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EVALUATION OF LEG BANDS FOR VISUAL IDENTIFICATION OF FREE-LIVING SILVER GULLS

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In 1899, Mortensen initiated the systematic marking of wild birds with numbered leg bands (Wood 1945), but apart from the use of modern alloys and color bands there have been few major developments in bird-band technology. Most types of bird bands used today still require the recovery of a dead bird or the recapture of a living bird in order to identify the band, even though these two sources of information have obvious disadvantages for the study of non-sedentary free-living birds. Many individual life histories are derived from banded birds being shot or found dead and hence for each bird there are only two records, and where an individual is retrapped at a particular colony during breeding seasons there are no data on where the bird went during the non-breeding season.

In this paper we report results from the use of bands with large numerals which were developed to enable individual identification of free-living Australian Silver Gulls (*Larus novaehollandiae*) at distances up to 50 m. The effectiveness and durability of the bands are evaluated, the nature and frequency of errors detected in field observations discussed, and the quality of the data returned is compared with that from other studies which used standard bands.

MATERIALS AND METHODS

Description of the number bands and color bands.—Carrick and Murray (1970) described the manufacture and specifications of the bands they developed to enable positive identification of free-living Silver Gulls. In brief, number bands were made from 1 mm thick aluminum alloy, and when flattened were 16 mm high × 25 mm. A unique 5-digit number was impressed into the band four times, the impressions were coated with black enamel paint, and the bands then sprayed twice with "Scotchlite Finishing Clear." When a number band was fitted to the leg of a gull, the numbers read vertically (Fig. 1), and the whole sequence could be seen from any angle. A return address for the bands was impressed onto the inside. Color bands were made from 0.9 mm thick commercial aluminum sheet, cut to 13 mm high × 24 mm for 1-color bands or 19 mm high × 24 mm for 2-color or 3-color bands. "Scotchlite" reflective colors and "Scotchcal" non-reflective black or white were heat-bonded

FIGURE 1. Examples of number bands recovered from Silver Gulls: 61942, taken from chick which died on nest; 15567, standard CSIRO 080 series band; 63180, recovered after 9 yr 7 mo; 61029, recovered after 12 yr 11 mo; 51264, from dead chick on nest; 59638, 8 mo; 65966, 9 yr 10 mo; 66192, 9 yr 10 mo; 63583, 11 yr 10 mo. The large 081 aluminum bands are 16 mm (high) × 25 mm, 1 mm thick, and were sprayed with Scotchlite Finishing Clear® after coating the number impression with black paint. These bands read from top to bottom. As can be seen, most wear occurs at the bottom, and it is recommended that bands with vertical number sequences should be placed on birds to read from bottom to top.

to the outside of the bands in various color and sequence combinations (Fig. 2). (Scotchlite®, Scotchcal® and Scotchlite Finishing Clear® are registered trademarks of the 3M Company.) White Scotchcal was heat-bonded to the inside of color bands to increase durability of the aluminum.

Gull banding.—Between June 1967 and November 1970, 17,410 Silver Gulls were banded in South Australia, using the bands described above (Table 1). Some 15,950 gull chicks were banded on the nest at 15 island breeding colonies, 173 juveniles were clap-netted and banded in the Beachport area, and 1287 adult gulls were banded after nest-trapping or clap-netting: 142 on islands at Encounter Bay and 1145 in the Beachport area (Fig. 3). Each banded gull was given a unique number band on one leg and a color band on the other. Some 467 types of color bands were used, being various combinations of blue, green, red, yellow, black, and white, size of band, vertical, horizontal, or oblique color sequencing. One-color and 2-color combinations were used for mass-banding of groups (e.g., each of 3530 chicks hatched on Penguin Island in Spring 1968 was given a 13 mm high yellow band on the right leg, referred to in text as R-Y), while 432 unique 3-color bands were used

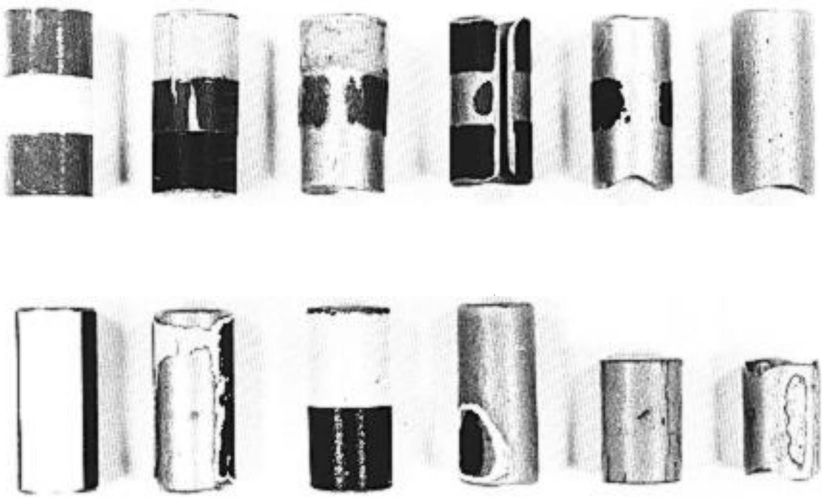

FIGURE 2. Examples of color bands used on Silver Gulls. RWR, new; YGBk, 1 yr 1 mo; YG-(=YGR), 8 yr 11 mo; BkGBk, 9 yr; GBk-(=GBkB), 10 yr; Bare metal (=WRW), 11 yr 9 mo; vBkW, new; vBkW, 12 yr 10 mo; WG, new; WG, 12 yr 2 mo; Y, new; Y, 12 yr 9 mo; v, each color runs vertically; B, blue; Bk, black; G, green; R, red; Y, yellow; W, white. The large bands are 19 mm (high) × 24 mm; the two small bands are 13 mm (high) × 24 mm. The color materials are Scotchlite® or Scotchcal® heat-bonded to aluminum.

on nest-trapped breeding adults (e.g., only one gull had the band black/red/green on the left leg, and one gull had the same color combination on the right leg. These are referred to as L-BkRG or R-BkRG).

