Darvic colour-rings for shorebird studies: manufacture, application and durability

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Since the early 1970s, studies at Durham University (U.K.) have established and maintained Darvic colour-ringed populations of several shorebird species in north-east England. Based upon this experience, the manufacture, application and use of Darvic colour-rings in shorebird studies in temperate climates are reviewed. Colour retention of Darvic rings is shown to be adequate for shorebird studies of at least 17 years duration. Given that most colour-ringing projects last no more than five years, use of Darvic is shown to be a reliable tool. Even for longer term studies, the number of older birds with overlapping or missing colour-rings should be less than 10% of those observed

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INTRODUCTION

When identifying cohorts or individuals in the field, researchers have often marked shorebirds with colour rings made from Darvic (pressed PVCU sheet). Despite their wide use, guidance regarding the manufacture and use of Darvic colour-rings is all but absent from the literature. Furthermore, Robinson & Oring (1997) recently suggested that Darvic colour-rings are inappropriate for long-term studies of shorebirds due to poor colour retention observed in their studies. Since the early 1970s, studies at Durham University (U.K.) have established and maintained Darvic colour-ringed populations of seven shorebird species on the Tees estuary, north-east England. Over 2,500 birds have been individually colour-ringed and monitored for up to 20 years after application of the rings. Based upon this experience, the manufacture, application and use of Darvic colour-rings in shorebird studies in temperate climates are reviewed in this paper.

THE MATERIAL

Colour-rings used on birds are generally made of either celluloid or Darvic. The use of celluloid is largely confined to short-lived species i.e. passerines, due to a lack of colour retention by the material (Rodl & Flinks 1998, Lindsey *et al.* 1995). For long-lived species e.g. shorebirds, colour-rings made of Darvic (pressed PVCU sheet) are in common usage due to the material's colour-fast properties, hard wearing and malleability (Coulson 1963). Darvic was originally manufactured by Imperial Chemical Industries, the rights for production subsequently being sold on to Weston Vinyls and then Wardle Storey based in the U.K. Darvic cannot be purchased direct from Wardle Storey but via suppliers such as William Cox Ltd. (Unit 13, L & G Estate, 11th Avenue, Team Valley, Gateshead, Tyne & Wear, U.K., NE11 9BR.)

For species that take a British Trust for Ornithology metal ring of size F or smaller i.e. an internal diameter of 9.0mm or less, we recommend the use of 0.5mm thick Darvic. When 0.75mm thick Darvic was available, we used this thickness of material for species such as the large gulls that took a British Trust for Ornithology metal ring of size F or greater i.e. of a 9.0mm or greater internal diameter.

RING MANUFACTURE

For the common European shorebird species, the internal diameter for colour-rings we recommend is given in Table 1. These dimensions equate to that of the metal rings used by the British Trust for Ornithology (B.T.O.) ringing scheme for a given species (Spencer 1984). For all species, the use of only two ring heights is advocated by the International Wader Study Group (I.W.S.G.), 'short' and 'tall', the latter twice the height of the former which equates to that of the B.T.O. recommended metal ring (Table 1).

When making rings, strips of Darvic are cut (using a guillotine & scissors) to the required length with the corners rounded on a sand-paper block or, less satisfactorily with scissors. The length of Darvic cut, in relation to the diameter of the finished ring, determines the degree of overlap. In contrast to celluloid split rings, Darvic rings are constructed to overlap in order to hold the ring closed. The degree of overlap ranges from up to 2.5 times the circumference of the ring size in question for species requiring a ring of 5.25mm internal diameter upwards (B.T.O. size D), down to 1.5 times for a 2.8mm internal diameter (B.T.O. size B2/B+). A 2.5 times overlap ring is more likely to remain on a bird's legs than one of 1.5 overlap. With time, Darvic rings may unwind to a slight degree.

Rings are formed into shape in a mould made of a material that will not expand with immersion in boiling water and does not retain heat for too long, a recommended material being Perspex or similar acrylic plastic. The mould, a block with a height equivalent to that of the rings, has vertical holes running through it of a diameter necessary to produce the required internal diameter of

the finished ring, i.e. one which takes into consideration the thickness of Darvic to be used and degree of overlap required. As a guideline, Table 2 lists the dimensions of the moulds and Darvic strips used by Durham University when constructing a range of ring sizes with 0.5mm thick Darvic.

