yr, Ollason and Dunnet, 1978); thus, there was little chance of detecting aluminum-banded pulli which may have returned to the island to breed. Young do not always return to the natal colony; several, breeding apparently for the first time on Eynhallow, had been hatched on other distant Orkney colonies, and one, hatched on Eynhallow, bred on the Aberdeenshire coast. Many banded pulli would, therefore, have remained undetected.

Differential Wear by Male and Female.—Males evidently spend more time than females at the nest site (Dunnet, Anderson and Cormack, 1963; Macdonald, 1975); greater band wear might, therefore, be expected to occur in the male. Where the weight loss data from 128 aluminum bands were treated separately for the sexes (see also Figs. 2 and 3), this was not shown to be true.

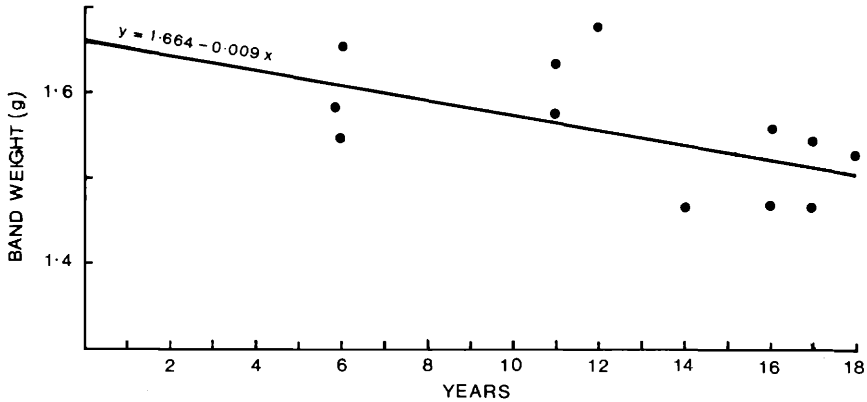

FIGURE 4. Adult Fulmar band wear. Monel series 3054651.

Monel Bands

As was found with the aluminum bands, monels showed uniformity of dimensions within continuous series (2.09% coefficient of variation for the weights of a complete series of 50), and, unfortunately, differences in weight between separate series were significant, e.g., $P < .001$ for two sets of 20. This disparity became more evident when comparing rates of weight loss for used bands; e.g., monel series SS37001 would have been initially heavier than series SS93001 (Fig. 5). It is also possible that differential wear between individual birds intensified the problem (Coulson, 1976) and additional wear on a few was due to abrasion by

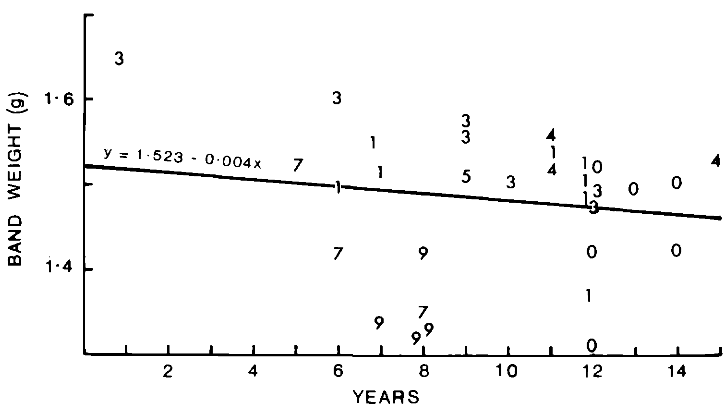

FIGURE 5. Adult Fulmar band wear. Monel series SS00401. Within-series groups are symbolized as follows: SS00—0, SS13—1, SS37—3, SS41—4, SS57—5, SS73—7, SS93—9.

adjacent, extra metal bands. The bands were grouped according to similarity of serial number to reduce the effects of variability in manufacture (Table 1). The mean annual weight loss was <1% in each case; weight did not correlate significantly with time.

Of 61 recovered monel bands, three had been closed to an oval shape on the tarsus and were not free to revolve. The resulting concentrated wear almost obliterated a single digit from the serial number in their 6th, 12th, and 18th years; the last was the oldest band so far recovered and weighed 1.528 g. It is clear, from close scrutiny of the inscriptions on the other 58 bands, that they would have had several years of useful life remaining, had they been left in place. The lightest monel band of all (SS00443) weighed 1.304 g in its 12th year, 0.155 g below average for a monel band of that age in the SS series, but its legibility was excellent.