Band resightings and field records.—During October 1968–August 1981, teams of professional ornithologists made extensive searches of south-eastern Australia to find and identify these banded gulls. During 1969, 1970, and 1971, the teams spent 848 days searching for banded gulls, but only 56 days during 1972–1981. About 60 occasional observers, scattered through South Australia and Victoria, also watched for banded gulls, and members of the public returned bands, found on dead or injured gulls, to the Australian Bird-Banding Scheme. The professional ornithologists concentrated on shores and coastal areas between Adelaide, South Australia, and Cowes, Victoria (Fig. 3) with occasional forays to more distant areas where banded gulls had been reported.

Banded gulls could be detected at distances up to about 100 m, although it was necessary to be much closer to identify color bands and read number bands. Usually, a flock of gulls was approached by 2–4 observers in a vehicle suited to the particular terrain. Gulls were not disturbed unduly by the slow movement of the approaching vehicle, but

TABLE 1. Summary of Silver Gull bandings, June 1967–November 1970, and resightings, October 1968–August 1981, in south-eastern Australia.

Banding site[a]	Gulls banded	Gulls resighted	(%)	Total resightings	$\bar{x}$[b]
1. ICI, St. Kilda, Adelaide	2178	40	1.84	77	1.93
2. Outer Harbour, Adelaide	1780	59	3.31	108	1.83
3. West Island	1331	113	8.48	188	1.66
4. Wright Island	731	70	9.58	121	1.73
5. Lake Mulgundawa	933	40	4.29	52	1.30
6. Seagull Is., Coorong	94	14	—	46	—
7. Lake Hawdon	2025	385	19.01	1373	3.57
8. Nora Creina	1084	240	22.4	1144	4.77
9. Lake George Islands	1154	388	33.62	1927	4.97
10. Cowrie Rock	536	203	37.87	3812	18.78
11. Pleasant Cove	63	58	92.06	1282	22.10
12. Penguin Island	4446	1629	36.64	12,363	7.60
13. Rivoli Bay	679	609	89.69	13,663	22.44
14. Southend Beach	121	100	82.64	1394	13.94
15. Harrington Rock	7	1	—	20	—
16. Cullens Rock	79	9	—	54	—
17. Mounce and Battye Rocks	151	17	11.26	78	4.59
18. Carpenters Rock	18	2	—	72	—
Totals	17,410	3977	22.84	37,774	9.50

[a] Colonies and banding sites 9–14 were within the intensive study area of the resighting program.
[b] $\bar{x}$ = mean number of resightings per resighted gull.

were always wary of observers on foot. With favorable conditions, number bands could be read with the unaided eye at distances of less than 2.5 m, with binoculars from 2.5–20 m, and with telescopes from 18–50 m distance. Color bands could be identified at up to 60 m. These approximate maximum distances for legibility depended on quality and clarity of the band, weather and light conditions, behavior of the banded gull at the time of observation, the individual observer's visual acuity and experience with reading gull bands, and the quality of the optical equipment. If possible, bands were read and checked by several observers. Where a digit or color remained in doubt after a gull had left the observation site, an appropriate coded comment, which remained with the record, was made in the field notebook (e.g., 6(5)047 signified that the digit 5 was doubtful). A resighting record was considered valid if the number band, color band, and leg sequence of bands recorded at the time of sighting corresponded with the banding records. Where discrepancies were found between observation records and banding records, a subjective decision was made whether to reject the observation, whether to accept it as possibly valid but requiring further field confirmation, or to accept it as valid despite the discrepancy. This decision was based on consideration of the combination of number band and

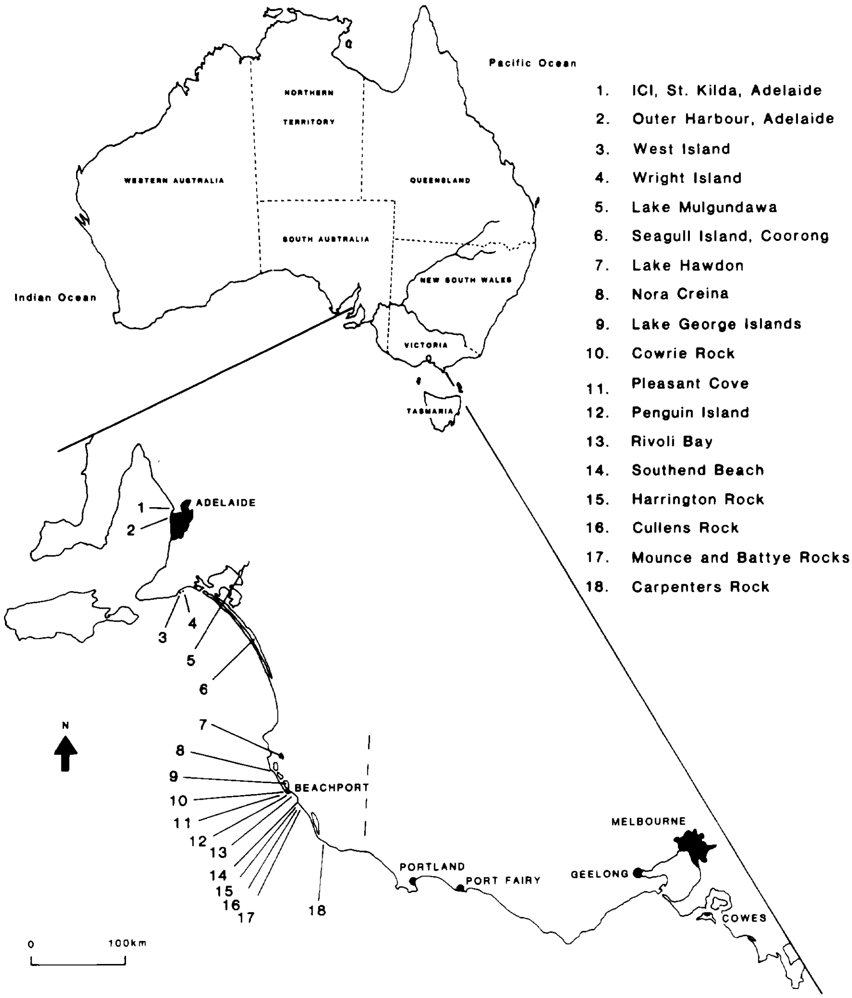

FIGURE 3. Banding locations of Silver Gulls in southern Australia, 1967–1970.

color band observed, the place of sighting, and the nature of the discrepancy (Table 2).