A shallow depth of water is heated in a pan to boiling point and then left simmering. A Darvic strip is picked up with fine forceps, softened by immersing it in the simmering water and then removed, wrapped around the forceps and inserted into the mould . When the required number of holes in the mould have been filled with one Darvic strip each, the mould is immersed in the simmering water until the Darvic rings haveexpanded. A flat-bottomed Pyrex beaker or flat piece of wood is then forced down on top of the mould and rings to prevent any ring spiralling that may have occurred. The mould is then placed in cold water to harden the material, removed and the colour rings subsequently pushed out with a pencil, forceps or like instrument. If the mould is constructed of a material that retains heat, spiralling is likely to occur at this stage. The internal diameter of the finished rings should be no smaller than the required dimension. A slightly larger internal diameter of ring than is required is not a problem as further reduction can be made on closure of the ring upon the bird's leg with ringing pliers.

COLOUR RING APPLICATION TO A BIRD

We recommend that, whenever possible, the placement of Darvic colour rings upon birds involves two persons; one holding the bird, the other putting the rings on, in order to minimise the risk of damage to birds' legs. To put a Darvic colour-ring on to a bird, unwrap the ring and rewrap it round the bird's leg, putting what was the outer end of the strip on first so that what was the inner end is now on the outside. Tighten the colour ring with ringing pliers using a hole size 1 or 2 above that for the metal ring to be used but do not constrict the leg. The ring will need to be closed to a smaller diameter than actually required as the ring will recoil slightly when the pliers are removed. If the metal ring is part of a colour-ring combination and on the same leg as a colour-ring, care must be taken to close the colour ring tightly enough that it doesn't slip over the metal ring in future. Care also needs to be exercised when using the pliers as the Darvic ring may be damaged (pinched), as experience will show. If this happens, the ring should be removed and a new one applied. Some researchers choose to apply adhesive to the ring at this stage, an action that has not been found necessary by Durham University researchers.

WHAT FIELD OBSERVATIONS SUGGEST AS AN IDEAL SCHEME

Previous field experience is invaluable when reading colour-rings and interpreting the effects that lighting conditions and background coloration have on the colours perceived. However, all observers, regardless of experience, can and do mis-read colour combinations. To ease field identification by both researcher and the general public, we recommend that the colours used for shorebird rings are restricted to dark blue (coded by I.W.S.G. as "B"), lime (or light green, L), dark green (G), orange (O), red (R), yellow (Y), white (W) and black (N = niger). In addition I.W.S.G. have recommended pale blue (P). Both types of greens and blues are frequently mis-read by observers. Often the dark colours are recorded as black and the pale colours as grey or even white (for pale blue). Dark green is also mis-read as dark blue and vice versa. Despite good light conditions, when a dark green ring lies within the shadow of the bird it can look convincingly black. When schemes allow, it is therefore sensible to restrict the number of variants of blue and green rings used. Furthermore it is often useful to place both rings of a confusing pair within a combination if circumstances allow e.g. YW, OR, BG, GN. This will improve the accuracy and speed at which combinations are read in the field. The positioning of two rings of the same colour together on the same section of leg should be avoided to prevent confusion of two short rings with one tall.

Colour rings positioned on the tibia of small to medium sized waders are frequently overlooked as they can often be hidden by body feathers; or because observers are viewing from an elevated position. This needs to be taken into consideration when designing a scheme or interpreting others' sightings. Experience shows leg flags on the tibia are much less likely to be overlooked. Further information on leg flags can be found in Jessop *et. al.* (1998).

The ease with which colour-ring combinations can be read differs between species and habitats, a point to be considered before embarking on a scheme. For example, colour-rings on Ringed Plovers are virtually impossible to read when birds are foraging across soft muddy substrates (due to mud obscuring the rings), whereas on an open sandy beach they are amongst the easiest of colour–ringed waders to read, because of the frequent pauses they make while foraging. Colours are also differentiated more easily against sandy or rocky substrates than mud, a consequence of poor reflective light levels from muddy substrates. Inexperienced observers may miss rings of similar colour to that of the leg e.g. an orange colour-ring on a Redshank. Remember that colour blindness presents some (male) observers with difficulties in interpreting colours, especially red and green.

Many workers have incorporated the metal ring as part of a colour-ringing scheme through necessity, i.e. a shortage of combinations for the species involved. Where possible, this should be avoided, as ageing may cause a colour-ring to unspiral slightly, allowing the metal rings to lie hidden within.

To avoid confusion resulting from occasional losses of a ring from a combination, the number of colour-rings per bird should be chosen at the outset to provide enough combinations for the study envisaged. Use of additional rings in the later stages of a study may lead to misinterpretations.

