Ringing & Migration (2008) **24**, 11–14

SHORT REPORT

On reading colour rings

CARL MITCHELL* and MARK TRINDER
WWT, Slimbridge, Gloucestershire GL2 7BT, UK

The use of engraved plastic leg rings (Ogilvie 1972) has proved an extremely useful tool for long-term studies of individual birds within populations. Several studies have examined the longevity of marks (*eg* Rees *et al* 1990) and the colour fastness of certain materials (*eg* Lindsey *et al* 1995). In addition, Kania (2001) asked observers to read letters on metal rings used on White Stork *Ciconia ciconia* using binoculars. Inexperienced observers misread up to 27% of letters, whereas trained observers misread up to 8% of letters. On reading numbered neck collars on Canada Geese *Branta canadensis*, casual observers made 23 times more mistakes than trained professionals (Raveling *et al* 1990). However, as far as we are aware, there is little information on whether letters on certain colour combinations are easier to read than others. We examined this using a simple experimental approach using two different telescopes, sets of engraved plastic rings with different colour combinations and several observers.

Each 'ring' consisted of a plastic strip *c* 38 mm x 105 mm, the same dimensions as commonly used on Whooper Swan *Cygnus cygnus* colour rings. Three engraved letters, each 20 mm tall, 10 mm wide and with a 2 mm cut width were repeated three times on each ring. Each set of rings comprised five commonly used colour combinations; dark blue with white letters, orange/black, pale green/black, white/black and yellow/black. Each ring set, therefore, comprised 15 different letters. The letters were randomly chosen from 15 letters normally used on engraved rings (A B C D F H J L N P S T U X Z). This reduced letter set does not include some letters which we have found can often be misread (*eg* E, G etc). Two sets of rings (10 rings in all) were attached to a post, approximately 1.5 m from the ground. So as not to introduce letter bias, the same engraved letters were used in each set of rings, but in a different order.

Two new telescopes were set up on identical tripods at a distance of 200 m from the rings. The first telescope cost *c* £400 (referred hereafter as the 'low-quality' or 'LQ' telescope); the second telescope cost £1400 ('high-quality, or 'HQ' telescope). Both telescopes were fitted with x20 – x60 zoom lenses set to the maximum magnification and had similar objective lenses (60 mm). Observations were undertaken on three days at approx 1100 h – 1400 h GMT; the weather on each day was similar, with some cloud, but not sunny.

Thirty-three observers (not including the authors) were asked to note the background and letter colours of each of the first set of five rings and to try to read the engraved letters. The order of telescope used was randomly varied during the course of the experiment. Observers were then asked to note the colour and read the letters on the second set of five rings with the other telescope. The time allowed for reading the rings was not limited. Although the order of using the telescopes was changed, observers may have 'gained' experience at reading rings during the first attempt, which helped in determining letters in the second attempt. Although the observations were made under similar weather conditions, it is possible that varying light intensity may have affected how clearly letters were defined. No account was made of the 'experience' of the observer at reading colour rings, since this was hard to quantify. In any case, the experience of observers submitting sightings to colour-ring studies is often not known.

In order to control for colour, in a separate experiment, 20 observers were asked to read the same 15 single black letters on two sets of yellow rings (the same size as previously) at a distance of 300 m (100 m greater than in the previous experiment) using the LQ telescope fitted with a x20 – x60 zoom lens set to the maximum magnification. Each letter occurred twice.

Generalised linear models (GLMs) with a binomial error structure were used to test for differences in the proportion of successfully read letters, with ring colour and telescope quality as explanatory variables. Additional modelling was undertaken to determine if any particular letters were consistently misread more often than expected by chance.

The colour of the ring was identified correctly in virtually all of the observations (97.8% correct, n = 320). Four observers reported an orange ring as red. One reported a yellow ring as gold, another a blue ring as black, and another a blue ring as dark green. One observer was colour-blind and made no attempt to identify the colours involved; hence the sample size given above was reduced from 330 (33 observers x 10 rings) to 320.

No letters were misread on yellow rings using either telescope. This caused a problem when fitting binomial GLMs due to parameter estimation at a boundary (*ie* 1) so

* Correspondence author
Email: carl.mitchell@wwt.org.uk

the yellow records were removed from tests for differences in letter readability caused by variations in colour and telescope. While differences in readability were detected for each colour, with the fewest letters read correctly on green rings using the LQ telescope (88.9%, Fig 1) and blue rings using the HQ telescope (92.0%), no significant differences were attributable to colour. However, significantly fewer letters were read accurately using the LQ telescope (t = 2.45, *P* = 0.02, Table 1). On average, 98.0% of letters were read correctly using the HQ telescope, compared with 93.7% using the LQ telescope. No significant interactions between colour and quality of telescope were detected.

Eighteen observers (54.5% of the sample) read all letters successfully using both telescopes. Ten observers (30.3%) read more letters correctly with the HQ telescope than the LQ one and 19 observers (57.6%) read the same number of letters correctly. Four observers (12.1%) read fewer letters correctly with the HQ telescope.