By 1978, banded gulls were much scarcer, and most number bands and all color bands were showing signs of wear. To provide further quantitative data on the effectiveness of these bands and the band resighting program, a sample of the surviving banded gulls (N = 237) was shot in 1978 and 1981. Although selection of the gulls to be shot was not based on formal randomization (for reasons of both public safety and local government regulations), the gulls were shot during all daylight

TABLE 2. Examples of appraisal of incorrect sighting records of Silver Gulls.

Incorrect record		Number of similar color bands used	Correct record possibilities*			Decision	
Left leg	Right leg		Left leg	Right leg	Comment	Left leg	Right leg
53724	GBG	1	GBkG 57358 GBG 57364	53724 GBG 57433 GBKG	This bird was reported as found dead at a village 40 km from banding place. The leg order was incorrectly reported by the finder, and one of the professional team incorrectly recorded GBkG as GBG.	accept as: GBkG	 53724
53757	GYW	1	BkYW 53744 GYW	53757 GYW 57411	At least two errors involved.	reject record	
vYG	(53970)	66	vYG	55970	At time of record, observer noted uncertainty about number, possibly because the bird flew away before confirmation was possible. Confusion of 5 and 3 was a common error. (In this instance band 53970 was not a possibility since it had not been used.)	accept as: vYG	 55970
—	55927	66	55927	vYG	The bird was standing on one leg, which carried the number band. Left and right legs were often confused when only one leg could be seen. L-55927 had been seen on 9 occasions at the place of the incorrect sight record.	accept as: 55927	 vYG
GWR	56787	1	56787 GWR 57351	vGW 57420 GWR	At least two errors involved.	reject record	
57304	Bk-W	6	57304	BkRW	Middle color strip (red) had faded or worn away.	accept as: 57304	 BkRW

TABLE 2. Continued.

Incorrect record		Number of similar color bands used	Correct record possibilities*		Comment	Decision	
Left leg	Right leg		Left leg	Right leg		Left leg	Right leg
(573(7)6)	BkGW	1	57316 57376 BkGW	BkGW BRBk 53751	This band number, and especially the fourth digit, was noted to be doubtful at the time of observation. R-BkGW was a unique band/leg combination.	accept as: 57316	 BkGW
Y	60296	3530	60296	Y	Leg reversal.	accept as: 60296	 Y
63745	W	750	63745 53780 WWW	RW WWW 65748	This incorrect record came 5 yr 5 mo after banding. Previous observations indicated that R faded or wore off within 2–4 yr.	accept as: 63745	 RW
66681	Y	3530	GWG	66681	Unlikely that R-Y was confused for L-GWG. More probably 1 or 2 digits of the number were incorrect (for instance, could have been L-56581). Some 3530 chicks were banded R-Y, hence the bird sighted could be one of many possibilities.	reject record	
69300	Nil	463	69300	WG	This bird lost the color band within 4 months. It had 41 subsequent confirmatory resightings.	accept as: 69300	 (WG)

* B = blue; Bk = black; G = green; R = red; W = white; Y = yellow; v = an individual color runs vertically on the band, otherwise assume individual colors run horizontally around band (see Fig. 2). Hence, L-GYW indicates green over yellow over white on the left leg.

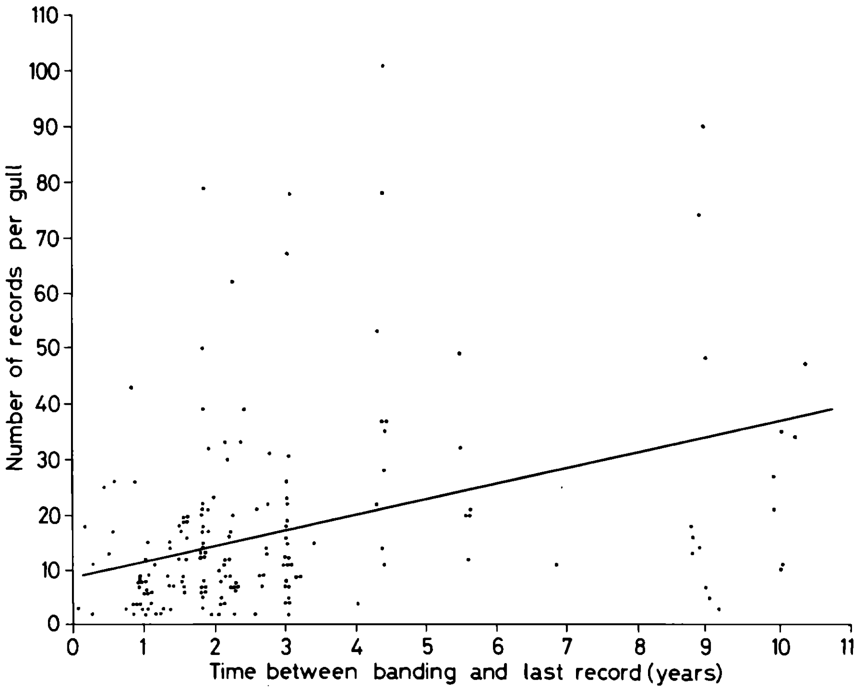

FIGURE 4. Correlation between the time Silver Gulls were known to be alive and the number of records for individual gulls, for a sample of 188 breeding adults banded at Beachport, South Australia, 1968 and 1969 (r_{xy} = .385).

hours and at many different sites in order to achieve a representative sample of survivors. Recovered number bands were washed, dried, and weighed to the nearest 0.001 g on an analytical balance. Where the serial number of a band could not be identified, bands were opened, flattened, washed in water, then 100% ethanol and finally xylene. After drying, the bands were swabbed with a solution of 30% hydrofluoric acid, 15% nitric acid, and 55% glycerine (Villella's solution). The aluminum affected by stamping of the serial number at the time of band manufacture etched away faster than the surrounding metal, and the digits were revealed, even on number bands which had been worn smooth. Recovered color bands were carefully examined for remaining traces of Scotchlite or Scotchcal, but were not treated further.