AGEING OF DARVIC COLOUR-RINGS: A QUALITATIVE ASSESSMENT

Slight unspiralling of a colour-ring through ageing may cause a second colour-ring to lie partially hidden within the first. When this occurs a part of both entwined rings can be seen as the bird "rotates". This can be interpreted by unfamiliar observers to the bird having

Table 1. Recommended colour-ring dimensions

Species	Latin name	Internal diameter (mm)	Height (mm)	
			Short	Tall
Oystercatcher	*Haematopus ostralegus*	9.0	9.0	18.0
Avocet	*Recurvirostra avosetta*	7.0	7.0	14.0
Stone Curlew	*Burhinus oedicnemus*	7.0	7.0	14.0
Little Ringed Plover	*Charadrius dubius*	2.8	5.5	11.0
Ringed Plover	*Charadrius hiaticula*	3.3	5.5	11.0
Kentish Plover	*Charadrius alexandrinus*	2.8	5.5	11.0
Eurasian Dotterel	*Charadrius morinellus*	4.3	5.5	11.0
Golden Plover	*Pluvialis apricaria*			
	Adult:	4.3	5.5	11.0
	Pullus:	5.25	7.0	14.0
Grey Plover	*Pluvialis squatarola*	5.25	7.0	14.0
Lapwing	*Vanellus vanellus*	5.25	7.0	14.0
Red Knot	*Calidris canutus*	4.3	5.5	11.0
Sanderling	*Calidris alba*	2.8	5.5	11.0
Little Stint	*Calidris minuta*	2.8	5.5	11.0
Temminck's Stint	*Calidris temminckii*	2.8	5.5	11.0
Curlew Sandpiper	*Calidris ferruginea*	2.8	5.5	11.0
Purple Sandpiper	*Calidris maritima*	3.3	5.5	11.0
Dunlin	*Calidris alpina*	2.8	5.5	11.0
Ruff	*Philomachus pugnax*			
	Adult female	4.3	7.0	14.0
	Adult male	5.25	7.0	14.0
	Pullus	5.25	7.0	14.0
Black-tailed Godwit	*Limosa limosa*	7.0	7.0	14.0
Bar-tailed Godwit	*Limosa lapponica*	5.25	7.0	14.0
Whimbrel	*Numenius phaeopus*	7.0	7.0	14.0
Eurasian Curlew	*Numenius arquata*	9.0	9.0	18.0
Spotted Redshank	*Tringa erythropus*	5.25	7.0	14.0
Redshank	*Tringa totanus*	5.25	7.0	14.0
Greenshank	*Tringa nebularia*	5.25	7.0	14.0
Green Sandpiper	*Tringa ochropus*	4.3	5.5	11.0
Wood Sandpiper	*Tringa glareola*	3.3	5.5	11.0
Common Sandpiper	*Actitis hypoleucos*	3.3	5.5	11.0
Turnstone	*Arenaria interpres*	4.3	5.5	11.0
Red-necked Phalarope	*Phalaropus lobatus*	2.8	5.5	11.0

Table 2. Specifications of color-rings and mould for given B.T.O. ring sizes

Internal diameter of ring (mm)	B.T.O. ring size	Length of Darvic strip	Diameter of mould hole	No. of wraps
2.8 & 3.3	B2/B+	20mm	4.5mm	ca 1.75
4.3	C2	43mm	7.0mm	ca 2
5.25	D2	50mm	8.0mm	ca 2.5
7.0	E	50mm	10mm	ca 2.5
9.0	F	70mm	11mm	ca 2.5

vertically striped rings similar to those readily available in commercially sold Celluloid rings. Glueing of the rings would prevent this happening.

After at least eight years in the field, some of our Darvic colour-rings on recaptured birds have become brittle. Thus ring breakage may occur in the field, and is probably the cause of the very limited ring loss noted amongst ageing birds ringed in the Durham University schemes. No birds have ever been seen in the field attempting to remove or break off colour-rings.

Though, with time, some Darvic colour-rings do fade slightly and become duller in temperate environments, experienced observers can allow for this when interpreting both their own and other people's sightings. Observations at Teesmouth of shorebirds ringed over 15 years ago have clearly demonstrated to researchers that most Darvic is colour fast, the exceptions being yellow and white, that can become buff and cream coloured, respectively. This has been noted predominantly amongst the oldest individuals, for example a Curlew recaptured 17 years after ringing, on which the yellow ring of the four-colour combination had turned to buff. This bird was still being recorded as bearing a yellow ring by the researchers concerned!

Of those species colour-ringed at Teesmouth of which some pass through to winter in the tropics e.g. Sanderling, no discernible difference has been noted in

Table 3. Colour-ringed Curlew *Numenius arquata* at Teesmouth

Years since ringing	Running total of the last sightings of birds*	Birds that were first noted with missing ring(s)	Birds that were first noted with overlapping rings
20	1		
17	3		
16	5	1	
15	9		
14	12		
13	15		
11	23		1
10	30		2
9	37	1	2
8	43	1	
7	62		2
6	71		1
5	89		1
4	100		2
3	114		
2	130		
1	163		
0+	223	1	

*For those individuals that had lost or overlapped rings, the first observation of this is taken as the last sighting.

