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INDIVIDUAL COLOUR BANDING FOR 8 000 BIRDS

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Individual identification of banded birds is indispensable for behaviour and population studies in the field. By carefully selecting the colours for leg bands and assigning numbers to them, up to 8 000 individuals can be banded uniquely and systematically for easy field identification and record keeping, allowing long-term study of large populations with overlapping generations.

INTRODUCTION

Colour banding for identification of individuals by sight has been used widely for behaviour and population studies of birds in the field. In his classical study of the life history of the Superb Fairy-wren *Malurus cyaneus,* Rowley (1965) used three bands (metal, plain colour and stripes) to distinguish a particular brood by individual marking of nestlings. For the monitoring of populations sight recoveries of uniquely marked individuals can help us assess the number of banded birds surviving in the population at any time without actually recapturing the birds. Thus population estimates based on the recapture rate of banded birds may be facilitated if sight recoveries are used as a sample for the calculation of an unbiased recapture rate (e.g. Kikkawa 1962).

The Australian Bird and Bat Banding Scheme (ABBBS) established a protocol of colour banding for individual recognition of sedentary species (Schema 3 in Lowe 1989), which permits use of three colour bands together with a metal band at a fixed position. Using six recommended colours (red, black, dark blue, light green, orange and yellow or white) under this scheme, up to $6^3 = 216$ combinations may be used at any one site on a given species.

In a study of large populations with overlapping generations, an enormous advantage may be gained if colour bands can be translated into numbers that give individuals unique numerical identities. To do this it would simplify the operation if 10 unique colours could be used in the scheme, allowing $10^3 = 1\ 000$ combinations to be used in an unbroken sequence.

In the course of a long-term study of a Silvereye *Zosterops lateralis* population on Heron Island, Great Barrier Reef, I have developed a numbering system using a combination of three bands on a bird to individually identify up to 4 000 birds in the field. In this paper I describe the numbering system developed and discuss its application from the experience gained over 25 years of banding using the system.

THE NUMBERING SYSTEM

The numbering system described here has been used only for the Silvereye project on Heron Island. It was developed between 1964 and 1972 when a total of 2 270 Silvereyes were banded on the island using two or three bands per bird. After trials of different makes only the celluloid split rings of size XF supplied by A. C. Hughes (Hampton Hill, United Kingdom) were used since 1966. A great variety of colours designed for aviary use was available and the following colours were used in the trials. Numbers 0 to 9 for the last digit were represented by unique colours including striped colours. The asterisks indicate those adopted for the long-term study (Table 1).

Single colours: red*, light blue**, dark blue*, light pink*, dark pink**, yellow**, orange*, light green*, dark green**, mauve, black, white.

Broad striped colours (two broad stripes per band): red-white* (white-red**), red-dark blue, red-light blue, red-light pink, red-yellow, red-light green, red-dark green, light blue-white, light blue-pink, light blue-yellow, light blue-orange, light blue-dark green, dark blue-white* (white-dark blue**), dark blue-yellow, dark blue-orange,

TABLE 1

Two series of 10 colours used in the numbering system.

	Series 1 (*)	Abbrev.	Series 2 (**)	Abbrev.
0	yellow-black	yk	black-yellow	ky
1	red	r	dark pink	dp
2	dark blue	b	light blue	lb
3	light pink	p	yellow	y
4	orange	o	orange-white	ow
5	light green	lg	dark green	dg
6	red-white	rw	white-red	wr
7	dark blue-white	bw	white-dark blue	wb
8	dark blue-white (narrow stripes)	bwb	black-white (narrow stripes)	kwk
9	white-light green	wg	light green-white	gw

dark blue-light green, dark blue-mauve, light pink-yellow, light pink-mauve, light pink-dark green, yellow-light green, yellow-dark green, yellow-mauve, yellow-black* (black-yellow**), orange-white**, orange-brown, white-light green* (light green-white**), light green-brown, light green-purple, light green-black, dark green-mauve, purple-black.

Narrow striped colours (four to six narrow stripes per band): red-white, red-dark blue, red-light pink, dark blue-white*, light pink-white, light pink-black, dark blue-yellow, orange-white, light green-white, black-white**, red-white-dark blue.

From these, two series of 10 colours each (marked with one and two asterisks, respectively) were selected for use from 1972 onwards and numbered as in Table 1.