RESULTS

There was a significant (r = .385; $P < .01$) positive correlation between number of records per individual gull and length of time that individual gulls were known to be alive; however, there was great variation in the frequency with which individual gulls were resighted (Fig. 4). Of the 17,410 Silver Gulls banded, 3977 (22.8%) were seen again,

TABLE 3. Band recoveries from 237 Silver Gulls banded in 1967–1970 and shot in 1978 and 1981.

Condition of bands	No.	%
Both bands, legible	116	48.9
Both bands, number only legible	53	22.4
Both bands, color only legible[a]	4	1.7
Both bands, neither legible[a]	1	0.4
Number band only, legible	21	8.9
Number band only, illegible[a]	1	0.4
Color band only, legible[b]	36	15.2
Color band only, illegible[b]	5	2.1
Totals	237	100

[a] All illegible number bands were readable after acid etching.
[b] By 1978 most Scotchlite and Scotchcal had worn off the aluminum bands. Where all traces of color were gone, the color band was considered illegible.

and of 6999 gulls banded in the intensive study area, Lake George to Southend, 2987 (42.7%) were seen again (Table 1). A total of 37,774 valid sightings was accepted to August 1981 ($\bar{x}$ = 9.5 resighting records per resighted gull): 35,189 resightings from the professional teams and 2585 from the occasional observers. Some 26 gulls had >100 records and 61 gulls had histories spanning >12.75 yr from banding.

Loss and wear of bands.—Loss and wear data were derived: (1) from general observations on the condition of bands while resighting banded gulls, (2) from specific observations on 246 adult gulls in the Beachport intensive study area, which were given unique 3-color bands in addition to their unique number bands, and (3) from a sample of 411 bands taken from 237 gulls shot in 1978 and 1981.

Some band losses were discovered within 4 months of banding, although until the end of 1971 the total incidence of gulls known to have lost either band was considerably less than 0.5%. By 1978, 5.4% of known surviving gulls had lost color bands, and 10.0% had lost number bands.

Of the 246 Beachport adults given unique color bands, 3 (1.2%) were known to have lost color bands and 5 (2.0%) were known to have lost number bands by August 1981, after 12–13 yr; however, many of these adults are thought to have died within a few years of banding. Of 237 banded gulls shot in 1978 and 1981, 41 (17.3%) had lost number bands and 22 (9.3%) had lost color bands (Table 3). Of the 196 number bands recovered, 160 (81.6%) were considered to have been still legible on the free-living gulls, 30 (15.3%) could be read only in the hand, and 6 (3.1%) required treatment with Villella's solution to be rendered legible. Of 215 color bands taken from the shot gulls, none was clearly identifiable on the free-living gulls, but 157 (73.0%) were identified in the hand. Some 58 (27.0%) had been worn to bare aluminum, with no traces of color.

TABLE 4. Comparison of resighting records from Silver Gulls, shot in 1978 and 1981, found to have fast-wearing, average-wearing, and slow-wearing bands.

Wear rate of band group	Number of individual gulls in group	Location of resighting records[a]					Total number of resighting records (Σ n)
		Beach	Swamp	Town	Dump	Colony	
Fast	30	186 (37.0)	61 (12.1)	145 (28.8)	44 (8.7)	67 (13.3)	503
Average	30	172 (32.2)	59 (11.0)	160 (30.0)	70 (13.1)	73 (13.6)	534
Slow	30	191 (34.1)	39 (7.0)	158 (28.2)	44 (7.8)	128 (22.8)	560

[a] Numbers in parentheses are percentages of total number of observations (Σ n) in wear rate group.

All recovered number bands (n = 196 from shot birds + 13 others = 209) were used in the regression of band weight on time (Fig. 5). This calculation gives a biased estimate of band wear, because the sample does not include the fast-wearing bands which were lost from gulls (41 of the gulls shot in 1978 and 1981 had lost the number band). However, it is clear that the mean band wear is at least .0411 g/yr. Inspection of recovered number bands indicated that properly closed bands were unlikely to drop off as a result of wear until the bands were lighter than about .45 g. Since unused number bands weighed .9556 g ($\pm$.0124 g SD), significant band losses (>5%) would have occurred from these Silver Gulls by 9 yr. By 1978, there was a marked variation in the weights of number bands, with some having lost almost twice as much aluminum as others (Fig. 5). These differences seem unlikely to be due to differences in the quality of the metal, but may be due to differences in behavior of the individual gulls. For instance, on gulls habitually frequenting sandy beaches and shores, bands may wear faster than on gulls which frequent villages or dumps. To test this, 3 band groups were selected from the plotted regression of band weights on time: one group contained the 30 bands showing the fastest rates of band wear, one the 30 slowest rates of band wear, and one the 30 bands showing rates of wear most similar to the calculated overall mean rate. The age distributions of gulls in each group were similar. The location records for the gulls carrying these bands were compared. There is significant heterogeneity among the 3 groups in the locations where the gulls were resighted ($\chi^2_{12} = 37.7$; $P < .001$). Inspection of the data (Table 4), however, reveals no clear trends. In part this may be because most resighting records were made during 1968–1972, whereas much, perhaps even most, band wear occurred during 1973–1981. If the behavior of individual gulls is not consistent over years, the paucity of observations during 1973–1981 would confuse elucidation of any relationship between gull behavior and rate of band wear. Even so, this comparison

