Variation in sighting frequencies of colour-ringed Redshanks *Tringa totanus* according to ringing-scheme and ring colour

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In a study of colour-ringed Redshanks *Tringa totanus*, wintering at Cardiff Bay, south Wales, it was found that individuals were seen less frequently if colour-rings had to be determined on a tarsus and a tibia rather than on the two tibias. This was a consequence of the difficulty of seeing rings on the tarsus whilst birds waded in mud or water and it is suggested that for waders which forage in muddy conditions, the use of colours on the tarsi should be limited. It was also noted that individuals bearing white rings were more likely to be sighted than those without, whereas, in comparison, those bearing black were less likely to be sighted. This was presumably because white rings could be more quickly determined from others and black rings less quickly determined. These results may have implications for studies that rely upon colour-ringing for the determination of site-fidelity and survival.

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INTRODUCTION

Colour-ringing has become a widespread technique for studies of the behaviour of many species of birds, including waders (Calvo & Furness 1992; Marchant 1995). By using different combinations of colours within a given ringing scheme, it is possible to distinguish individuals and thus to study movements and survival (*e.g.* Metcalfe & Furness 1985; Roberts 1991; Smith *et al.* 1992; Jackson 1994; Burton & Evans 1997; Burton in press). To avoid the misidentification of individuals, such studies clearly rely upon rings retaining their colour and birds retaining their rings. Previous studies, however, have reported that ring loss may be a problem, even over a single year (Coulson 1963; Anderson 1980; Reese 1980; Rees *et al.* 1990; Nisbet 1991; Spendelow *et al.* 1994). Rings may be lost through wear, removal by the bird or by being snagged on vegetation and subsequently pulled off. 'Darvic' plastic rings have been shown to be preferable to those made of acetate, celluloid or 'Scotchlite' bonded to aluminium, due to their colour retention (particularly after exposure to UV light) and their low rate of wear and thus loss (Coulson 1963; Anderson 1980; Rees *et al.* 1990; Spendelow *et al.* 1994; Lindsey *et al.* 1995; Marchant 1995), although Robinson & Oring (1997) have recently suggested that Darvic rings may also fade over time.

Although the problems of ring wear and colour retention are now well understood, there has been little study of the ease with which different colour-ringing schemes or different colours may be read in the field. Schemes in which rings are placed on the tibia may be unsuitable for short-legged species as rings may be hidden by feathers. In contrast, schemes in which rings are placed on the tarsus may be unsuitable for wading species, as rings may be frequently covered with mud. Certain colours or combinations of colours may also be easier to determine than others, especially in poor light (Coulson 1963). If certain colour-ringing schemes or colours are easier to read than others, then the numbers of times that individual birds are identified may vary. As a result, studies of site-fidelity and survival may be biased.

The present study formed part of a longer-term investigation in which colour-ringing has been used to determine the site-fidelity and survival of Redshanks *Tringa totanus* wintering at Cardiff Bay in south Wales. The study aimed to establish whether the number of times that an individual was seen was affected by either the colour-ringing scheme used or the colours.

STUDY SITE AND METHODS

Cardiff Bay (51°27′N, 3°10′W) is formed by the combined estuaries of the Rivers Taff and Ely before they flow into the larger Severn Estuary. The bay is 175 ha in area and in winter supports an average of 250 Redshanks and a variety of other waterfowl (Burton *et al.* 1999).

Samples of Redshanks were caught by cannon- or mist-netting at high tide roosts in and around Cardiff Bay in the winters of 1994/95 and 1995/96. Each bird caught was aged according to its plumage characteristics (Prater *et al.* 1977) as either an adult or a first-winter bird and the majority of adults then given unique combinations of Darvic plastic colour-rings for subsequent identification in the field. In total, 144 adult Redshanks were individually colour-ringed during the two winters.

Two different colour-ringing schemes were used during this period (see Figure 1). On scheme A birds, the constant 'scheme colours' of yellow over white were on the right tarsus, a colour (red, orange or yellow) above