In the Heron Island study three colour bands were used for each bird without a metal band. In the two series each bird carried two colour bands on one leg and one on the other. Thus one series of 10 colours for three bands provided 2×10^3 = 2 000 combinations where two alternative sets were obtained by placing two bands on either the left or the right tarsus. If a metal band is required it can be placed on the leg that carries one colour band (below the colour band). If it is not required, the space may be used for an additional colour band to boost the number of combinations. Rather than using a variety of colours I recommend black for the booster band, which may be placed on the leg that carries one colour band otherwise. By placing the black band either above or below the colour band, an additional 2 000 combinations can be obtained. The first digit may be numbered according to which leg carries one colour band if the booster band is not used, or the position of the booster band if it is used, as shown in Table 2. The second and third digits are obtained by simply reading the two colour bands from top to bottom on whichever leg carries two colour bands. The last digit is read on the single colour band on the other leg. Thus, using the Series 1 bands an unbroken sequence of 2 000 (or 4 000 including a booster band) can be obtained; for example, with our convention of writing left leg/right leg and a comma between the top and bottom bands we may express the combinations from 0 000 (yk,yk/yk = 0,0/0) to 1 999 (wg/wg,wg = 9/9,9) without a booster band, or 0 000 (yk,yk/yk,booster = 0,0/0,black) through 2 000 (yk,booster/yk,yk = 0,black/0,0) to 3 999 (booster,wg/wg,wg = black,9/9,9) with a booster band.

TABLE 2

Numbering of the fist digit.

	Left tarsus		Right tarsus	
	top	bottom	top	bottom
Without booster band				
0 000–0 999	colour,	colour	colour	(metal)*
1 000–1 999	colour	(metal)*	colour,	colour
With a booster band				
0 000–0 999	colour,	colour	colour,	black
1 000–1 999	colour,	colour	black,	colour
2 000–2 999	colour,	black	colour,	colour
3 000–3 999	black,	colour	colour,	colour

*The metal band was not used in the Heron Island study.

Between 1972 and 1978 a total of 1 481 Silvereyes, mostly surviving young in their first year, were banded on Heron Island. Since 1979 an intensive banding through the breeding season consumed about 500 combinations per year, exhausting one series of combinations (without a booster band) in about four years. I then introduced the Series 2 bands as alternatives to the Series 1 so that the same number could be read on each alternative colour corresponding to the Series 1 (Table 1). Following the above coding, this added 2 000 combinations from 2 000 (ky,ky/ky = 0,0/0) to 3 999 (gw/gw,gw = 9/9,9) (since no metal or booster band was used on Heron Island). If a booster band were included, use of the second series would have permitted an additional 4 000 combinations from 4 000 (ky,ky/ky,booster = 0,0/0,black) through 6 000 (ky,booster/ky,ky = 0,black/0,0) to 7 999 (booster,gw/gw,gw = black,9/9,9).

After eight years I decided to go back to the Series 1 bands as very few birds survived eight years. Between 1975 and 1987, the number of birds older than eight years in the population varied from 0 to 9 (2.1 %). As a precaution the same combinations as those of the birds known to be alive at age 6 (allowing two years of non-sighting) were not used in subsequent banding to avoid possible duplication. Other confusing combinations (see below) were also avoided and, as a result, 130 combinations were not used in banding 2 862 birds between 1988 and 1994.

In selecting the 10 colours for each series, confusing colours in field conditions were avoided. Shade and contrast in hues, particularly in poor light conditions, also needed to be considered. In Series 1, three shades of longer wavelengths (red, orange and light pink) and two shades of shorter and middle wavelengths (dark blue and light green) were used in single colours. The light colours, such as light pink and light green, and orange to some extent, faded after three or four years. Black and white were avoided as single colours. Contrast in shade was an important consideration in selecting broad striped colours. For example, blue-white and green-white were never used in the same series. In Series 1 these bands were placed on the leg as blue-white and white-green. For the numeral 0, yellow-black was used but purple-black or orange-brown would have been equally effective. Because only one narrow striped colour (blue-white) was used (number 8), this number could be served by some other narrow striped colours (e.g. red-white, green-white) without causing confusion.

In Series 2, colours corresponding to Series 1 were selected to represent the 10 numerals (Table 1). For plain colours, dark pink replaced red of Series 1 and light blue and dark green were used in place of dark blue and light green, respectively. Orange was replaced with orange-white while all broad striped colours of Series 1 were used upside down in Series 2. Blue-white (bwb) of the narrow striped colour was replaced with black-white (kwk) in Series 2, but other narrow striped colours would have been more effective as an alternative. Fading of colours also occurred in Series 2 bands but caused little confusion within the series.