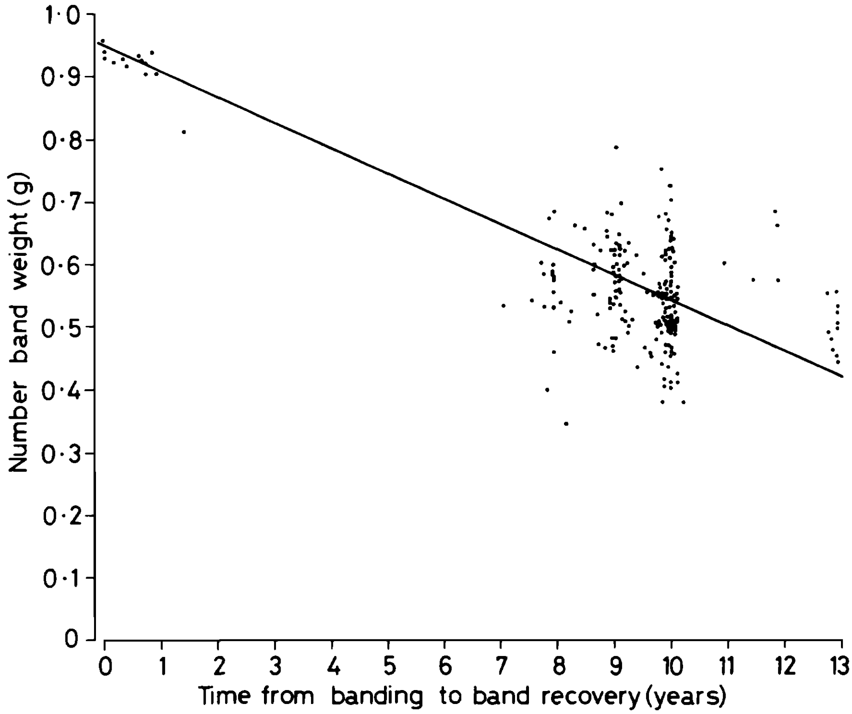

FIGURE 5. Regression of weight of number band (n = 209) on time (years). Regression equation is y = .9556 − .0411x (years).

does indicate considerable potential for field study of band wear and the reasons for differential band wear.

With color bands, the problem was not so much one of when bands were lost, but rather when the color of the Scotchlite or Scotchcal was not identifiable. Red Scotchlite showed some fading in 9 months, marked fading by 2 yr, and appeared white by 3 yr. All other color materials showed deterioration and evidence of peeling from the aluminum base by 4 yr. By 1978, no color bands had sufficient color left to enable positive identification on the free-living gulls. In the hand, from the 1978 and 1981 shootings, the proportions of color bands which could be identified positively ranged from <10% for bands originally bearing some red (e.g., WR), 16% for unique 3-color bands (e.g., BBkG), 54% for Y, and 73% for WG. Red Scotchlite appeared to wear away faster than the other materials, in addition to fading much faster, but with the exception of that material, the durability of colors on the bands appeared to be a function of the actual sizes of material bonded to the aluminum base. The larger the individual pieces of color material, the longer color could be identified on the bands.

TABLE 5. Problems detected in 37,774 resightings of number bands on Silver Gulls (68 unresolved errors not included).

Problems[a] detected	Correct digit									
	0	1	2	3	4	5	6	7	8	9
Digit not read	5	3	16	43	9	29	27	12	14	19
Digit read as:										
0	—	—	1	—	—	—	—	—	4	1
1	1	—	—	—	—	1	1	39	—	3
2	2	—	—	5	—	—	—	—	3	5
3	—	—	2	—	1	14	3	2	2	—
4	—	1	2	2	—	—	1	1	1	—
5	—	—	—	9	—	—	16	—	2	—
6	3	—	—	5	—	37	—	—	—	6
7	—	15	3	8	2	—	—	—	—	—
8	7	—	—	4	—	2	4	2	—	3
9	2	3	4	1	—	5	8	1	3	—
Recorded as dubious, but later checked as correct	18	26	17	30	28	75	67	24	25	44
Totals	38	48	45	107	40	163	127	81	54	81

[a] Some 329 number bands were misread leading to an incorrect field record. In addition, 68 other resighting records contained possible digit errors in combination with possible color errors. These multiple errors could not be resolved, and the 68 records were rejected.

Errors in resighting bands, recording and processing data.—Regular checks during field work and data processing indicated that almost all errors were made at the time of the original field observation, sometimes by the recorder, but usually by the observer. The accuracy and efficiency of most observers improved markedly with an experience of only a few days, but some observers never improved to the level of accuracy where their observations were accepted. Common early errors were reading digits incorrectly (e.g., reading 7 as 1), and reversing the sequence of two adjacent digits. Such errors sometimes went undetected when a bird flew away before the bands could be checked by a second observer, or when the bands were seen at such a distance that only one observer had sufficiently acute vision to read the bands. For the purpose of this section, all errors will be considered together, regardless of the source.

The most common error was leg reversal. Some 328 observations (.87% of all resightings) had the incorrect leg sequence for bands. Leg reversal errors occurred mainly when a gull, standing sideways to the observer, was seen near the limit of an observer's ability to read a band, or when a gull was standing on one leg with the second leg hidden. Leg reversal errors also occurred when a gull was in the hand: e.g., L-GBkG, R-53724 was sighted and recorded correctly on 21 occasions over 2 yr, but on the last occasion it was found dead by a local villager who reported

TABLE 6. Number of problems detected per 10,000 readings of each digit.