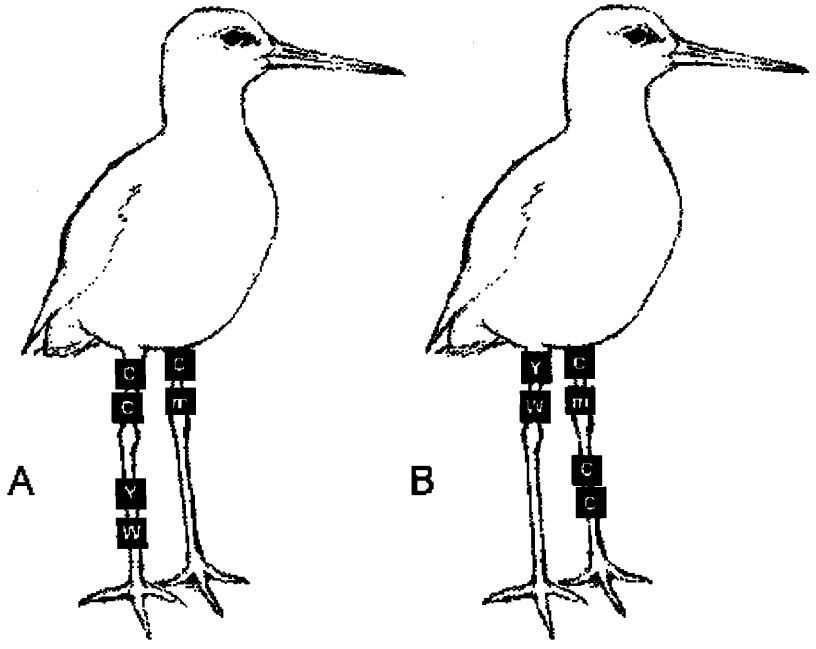

Figure 1. The positions of rings on Redshanks of schemes A and B. C = colour (black, dark blue, dark green, lime, orange, red, white or yellow), W = white, Y = yellow, m = metal. On scheme A birds, the colour on the left tibia was either orange, red or yellow; on scheme B birds this ring was either lime or white.

the numbered metal ring on the left tibia and two other colours on the right tibia. On scheme B birds, the constant scheme colours of yellow over white were on the right tibia, a colour (either lime or white) above the metal ring on the left tibia and two other colours on the left tarsus. Colour-rings on the tibia were 8 mm in length and those on the tarsus 12 mm.

Cardiff Bay was searched regularly (by the author) for colour-ringed individuals from August 1996 to March 1997. Sighting frequencies over winter (1 October to 31 January) were calculated for those individuals seen between August and October 1996 and again from February to March 1997 and thus known to be alive throughout that period. During the winter, the entire bay was searched once an hour over a total of eight complete tidal cycles, spread over 31 days. Redshanks are typically site-faithful during winter (Furness & Galbraith 1980; Rehfisch *et al.* 1996; Insley *et al.* 1997; Burton in press).

An initial test aimed to determine whether there was a difference in the numbers of times that individuals of the two schemes were sighted. As only occasional Redshanks colour-ringed elsewhere have ever been sighted at Cardiff, (indeed none were seen in the bay during the winter of 1996/97), it was not necessary to read the scheme colours on individuals from either group in this study. Thus scheme A individuals could be identified by determination of the colours on the two tibias alone and scheme B individuals by determination of those on the left tibia and left tarsus. It was predicted that scheme B individuals would be seen less frequently as rings on the tarsus were often likely to be covered in mud.

Further tests investigated whether the numbers of times that individuals of scheme A were sighted varied according to the colours used. On birds from scheme A, the colour on the left tibia was always one of just three bright colours: red, orange or yellow, and was thus easily read. Eight different colours were available for the two rings on the right tibia, however (black, dark blue, dark green, lime, orange, red, white and yellow). It was predicted that individuals bearing white rings on the right tibia would be identified more frequently than others, as such a bright colour would be easy to read. In contrast, black rings may take longer to distinguish and it was predicted that individuals with these rings would be less often identified. We also investigated whether the probability of seeing an individual depended upon the combination of colours used on the right tibia, i.e. whether there were two bright colours (lime, orange, red, white or yellow) together, a bright colour and a dark colour (black, dark blue or dark green) or two dark colours. The following generalized linear model (see McCullagh & Nelder 1989) was used to relate the probability of seeing an individual at Cardiff Bay (the number of days seen divided by the number of days of fieldwork) to the number of rings (0, 1 or 2) of each colour on its right tibia and the interaction between them:

$$\text{logit}(p) = \mu + \alpha_3 b + \alpha_4 g + \alpha_5 l + \alpha_6 n + \alpha_7 o + \alpha_8 r + \alpha_1 w + \alpha_2 y + \beta_{11} x_1 + \beta_{22} x_2^1 + \beta_{33} x_3^2$$