In practice, observers, including students and volunteers, learned the decimal colour banding system within a few days and were able to identify individuals in the field without much difficulty. Experienced Silvereye workers associated band colours with numbers and were able to read the identification number (ID) directly from the colour bands of any banded bird sighted in the field. This instantaneous translating of colours into numbers enabled recording of rapidly moving individuals engaged in complex behaviour of foraging (see Catterall *et al.* 1982) or fighting (see Kikkawa 1980). Use of a micro-cassette recorder with a small microphone attached to the binoculars facilitated the recording of many IDs in rapid succession.

DISCUSSION

Protocol

The Silvereye *Zosterops lateralis* is by far the most frequently banded species in Australia. Between 1953 and 1995 over 270 000 individuals have been banded with a reasonably high recovery rate (12.5%) despite their migratory habits (Baker *et al.* 1995). Thus it would be confusing to apply colour banding for individual recognition at the banding stations monitoring their movements. The numbering system described above would be more suitable for intensive studies of non-migratory populations such as found on islands or other sedentary species. For Silvereyes the size XF colour bands are suitable without reshaping but three colour bands on one leg should be avoided (Schema 4 of the protocol, Lowe 1989) as the upper section of the tarsus is often obscured from the view.

The protocol of ABBBS for colour banding in Australia for individual recognition in the field normally requires two colour bands on the left tarsus and one colour over metal band on the right tarsus for known sedentary species (Lowe 1989). Species with short tarsi accommodate up to two bands on each tarsus, but those which often sit on their legs, such as estrildid finches, do not readily permit individual recognition. The subject must allow full view of two bands on each tarsus.

If the protocol permits decimal-translation of colours by recommending the use of 10 colours instead of six, Series 1 or 2 or an equivalent could be adopted for Scheme 3 or special cases. If a metapopulation consisting of several subpopulations, each with fewer than 100 birds, is studied, the site may be coded by the first, the yearly cohort by the second and the individual by the last two digits. Similarly, different broods may be prefixed by different numbers.

Banding procedure

To prevent misplacement of bands the banding sheets with the appropriate combinations of colours against serial numbers were prepared and the colour bands put on a string in the order of banding. The three bands per bird would always appear on the string in the order of banding, from left to right and top to bottom, and the order of bands for 30 individuals per banding sheet had been checked against the entry on the sheet. An example from the Heron Island banding sheet is shown in Table 3.

After banding, the band combinations on the bird were checked against the coding on the banding sheet. Because bands in the wrong order or on the wrong tarsus will produce a correct combination for another number, it is difficult to detect error or correct it once a wrongly banded bird is released. Such errors rarely occurred on Heron Island and any banding anomaly was corrected quickly by recapturing the bird concerned.

Even when all released birds carry correctly banded colours, errors of identification may occur unwittingly and unnoticed because all possible combinations of colours used within each series have corresponding numbers. The practice of reading numbers (instead of colours) quickly while recognizing the left and right legs of birds in various positions (e.g. facing away upside down) is extremely important in achieving accuracy of identification.

Fading of colours

Some colours faded during the life of Silvereyes on Heron Island, where light intensities in sunny gaps and edges of woodland were very high (Endler 1993). Fading and discolouring of bands were similar to those reported by Lindsey *et al.* (1995) on the bands obtained from the same source and exposed to natural sunlight in Hawaii. The rates of colour change were similar to those that occurred to bands carried by free-flying birds at high altitudes of Hawaii (Lindsey *et al.* 1995). On Heron Island fading of some colours started in the second year of banding, but all faded colours were assignable to the original colours in hand after five years on the bird. The only confusing colour in the hand was faded light blue which resembled unfaded light green. However, these two bands were used in different series and the identity of the carrier was revealed from the combination of colour bands on the bird. Efforts were made to recapture birds with fading bands and most birds carrying old bands were rebanded after four or five years. Identities of such birds

TABLE 3

A section of the banding sheet for Heron Island Silvereyes.

		Colour bands				
Date/time	Number	left	right	Site/nest	Age	Morphometrics
	6521*	r	lg,b			
	6522	b	lg,b			
	6523	p	lg,b			
-------------	6524	NOT TO BE USED		--------------------------------		
	6525	lg	lg,b			
	6526	rw	lg,b			
	6527	bw	lg,b			
	6528	bwb	lg,b			
	6529	wg	lg,b			
	6530	yk	lg,p			
	------	—	—			

*The numbers 6 000s indicate the second round use of the Series 1 bands with two bands on the right tarsus. In this banding the Series 1 bands were used for IDs 1 000 to 2 999 for the first round and 5 000 to 6 999 for the second round.

were seldom in doubt as observations were made frequently and recapturing was relatively easy. If rebanding is not possible or birds are not confined to the study area, the metal band is essential to maintain the identities of the colour-banded birds.