Problems detected	Correct digit									
	0	1	2	3	4	5	6	7	8	9
Digit not read	4.4	2.2	12.4	24.2	7.9	9.1	6.7	7.9	11.7	8.4
Digit read as:										
0	—		0.7						3.3	0.4
1	0.9	—				0.3	0.2	25.6		
2	1.8		—	2.8					2.5	1.3
3			1.5	—	0.9	4.4	0.7	1.3	1.7	2.2
4		0.7	1.5	1.1	—		0.2	0.7	0.8	
5				5.1		—	4.0		1.7	
6	2.6			2.8		11.7	—			2.6
7		11.2	2.3	4.5	1.8			—		
8	6.1			2.3		0.6	1.0	1.3	—	1.3
9	1.8	2.2	3.1	0.6		1.6	2.0	0.7	2.5	—
Recorded as dubious, but later checked as correct	15.8	19.5	13.2	16.9	24.6	23.6	16.6	16.4	20.8	19.4
Totals	33.4	35.8	34.7	60.3	35.2	51.3	31.4	53.9	45.0	35.6

the bands as L-53724, R-GBkG. The team member noting the recovery added a second error, by recording the bands as L-53724, R-GBG.

Table 5 shows the frequency of digit errors, omissions, and uncertainties in field records. Of 37,774 records, 329 (.87%) were found to contain digit errors. A further 68 (.18%) contained errors which could not be explained, so those records were rejected totally and are not included in the total of 37,774 records analyzed. Table 6 shows relative occurrences, corrected for the different frequencies with which digits occurred on the bands actually used, and then standardised per 10,000 digit resightings. The most common errors were sighting or recording 7 as 1, 5 as 6, and 1 as 7 (Tables 5 and 6). Considering the relative frequencies of digits on the resighted bands, the digit 3 caused the most problems, followed by 7 and 5 (Table 6).

With color bands, the most common errors were to read green or blue bands as black, when the bands were in shadow, and dirtied white bands as yellow. The most common error made while recording color bands was to write blue (B) instead of black (Bk). Color bands were recorded incorrectly 109 times when the bands were known to be in good condition (.3% error). Once the color bands showed signs of wear or fading, color band errors and color uncertainties increased markedly. From 1973 onwards, 841 records had color band discrepancies which could be attributed to wear or fading (53.7% error). Even so, most of the worn or faded color bands retained enough identifying color traces

TABLE 7. Comparison of data derived from Silver Gulls banded in 1967–1970 and recovered in 1978.

	Recovery method of band	
	Shooting	Non-recaptured resighting
Number of birds	171	125
Mean number of resighting records	17.5	19.0
Range of resighting records	0–104	0–134
Percentage of gulls with only one record after banding (including recovery record)	10.5	11.2
Mean number of days between penultimate record and last record	1815	1501

to be useful for additional confirmation of the accuracy of number bands recorded (see Table 2).

Comparison of records from a shot sample with records from a non-shot sample.—Shooting is a common, effective method for recovering bands from free-living birds; however, it has the obvious disadvantage of terminating the return of data. With Silver Gulls, it was particularly quick and easy to shoot a selected individual within a range of 6–60 m. In order to assess the effectiveness of the visual resighting program, the histories of the 171 gulls shot during 1978 were compared with the histories, prior to the start of the shooting program, of 125 gulls which were seen-only during 1978 (Table 7). The shot sample was taken concurrently with routine field searches, during otherwise standard observation procedures. Excluding all records made on the seen-only gulls after the 1978 shooting program, the shot birds still had slightly fewer resighting records ($\bar{x}$ = 17.5) than the seen-only gulls ($\bar{x}$ = 19.0), but in all of the comparisons shown (Table 7) there were no significant differences between the data sets (Fig. 6). We conclude therefore that, with respect to the number of individual gulls "recovered" by the two methods over the particular trial period, resighting of these bands by trained observers was as effective as the shooting program. We note, however, that some of the gulls shot in 1978 had bands which were no longer readable on the free-living gulls. These were the fast-wearing bands, and had the intensity of sightings been greater in 1976–1977, it is highly probable that there would have been significant differences.

By the end of the field program, the range of resighting frequency, for the 3977 resighted gulls, was 1–204. There were major differences in distances of dispersal and foraging movements between individual gulls, even considering gulls from a particular colony and the same age cohort, which in part accounts for the great range in resighting frequency. However, the proportion of gulls recorded in 1978 for the first time since banding (18/171 of shot gulls, 14/125 of seen-only gulls:

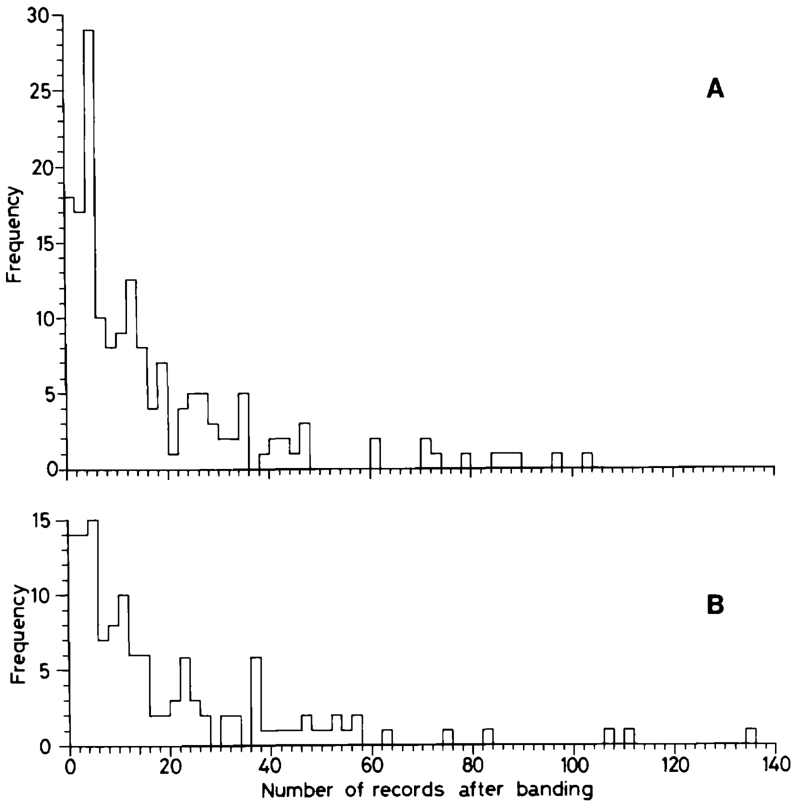

FIGURE 6. A—Frequency of resighting records for 171 Silver Gulls shot in 1978; B—Frequency of resighting records for 125 Silver Gulls seen but not shot in 1978. The gulls were banded in 1967–1970.