DISCUSSION

Monel bands were not available in the earlier stages of the Eynhallow Fulmar study, and were not used until 1958. The more short-lived aluminum bands failed to last sufficiently long to give enough information on the age of birds breeding for the first time, but, being readily recovered from breeding adults, they showed quickly how wear occurred.

Breeding adults can be seen at the nest sites each month from the end of October to the following September, males more frequently than females (Macdonald, 1975). They have a shuffling gait, with the metatarsus touching the ground; bands are, therefore, likely to be rapidly abraded, especially by the male. With monel bands, that is not true. Weight loss on the average is only about 1%/yr, and the aluminum bands indicated no detectable differential wear between the sexes. Except in the few cases where single digits were erased due to poor band fit, monel bands retained their inscriptions well for up to 18 years. The low rate of wear is thought to be due to the Fulmar's relative immobility once it is on the ground.

Some damage to the upper edge of monel bands did occur on pulli which had an additional color-coated monel year-band. This was noticeable on adults also where aluminum color bands were added. In no case was the damage so severe as to make the address indecipherable.

Poulding (1954) found a 50% loss of aluminum bands in 4½ years in juvenile Herring Gulls due to industrial wastes and chlorine in sewage outfalls which birds frequented. Ludwig (1967) suggested that saltwater alone did not corrode aluminum bands since they lasted up to 26 years on Caspian Terns, whereas monel lasted poorly because these birds defecate on their legs. No evidence exists for corrosive effects or "crevice attack" (Spencer, 1972) on Fulmar rings.

The useful life of a band may terminate by being worn so thin that it weakens and falls, is pulled off, or by damage to the inscription. In the former case, an "end point" (Ludwig, 1967) or critical percentage of the original weight at which the band falls may be regarded as the criterion, but this should be combined where possible with information on inscription wear because some bands become illegible long before they drop off. In the present study the comparative ease of recapture of breeders on the nest compensates for any loss of address or even partial obscurity of the serial number, but this remains a problem with the long-absent prebreeder.

I have shown that the useful life of butt-ended aluminum bands was six to nine years and double-ended ones perhaps one or two years longer. Survival rates of breeders based on recovery data from all aluminum-banded Fulmars on Eynhallow gave the mean life expectancy of breeding adults as 5.02 years (J. C. Ollason, pers. commun.) but similar calculations for monel-banded Fulmars gave a mean of 33.92 years for males and 35.47 years for females (Dunnet and Ollason, 1978). The average period of Fulmar adolescence is 9.2 years (Ollason and Dunnet, 1978); therefore, a band placed on a nestling would have to remain intact more than 44 years in order to outlive the bird. An average monel band of 1.6 g at 1% annual weight loss would lose 0.704 g in that time (44% of its original weight). Many monel bands would not reach that impressive age, in some cases because of lighter starting weight and loss of identity due to abrasion, particularly in bands which are not free to revolve on the tarsus. Ludwig (1967) recognized the need to apply correction factors to survival data to allow for band loss in order to achieve life tables for Ring-billed Gulls. Fordham (1967), working on Dominican Gulls, also recognized the need for knowledge of "mortality rates" for bands before trying to deduce mortality rates for the long-lived birds that wear them. Working on Herring and Lesser Black-backed gulls, Coulson (1976) describes how band wear continues to hinder long-term population studies.

A case exists for improved band quality and design; a slightly thicker band (consistent with ease of closing) with only marginal weight increase would permit longer life by increasing the period to "end point" and would also allow for deeper embossing. Uniformity of the stamping process, between individual characters, bands, and series of bands should be aimed for. Excessively deep embossing of one digit in a complete series of 100 has been known to cause deformity of the band to a non-circular shape on being closed, leading to concentrated wear. It is important that the band is free to revolve on the tarsus, giving uniform wear. Each band should, therefore, be cut to the correct length during manufacture.

SUMMARY

From breeding fulmars in Orkney, 128 aluminum and 61 monel bands were examined for pattern of wear and for weight loss. Measurements indicated that greatest wear was on the inner surface of the band. Reduced band diameter or non-circular shape leads to concentrated wear, early weakening of the band and obliteration of symbols. Butt-ended aluminum bands lasted up to 8 years and double-ended

ones up to 11. Monel bands can last more than 18 years. Differential band wear for males and females was not found. A lack of uniformity of measurement between the different monel series confined analysis of weight loss to restricted numbers of bands within certain series. It is suggested that better quality control in manufacture and possibly the redesigning of bands would help increase their useful life.

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