Only the letter D was misread significantly more often (12.1%) than predicted by chance (t = –2.1, *P* = 0.05, Table 2). In most cases, the letter D was misread as O. The only other letter misread more than 10% of the time was N (10.6% misreads, t = –1.69, *P* = 0.11) which was misread most often as H. All other featured letters (B, F, H, J, L, T, U, X, Z) were correctly identified more than 93% of the time, and four letters (A, C, P and S) were read correctly 100% of the time.

The results of reading the two sets of single black letters on yellow rings are shown in Fig 2. Two letters, S and Z, were read correctly by all 20 observers. The letters most frequently misread were D (67.5% correct) which was most commonly misread as O, and B (82.1% correct) which was most commonly misread as S (Fig 2).

Researchers, and in particular ecological modellers, ought to be aware of potential problems for studies where colour-mark sightings form an integral part of population

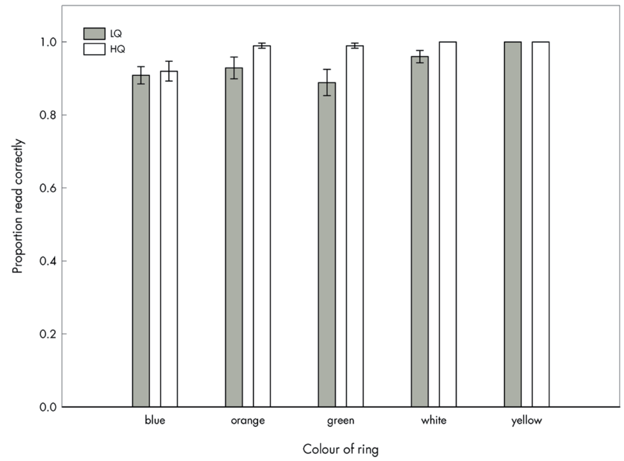

Figure 1. The average proportion of correctly read letters on rings of different colours observed through the LQ and HQ telescopes at 200 m (sample size = 33 observers). Error bars: ± 1 SE.

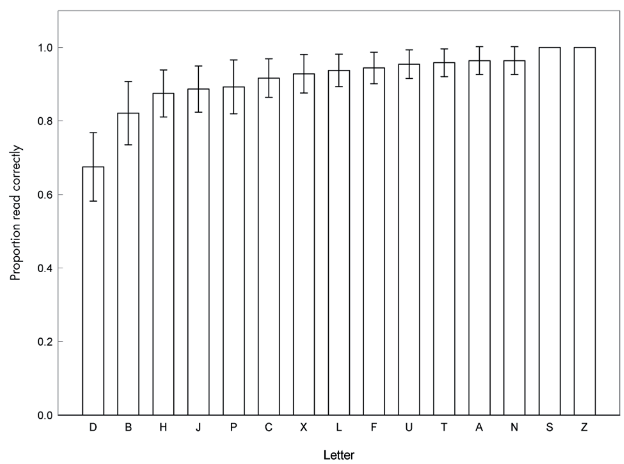

Figure 2. The average proportion of observers that correctly read black letters on yellow rings observed through the LQ telescope at 300 m (sample size = 20 observers). Error bars: ± 1 SE.

modelling. Those planning future studies might consider their choice of colour rings not only on potential effects on behaviour (see Calvo & Furness 1992 for a review), but also on how well the rings can be read in the field. The colour combinations used here were not exhaustive and the sample size was comparatively small, yet variations approaching statistical significance were detected between different coloured rings. When controlling for ring colour, in the second experiment, most letters were read correctly but, at the greater distance (300 m), certain letters, notably D and B, were either harder to read than others, or were more easily confused with other letters.

Researchers should be aware that using different colours within the confines of a single study may introduce varying rates of accuracy in ring reading, especially when observations are made by members of the public. Attention

Table 1. Output from binomial GLM comparing the proportion of correctly read letters with the idealised value of 1 (*ie* all letters read correctly). Only the difference between telescopes explained a significant amount of variation in the proportion of correctly read letters (figures shown indicate the significance of the difference between the quality of telescope, *ie* HQ/LQ). Note that all yellow ring observations were removed to prevent poor model fits due to 100% correctly read letters on this colour. SE, standard error.

Explanatory variable	Parameter estimate (SE)	t	*P*
Blue	-0.490 (0.356)	-1.38	0.17
Green	0.326 (0.492)	0.66	0.51
Orange	-0.107 (0.412)	-0.26	0.80
White	1.046 (0.677)	1.54	0.12
Difference between telescopes	-0.600 (0.245)	2.45	0.02*

Table 2. The proportion of individual letters read incorrectly for five different colour rings (sample size in parentheses). Note letters A, C, P, S were read correctly on all colour rings and were not tested.