10.8% of total sample) suggests that the behavior of these individuals had changed with time.

Thus, of the two methods, resighting of readable band numbers on uncaptured birds has overwhelming advantages for Silver Gulls and similar species: the method leaves the birds unharmed for further resightings and, with trained observers, allows for convenient searches in areas of urban development. Shooting is quicker, and will always be effective at greater distances than a band can be read, but it destroys the potential for future information and is unsafe or prohibited in many areas of human activity.

DISCUSSION

Following Lack's classic field study of Robins (Lack 1939, 1940), resighting records have been used very successfully to establish the presence of uncaptured, uniquely color-banded birds in many ecological and behavioral studies, for example, on corvids (Rowley 1971, 1973), a cracticid (Carrick 1960, 1963, 1972), larids (Carrick and Murray 1970; Carrick 1972; Mills 1972, 1973, 1979) and a procellariid (Carrick and Dunnet 1954). Attempts have been made to read standard number bands on uncaptured, free-living birds (Carrick et al. 1957; Kadlec and Drury 1968, 1969; Kadlec 1975; Butler et al. 1980), but most number bands in use today require the banded bird to be in hand for the unique serial number to be read. To our knowledge, the number bands described in this paper are the first developed to enable resighting of the bands to be used as the primary method of bird identification.

Of 17,410 Silver Gulls given these aluminum number bands, 22.8% were seen again. These gulls had a mean of 9.5 resightings. Considering only those 1287 gulls banded as adults, 85.6% were seen again, with a mean of >20 resighting records per bird. These figures may be compared with returns from other seabird programs which used the conventional types of bands. Recovery rates range from about .1–20% (Hitchcock and Carrick 1958; Dunnet et al. 1977), with, typically, a single record after banding for any bird. Even with gulls, which are amongst the most accessible seabirds, returns from standard bands are usually about 5%, rarely approach 20% (Table 8), and, again, typically consist of just a single record after banding. Such limited data can represent an extremely poor return for the expense and time invested in the initial banding programs. Using the new bands on Silver Gulls, we now have many detailed life histories which show the movements of individuals after they left the banding locations. Some individuals were identified at their breeding or natal colony and then up to 450 km away in the non-breeding months, in 3 different years. Over the 14 years of resightings, 1.1% of number band records were found to contain digit errors or digit omissions, even with observers in the field checking each other. This emphasizes that only those actively involved in the details of such a study can make the final decision of validity of a recovery. Some 2.5% of all color-band resightings were also in error, but this includes errors due to wear and fading of colors after about 4 yr. Some .9% of records showed leg reversal errors. Investigation of the sources of errors revealed that almost all were made in the field by the observers, rather than at some later stage; hence, where possible all observations must be checked and rechecked by 2 or more people. This greatly minimizes the level of errors, and also identifies any observers who are prone to make errors. When errors were found in the data files, field records were compared with original banding records, and only 68 of 37,842 sightings (.2%) had to be rejected because the errors could not be resolved with a reasonable degree of certainty. Of concern was the thought that errors could be made which *might not be detected.* For instance, if bands L-62817 R-Y were incorrectly read or recorded as L-62811 R-Y, which was another valid band combination, the latter

TABLE 8. Comparison of return data from gull banding programs.

Species	Banding period	Country	No. banded	Percentage recovery	Data source
Larus argentatus (Herring Gull)	1909–1963	Britain	99,718	3.9	Spencer (1971)
	1966–1974	Britain	16,822	4.7	Parsons and Duncan (1978)
	1966–1972	Canada	12,785	1.8	Threlfall (1978)
	1913–1956	Sweden, Norway, and Finland	13,900	9.5	Olsson (1958)
	1931–1957	U.S.A.	37,414	3.1	Smith (1959)
	1934–1939	U.S.A.	31,694	3.8	Paynter (1966)
	1950–1957	U.S.A.	3028	2.7	Hofslund (1959)
	1961–1962	U.S.A.	1015	19.1	Kadlec and Drury (1969)
	1967–1969	U.S.A.	23,066	2.2	Kadlec (1975)
Larus canus (Common Gull)	1931–1971	Denmark	31,565	3.2	Sorensen (1972)
Larus fuscus (Lesser Black-backed Gull)	1909–1974	Britain	68,230	4.9	Dunnet et al. (1977)
Larus marinus (Great Black-backed Gull)	1909–1974	Britain	14,943	5.3	Dunnet et al. (1977)
Larus novaehollandiae (Silver Gull)	1950–1957	Australia	9123	1.8	Carrick et al. (1957)
	1953–1963	Australia	54,217	2.8	Murray and Carrick (1964)
	1967–1970	Australia	17.410	22.8	Present paper

record would be accepted unless L-62811 was known to be elsewhere at the same time, or dead. We can only speculate that, in our study, undetected errors should be few, and at least an order of magnitude less than the number of errors detected, because of the large number of different types of color bands used. Clearly, undetected errors would be reduced to negligible levels by avoiding multiple use of color bands to denote cohorts and by using discontinuous number band sequences.