Table 4. Colour-ringed Turnstone *Arenaria interpres* at Northumberland

Years since ringing	Running total of the last sightings of birds
3	0
2	42
1	111
0+	179

Table 5. Colour-ringed Turnstone *Arenaria interpres* at Teesmouth and Northumberland

Years since ringing	Running total of sightings of birds*	Birds that were first noted with missing ring(s)	Birds that were first noted with overlapping rings
18	0		
17	0		
16	3		
15	6		
14	12	1	
13	13		
12	14		
11	19	2	
10	21		
9	30		2
8	37		1
7	52	2	5
6	64	3	
			2
5	73	1	1
4	81		
3	87		
2	142		
1	233		
0+	321		

*For those individuals that had lost or overlapped rings, the first observation of this is taken as the last sighting.

colour retention of colour-ringed resident and passage birds.

Within a muddy estuarine habitat, white Darvic rings have been reported as "stained". Of the few birds recaptured with such rings at Teesmouth, the "staining" has proven to be sediment adhering to the ring.

AGEING OF DARVIC COLOUR-RINGS: A QUANTITATIVE ASSESSMENT

Data are presented from two of the species colour-ringed by Durham University, Turnstone and Curlew. The Turnstone populations studied occupied primarily rocky and sandy shore intertidal habitat whereas the Curlew frequented intertidal mudflats and inland pastures. Populations of both species have been colour-ringed at Teesmouth since 1975 and a second population of Turnstones colour-ringed since 1997 along the Northumberland coast. Either a four or three ring combination on the tibia was used on the Curlew i.e. one or two rings on each tibia, the latter combination repeated on the tarsi. Turnstone were identified from two, three or predominantly four ring combinations on the tarsus.

Of 448 Curlew colour-ringed at Teesmouth since 1975, table 3 provides a summation of the years between ringing and either their last sighting or, if rings have been lost/overlapped, first record of the latter event. The data are based on observations from 1992 onwards when 196 of the 448 birds were ringed. Many of the birds ringed were passage migrants for which re-sightings are few due to the nature of the studies at Teesmouth. These data show that over 93% of "final" sightings are of Curlew with complete ring combinations.

Of the 184 Turnstone individually colour-ringed during 1997 - 1999 in the Northumberland study, 179 (97%) have so been resighted so far; no ring loss or overlapping has been noted (Table 4). Only after five years have ring loss or overlap been noted in Turnstone at Teesmouth (Table 5). 93% of "final" sightings have been of birds with complete ring combinations.

DISCUSSION AND CONCLUSIONS

We consider the colour retention of Darvic rings of the recommended colours to be adequate for shorebird studies of at least 17 years duration. These findings contradict those of Robinson & Oring (1997) whose results when reportedly using Darvic are more akin to that expected from the use of Celluloid. The long life span of shorebirds dictates that colour rings should only be made from colour fast materials e.g. Darvic, thus allowing different birds (and, more importantly, schemes) to be recognised regardless of the life span of a given research project. To ensure the distinctiveness of different schemes, the use of colour rings on the tibia of small sized shorebirds as a scheme identifier is best avoided. A Darvic flag is a much more reliably reported mark at this leg position.

No reference to ring loss or overlap is known in the published literature on shorebirds, though this has been witnessed by some shorebird studies and within two years of ringing (P.Potts *pers comm.*). Experience from Teesmouth suggests that early ring loss/overlap can be a consequence of inadequate initial tightening of rings with pliers. We recommend not opening out the Darvic ring more than necessary during application.

Given that most colour-ringing projects last no more than five years, use of Darvic is shown by studies at Teesmouth to be a reliable tool. Even for longer term studies, the number of older birds with overlapping or missing colour-rings should be less than 10% of those observed (most of which within the Teesmouth populations could be identified by elimination). Thus when interpreting sightings of "foreign" ringed birds, the possibility needs to be entertained of ring loss/overlap, particularly given the current number of longer-term schemes.

Finally, it should be remembered that observers' awareness of birds with leg injuries is heightened when such individuals are colour-ringed. It is not uncommon for birdwatchers to comment on a limping colour-ringed bird, assuming that the rings are responsible for the lameness. When such birds have been recaptured, the injury is invariably found to be unconnected with the presence of rings e.g. foot sores. Systematic collection of data on such individuals would be valuable to counter any arguments in the future.

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