where p is the probability that an individual is seen and b, g, l, n, o, r, w and y the number of dark blue, dark green, lime, black, orange, red, white and yellow rings respectively that it bears, such that $b + g + l + n + o + r + w + y = 2$. x_1 x_2 and x_3 are class variables indicating respectively whether the bird bore two bright rings together, a bright ring with a dark ring, or two dark rings. A binomial error distribution was assumed, with the logit link function used to ensure valid probability estimates in the range (0,1). The estimated values of the model parameters α_i indicate the relative chances of individuals bearing rings of the respective colours being

sighted. Likewise the estimated values of β indicate the relative chances of individuals bearing the respective combinations being sighted. Differences in sighting probabilities between individuals bearing different colours were tested for by imposing appropriate constraints on the α and applying likelihood ratio tests (see Wetherill 1981, pp. 350-353). For example, under the assumption that sighting is unaffected by colour, all the α coefficients are set equal.

RESULTS

Sixty-six individually colour-ringed adult Redshanks were seen at Cardiff Bay between August and October 1996 and again from February to March 1997 and were thus known to be alive throughout the winter period. On 31 fieldwork days between 1 October and 31 January, these individuals were seen on a mean of 4.41 days (s.e. = 0.42, n = 66, range = 0-14). However, the number of sightings varied between individuals from the two schemes. Individuals of scheme A were seen on a mean of 5.27 days (s.e. = 0.67, n = 30, range = 0-12) and those of scheme B on a mean of 3.69 days (s.e. = 0.50, n = 36, range = 0-14), an almost significant difference ($t = 1.92$, d.f. = 64, $p = 0.05$). As birds from scheme B were seen less frequently, the following analyses only consider those from scheme A.

In the original model generated to investigate the effect of colour on sighting probabilities, the estimated white α coefficient was the largest, and the black α the smallest. Subsequent likelihood ratio tests showed that, in relation to other colours, the presence of at least one white ring (on the right tibia) significantly increased the probability of seeing an individual of scheme A ($\chi^2 = 14.69$, d.f. = 1, $p < 0.001$). In contrast, black rings decreased this probability ($\chi^2 = 5.81$, d.f. = 1, $p < 0.05$). Permitting for these colours, no significant difference was found for the estimated coefficients of those remaining: dark blue ($\chi^2 = 0.49$, d.f. = 1, n.s.), dark green ($\chi^2 = 1.46$, d.f. = 1, n.s.), lime ($\chi^2 = 0.37$, d.f. = 1, n.s.), orange ($\chi^2 = 0.00$, d.f. = 1, n.s.), red ($\chi^2 = 0.03$, d.f. = 1, n.s.) and yellow ($\chi^2 = 0.09$, d.f. = 1, n.s.). Permitting for all colours, the probability of seeing a bird was not affected by the interaction between the two rings ($\chi^2 = 0.06$, d.f. = 1, n.s.), i.e. whether there were two bright rings together, a bright ring with a dark ring, or two dark rings.

DISCUSSION

The present study has shown that individual Redshanks were seen less frequently ($p = 0.05$) if colour-rings had to be determined on a tibia and a tarsus, rather than on the two tibias. This was clearly a result of the problem of seeing rings on the tarsus whilst individuals foraged in the water or mud. As a consequence, scheme B Redshanks were seen so infrequently that it was deemed unreliable to include them in survival calculations (Burton in press). For the study of other long-legged waders which forage in muddy conditions, it would also, therefore, be preferable for the majority of colour-rings to be on the tibias rather than the tarsi. The large number of colour-ringing schemes already active for many species may preclude this, however (Marchant 1995; S. Browne & H. Mead pers. comm.). If some rings do have to be placed on the tarsi, making them the scheme rings may in some studies be advantageous. For species which frequent other habitats, such as rocky or sandy shores, the use of colour-rings on the tarsi should not be so problematic.

Up to nine Darvic colours are used in present colour-ringing schemes for waders (Marchant 1995; S. Browne & H. Mead pers. comm.), eight of which were used for Redshanks at Cardiff. This study has shown that the presence of white rings on the right tibia significantly increased the probability of seeing scheme A individuals. It is probable that white rings were simply more quickly determined than others and that as a result individuals with one or more white rings were easier to identify. It is not thought that yellow rings on the right tibia were mistaken for white, as individuals with a yellow ring in this position would have been seen less often than those with neither yellow or white. It was noted, however, that white rings on the tarsus discoloured to yellow over time, as a result of an encrustation. This problem may have been site-related, but could occur in studies on other estuaries. In contrast, individuals had less of a chance of being seen and identified if they bore black rings on the right tibia. It is probable that this was because it took a long time to distinguish black from other dark-colours (dark blue and dark green) and that individuals with black rings were less frequently identified as a result.

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