Table 4 identifies colours that changed sufficiently to cause confusion in the field. When a faded colour was unassignable to a number, the identity of the bird carrying it was usually revealed by the numbers represented by other colour bands on the bird, in combination with the identity of its mate or the nesting territory in summer. Confusing combinations between the two series were not used if the bird carrying these colours were known to be alive. For example, the number 2 888 (kwk,kwk/kwk) or 3 111 (dp/dp,dp) was not to be used if 0 888 (bwb,bwb/bwb) or 1 111 (r/r,r) was alive, respectively.

Fading of colours may not be so severe in southern parts of Australia or on birds of the forest interior where light intensities are not expected to be very high.

Loss of bands

If old birds were not rebanded they began to lose bands after 5 years. Although our bands were not sealed with acetone at banding, some birds did not lose any of the three bands for as long as nine years on Heron Island. When one band representing the last digit was missing it was usually possible to identify the individual from the list of surviving birds in the previous season. When the bird carries one band on each tarsus there are 40 possible combinations within the same series that the bird may have had before losing the band. These combinations were usually reduced to 20 by knowing the age groups likely to lose bands, and possibilities were further narrowed to fewer than five by knowing surviving individuals carrying old bands. Every effort was made to recapture such individuals for rebanding. No birds lost two bands in the same season, but there were two cases in which a bird had lost two out of three bands before recapture after nine years. These birds were well known to the observers as they maintained the same nesting territories year after year (see Kikkawa 1987; Kikkawa and Catterall 1991).

Effects of colour on behaviour and mortality

Silvereyes pair for life and breed monogamously (Kikkawa 1987). Effects of band colours on mate selection and other behaviour have not been assessed but are not expected to be significant. If species have different mating systems, the colour of bands may have significant effects (Burley 1986).

The numbering system used here will easily permit analysis of such effects. For example, if the colours of the bands put on young affected the feeding rate of fledglings by the parents, this might cause differential mortality of juveniles. A comparison of survival rate between birds carrying predominantly red colour (r or rw on at least two bands) and those carrying predominantly blue colour (b or bw on at least two bands) was made on the nestlings banded in the 1988/89 season. There were 44 young banded with red colour and 46 with blue colour and 5 each from the two groups (11.4% and 10.9%, respectively) survived until their first breeding season, indicating that

TABLE 4

Colours that become confusing after fading.

No.	Series 1	Series 2
0	yk	ky
1	r	dp fades similar to r (1 of Ser. 1)
2	b	lb fades similar to lg (5 of Ser. 1)
3	p fades similar to white (not used)	y fades similar to p (3 of Ser. 1)
4	o fades similar to p (3 of Ser. 1)	ow fades similar to rw (6 of Ser. 1)
5	lg fades similar to y (3 of Ser. 2)	dg fades similar to black (not used as a number)
6	rw	wr
7	bw	wb
8	bwb fades similar to kwk (8 of Ser. 2)	kwk
9	wg	gw

red and blue bands did not affect the survivorship of the first year birds differentially ($X^2 = 0.0056$, $P > 0.90$).

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PEER REVIEW

Letters from Readers

North West Island: *Corella,* 1996, Vol. 20(3): pp. 107–110.

In the paper entitled "Seabird Islands No. 231: North West Island, Great Barrier Reef, Queensland", Hulsman's statement that earlier population estimates were "rough guesses or unreliable extrapolations" is supported. Hulsman, referring to M. Vaneck's (pers. comm.) work in the early 1980s, presents a population estimate of greater than 500 000 pairs with a 25 per cent variation between years. It is unfortunate that details of this information are not yet publicly available thus making replication impossible.

For those interested in a sound, statistically based estimate of the Shearwater population for North West Island perhaps the most reliable estimate is that of M. Donahoe performed in 1986 which resulted in an estimated 293 091 "burrows suitable for use". This estimate was based on sound, replicable survey methods. No other survey of North West Island has consisted of 32 transects. This information was made available by Dyer, Hill and Barnes in *Emu* 1995, Vol. 95, Pp. 272–279.

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