With a banding program of 20,000 birds, it would be best to avoid a sequence such as 50000–69999 and instead use, for example, 20000–24499, 45000–49999, 60000–64499, and 75000–79999. These number bands could be paired with one of the 216 three-color combinations of black, blue, green, red, yellow, and white, used randomly. The probability of an erroneous sighting then resulting in another valid number band and color band combination is minute. Since most band wear occurs near the foot, we suggest that bands with vertical number sequences should be placed on the bird's leg to read from bottom to top.

A most urgent need is to continue the experiments of Kadlec (1975), and others, to find an alloy that will increase the durability and readability of bands. For long-lived species of seabirds, exceptionally durable alloys are needed to last 30 yr or more with intermittent immersion in the sea, brackish water and mud, and abrasion by sand. Poulding's (1954) data suggested that *Larus argentatus* actively removed leg bands, resulting in a 50% loss of bands in the first year. Paynter (1966) thought that band loss from Herring Gulls was probably about 5% per year. Kadlec and Drury (1968) reported that by the sixth year about 20% of standard aluminum bands were being lost per year from Herring Gulls. Later this estimate was amended to 56% loss by the fourth year (Kadlec and Drury 1969), although Kadlec's (1975) most recent figure was 3% loss to the end of 7 yr. Mills (1972) used various types of bands on the Red-billed Gull of New Zealand, *Larus novaehollandiae scopulinus,* and found significantly fewer lock bands were lost than butt-to-butt bands (24% versus 89% loss) over 10 yr, but lock bands wore more quickly because of their imbalanced weight. Spear (1980) found that 23% of number bands on *Larus occidentalis* were lost by 3.7 yr, and the loss rate thereafter was 16% per year. Clearly, the loss rate from gulls is very variable. Paynter (1966) considered that losses could be due to bands weakening with wear, bands being removed by the birds, and "an inconsistent or fluctuating loss" due to such factors as time immersed in saline water "or because the new bands are not of uniform strength." With the size and weight of our bands, it seems unlikely that even adult Silver Gulls (weighing ca. 400 g) could remove bands unless the metal had inherent defects or the banding technique was faulty. Removal of defective bands by the gulls would explain the low early losses noted. By 9–10 yr, 10% of surviving Silver Gulls were known to have lost number bands and 5% were known to have lost color bands. It is possible to recapture banded birds to replace worn or lost bands, but this sometimes results in bird mortality, which we wished to avoid. Number bands of the type we describe would have increased durability, and readability, on larger birds. Relatively increased in size for use on Herring Gulls, for instance, duration and distance of readability should be doubled on the figures we give for Silver Gulls.

The lower incidence of loss of color bands, compared with number bands, was attributed to the Scotchlite and Scotchcal bonded to the outside and inside surfaces of the aluminum, protecting the metal from wear and corrosion. Even so, there were obvious differences in wear rates of similar color bands on different gulls, as for the number bands. We have not been able to explain this adequately, although we have suggested that it may be a consequence of individual gull behavior. Durability of number bands might be improved by cementing a plastic layer to the inside, as we did for the color bands, finding a durable clear coating that could be sprayed or painted on the outside of the bands before they are placed on the gulls, and increasing the band size and thickness when used on larger birds.

We consider that the results of this program give an unequivocal indication of the effectiveness and usefulness of number bands which are readable on free-living birds, and also of the value of combining these number bands with clearly visible color bands. Our band return rates were far better than those which have been achieved by most other large-scale gull-banding programs (Table 8), approaching the returns that could have been achieved by actively seeking out and then shooting the banded gulls. A major and obvious advantage of "visual recapture" is that it is a non-destructive method of sampling: once banded, the gulls need not be handled or disturbed again. Another equally important advantage is that part-time observers can be trained and encouraged to read the bands, needing only binoculars and notebooks instead of trapping equipment or guns. Many valuable records came from part-time observers who were scattered throughout southern Australia, and who were prepared to search their home ranges on a regular basis looking for the banded gulls. Having color bands and number bands on the birds was especially essential here, because most of the part-time observers were alone when they were reading bands, so the match of color and number with the banding record was the only check of validity. As colors faded or wore away, the advantage of having single bands with 3 colors, rather than 3 individual bands each with a single color, was demonstrated. Where one color of a sequence was lost from a 3-color band (e.g., L-BkRG becoming L-Bk/metal/G), there were far fewer original combinations possible (6) than if 1 of 3 single-color bands had been lost (e.g., if L-Bk/R/G became L-Bk/R, there are 18 possibilities for the original combination. The problem of loss of colors may be resolved by bonding a few layers of the color base to the band so that a fresh layer is revealed as each outer layer becomes abraded. Anderson (1980) has indicated that polyvinyl chloride (Darvic) color bands could be more durable, although at present these are not available commercially.

SUMMARY

Carrick and Murray (1970) described a new type of aluminum band that was designed to enable identification of large numbers of uncaptured, free-living birds. During 1967–1970, these number bands, used together with color bands on the other legs, were placed on 17,410 Silver Gulls in South Australia. The number bands had a maximum readable life of about 10 yr on these free-living gulls, although after this period the numbers could be revealed on smooth bands by etching the aluminum with Villella's solution. The color bands used had a maximum readable life of about 3–4 yr. Our results from these bands indicate enormous potential for studies using readable number bands, with returns far exceeding those from conventional bands. The nature and frequency of the errors detected in data files are discussed. Errors were made mostly during field observations, rather than subsequently, and the necessity is emphasized to continuously check and recheck all sighting records while the banded bird is still present at a location. Because all gulls had 2 bands, a number band and a color band, both of which were readable on the uncaptured birds, less than .2% of records were rejected as a consequence of unresolved errors. Undetected errors were probably few, but these could be reduced to negligible levels by the appropriate use of color bands to confirm the accuracy of reading of number bands. To our knowledge, this is the first study that has used resightings of number bands on free-living, unrecaptured birds as the primary method of data acquisition.

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