Letter	Yellow ring	Blue ring	Orange ring	White ring	Green ring	Overall failure rate (%)	t	P
A	0 (26)			0 (40)		0		
B	0 (26)		0.10 (20)		0.10 (20)	6.1	-0.39	0.70
C	0 (26)			0 (20)		0		
D			0.08 (26)		0.25 (20)	12.1	-2.10	0.05
F	0 (20)		0.09 (46)		0 (26)	4.3	0.14	0.89
H		0 (20)	0.08 (26)	0 (26)	0 (20)	2.2	0.88	0.39
J		0.09 (66)		0 (26)		6.5	-0.62	0.54
L		0.04 (26)		0.05 (40)	0 (26)	4.5	0.06	0.95
N	0 (20)	0.15 (46)				10.6	-1.69	0.11
P			0 (20)		0 (20)	0		
S	0 (20)	0 (20)				0		
T			0.05 (40)		0 (26)	3	0.50	0.62
U	0 (20)			0.05 (20)		2.5	0.51	0.62
X				0.04 (26)	0.05 (20)	3	0.50	0.62
Z	0 (20)				0.10 (20)	5	-0.06	0.95

might be paid to the combination of light foreground with dark letters, and vice versa and the type of bird under study. Personal experience suggests that, for geese and swans, white letters on a dark background (intuitively the colour combination giving the most contrast) sometimes become engrained with dirt/mud and letters are harder to read. Conversely, on colour rings fitted to seabirds, white guano can lead to dark letters on white rings being harder to read (M.P. Harris, pers comm).

Bregnballe & Gregersen (1995) examined the resighting probabilities of colour rings on Cormorants *Phalacrocorax corax*, calculated as the number of individuals resighted outside Denmark divided by the number of chicks ringed. Red rings were seen most frequently (23.3%), followed by black (16.1%), green (16.0%), blue (15.6%), white (12.8%) and yellow rings (8.6%). The colour combinations most often resighted correctly were in contrast to the findings of the present study which found light-coloured rings with black letters to be those most frequently read correctly. Baccetti & Morelli (2007) reported on resighting probabilities of Greater Flamingo *Phoenicopterus ruber* colour rings using 14 observers: letters on yellow rings were read correctly most often (91.1%) compared with white rings (89.3%), green (75.4%), blue (75.2%) and black (69.8%). In terms of determining the colour of the rings, white was identified correctly in all cases (100%), followed by yellow (98.3%), black (98.3%), green (97.1%) and blue (80.7%).

If only one colour combination is used throughout the course of the study, the effect of the colour of the ring on the probability of accurate reading might be expected to be relatively constant (although one still needs to be aware of biases introduced by other factors, *eg* quality of optics, experience/ability of observer etc). However, if the study switches from one colour combination to another after a period of time or, perhaps of greater concern, between cohorts, variations in accuracy associated with different colour rings may lead to the resighting probabilities changing.

Further work is encouraged in examining whether certain colours or letters are easier to read than others and which solid colour rings (often used in wader studies) are easiest to assign to the correct colour in field trials. Choice of high-quality optics appears to be of importance for maximising ring-reading effort. Training of ring readers is encouraged. Those collating ring sightings need to be especially vigilant when receiving sightings from the public, when the experience of the observer and the quality of the telescope are unknown. Note that all combinations used must be cleared by the relevant colour-ring co-ordinators before projects commence.

ACKNOWLEDGEMENTS

Thirty-three staff at WWT, Slimbridge, and 20 attendees at the 2007 Scottish Ringers' Conference, Braemar, undertook the field trials, and are thanked. Raymond Duncan, David Jardine and Richard Hearn are thanked for help with setting up the ring reading. The study followed a conversation at the Scottish Ringers' Conference with Paul Shimmings who, together with Mike Harris, Baz Hughes, Thomas Bregnballe, Chris Redfern and two anonymous reviewers, kindly improved an earlier draft.

REFERENCES

Baccetti, N. & Morelli, F. (2007) *Results of the Antequera 'ophtalmic' tests*. www.infs-acquatici.it/Test%20of%20code%20reading.htm. (accessed 18 April 2008; archived by WebCite® at www.webcitation.org/5XFoiRUn1).

Bregnballe, T. & Gregersen, J. (1995) Does ring colour influence identification probabilities of colour-ringed Great Cormorants? *Cormorant Research Group Bulletin* **1**, 23–26.

Calvo, B. & Furness, R.W. (1992) A review of the use and effects of marks and devices on birds. *Ringing & Migration* **13**, 129–151.

Kania, W. (2001) Errors in experimental readings of White Stork ring numbers by binoculars. *Euring Newsletter* **3**. (Available at www.euring.org/about_euring/newsletter3/kania.htm).

Lindsey, G.D., Wilson, K.A. & Herrmann, C. (1995) Color change in Hughes's celluloid leg bands. *Journal of Field Ornithology* **66,** 289–295.

Ogilvie, M.A. (1972) Large numbered leg bands for individual identification of swans. *Journal of Wildlife Management* **36**, 1,261–1,265.

Raveling, D.G., Zezulak, D.S., Silveira, J.G. & Weldon, J.A. (1990) Accuracy in recording neck-band codes of Cackling Canada Geese. *California Fish and Game* **76**, 205–210.

Rees, E.C., Owen, M., Gitay, H. & Warren, S. (1990) The fate of plastic leg rings used on geese and swans. *Wildfowl* **41**, 43–52.

(MS received 18 December 2007; accepted 19 April 2008)